Connected Vehicle Pilot Deployment Program Phase 3

Comprehensive Transition Plan – New York City

www.its.dot.gov/index.htm
Final Report — November 17, 2021
FHWA-JPO-18-716

U.S. Department of Transportation

Produced by New York City Department of Transportation.
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
ITS Joint Program Office

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This document is based upon work supported by the Federal Highway Administration under contract number DTFH6116H00025.
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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-18-716		

4. Title and Subtitle	5. Report Date
Connected Vehicle Pilot Deployment Program Phase 3 Comprehensive Transition Plan – New York City	November 17, 2021
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Talas, Mohamad (NYCDOT); Rausch, Robert (TransCore), Benevelli, David (TransCore), Sim, Samuel (TransCore)	
9. Performing Organization Name And Address	10. Work Unit No. (TRAIS)
New York City Department of Transportation Bureau of Traffic Operations 34-02 Queens Boulevard Long Island City, NY 11101	11. Contract or Grant No. DTFH6116H00026
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
ITS-Joint Program Office 1200 New Jersey Avenue, S.E. Washington, DC 20590	Final Comprehensive Transition Plan
	14. Sponsoring Agency Code HOIT-1

15. Supplementary Notes

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16. Abstract

This plan documents the transition of the New York City Connected Vehicle Pilot Deployment project from its Phase 3 operation to a shutdown state beginning January 4, 2022 whereby the City can certify that the lower 45 MHz of Dedicated Short Range Communications spectrum is no longer in use per the Federal Communication Commission's Docket 19-138 First Report and Order published May 3, 2021.

17. Key Words	18. Distribution Statement
New York City, connected vehicle, pilot, DSRC, C-V2X, FCC, transition, shutdown	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	28	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Acknowledgements

The New York City Department of Transportation (NYCDOT) and its pilot deployment team thanks the many fleet owners dedicated to bringing connected vehicle technology to New York City. These stakeholder organizations demonstrate their commitment towards attaining Vision Zero's goals through their participation. The various NYCDOT vehicle fleets, NYC Department of Citywide Administrative Services (DCAS) vehicle fleets, MTA/NYCT, and Pedestrians for Accessible and Safe Streets (PASS) have expended considerable resources participating in the development of the overall Concept of Operations as well as this document.

Finally, the team wants to thank the USDOT for sponsoring this project and laying the foundation for future connected vehicle deployments.

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1 Summary of the Operational System Under Phase 3

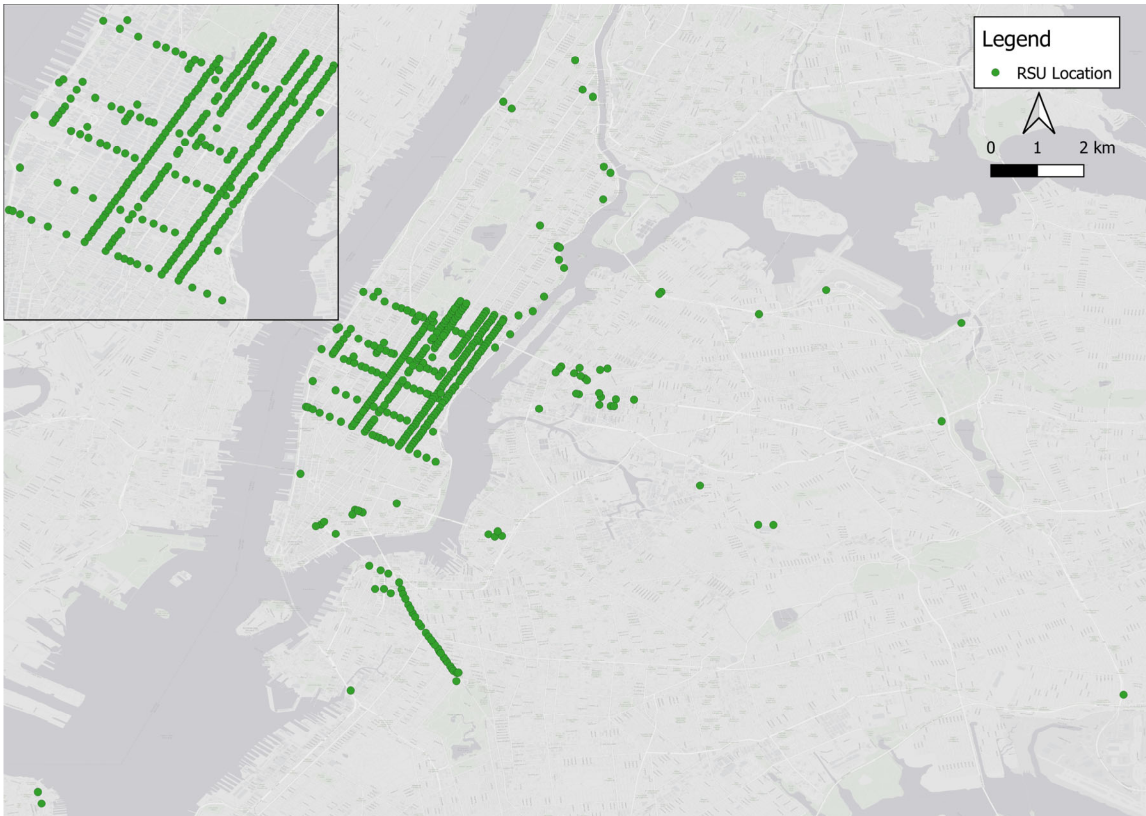
The New York City Connected Vehicle Pilot aims to improve the safety of travelers and pedestrians in the city through the deployment of connected vehicle technologies. This objective directly aligns with the city's Vision Zero initiative, which began in 2014 to reduce the number of fatalities and injuries resulting from traffic crashes.

Led by the New York City Department of Transportation (NYCDOT), the pilot aims to reduce crash frequency and severity, manage vehicle speeds (to the regulatory limit), and evaluate the benefits of deploying connected vehicle technology in a dense urban environment with frequent interactions among the participating vehicles.

This section describes the New York City Connected Vehicle Pilot Deployment system. It summarizes the facilities deployed based on the project's plans, design, implementation, and operation. Details of these processes are available at the USDOT's Connected Vehicle Pilot web site (https://www.its.dot.gov/pilots).

1.1 Connected Vehicle Equipment

New York City's deployment provides an ideal opportunity to evaluate connected vehicle technology and applications in tightly-spaced intersections typical in a dense urban transportation system. It is the largest connected vehicle technology deployment to date. The pilot area encompasses three distinct areas in the boroughs of Manhattan and Brooklyn. The first area includes the 8-mile segment of Franklin D. Roosevelt (FDR) Drive from Brooklyn Bridge to Robert F. Kennedy (RFK) Bridge in Manhattan. The second area includes the four (4) one-way corridors and five (5) two-way cross-streets, as well as additional sites for location accuracy in Manhattan. The four avenues equipped for connected vehicles are 1st, 2nd, 5th, and 6th (Avenue of the Americas) and the cross-streets equipped are 14th, 23rd, 34th, 42nd, and 57th. The third area covers a 1.6-mile segment of Flatbush Avenue in Brooklyn from Prospect Park to the Brooklyn Bridge. Additional locations have been equipped to provide fleet management services including firmware/software downloads, data collections, location accuracy services, and security credential updates. This infrastructure encompasses a population of ~450 Roadside Units (RSUs) covering the areas shown in Figure 1. NYC CVPD RSU Locations below.



(Source: NYCDOT)

Figure 1. NYC CVPD RSU Locations

The following sections describe various system components that provide the safety services, collect data for evaluation of the system's performance, and support ongoing maintenance and operation necessary to support the fleet and infrastructure.

1.1.1 Aftermarket Safety Devices

Utilizing these connected vehicle services are a fleet of 3000 vehicles primarily owned by various New York City departments. Forty-three combinations of manufacturer and model constitute the fleet and each has been installed with an After-market Safety Device (ASD) otherwise known as an On-board Unit (OBU). These units connect to the vehicle's Controller Area Network (CAN) data to obtain speed information directly from the vehicle systems in support of improving location accuracy via a combination of beacon triangulation (from RSUs) and Dead Reckoning in association with using Global Network Satellite System (GNSS) location services. The ASD/OBU devices have been provided by Danlaw.

1.1.2 Roadside Units

The RSUs provide the first node of a network that connects vehicle equipment (see section above) with additional safety information and support services. The RSU's broadcast messages describing roadway geometry and speed limits, signal indications, and traveler information regarding work zones, special travel conditions, and alert information. They also provide support services to improve the vehicle's location accuracy, as well as services for downloading software updates, uploading data, and connecting to external systems for the acquisition of security credentials. The RSUs also provide ASD "sightings" that are used by the traffic management system to measure travel times within the project area.

1.1.3 Personal Information Devices

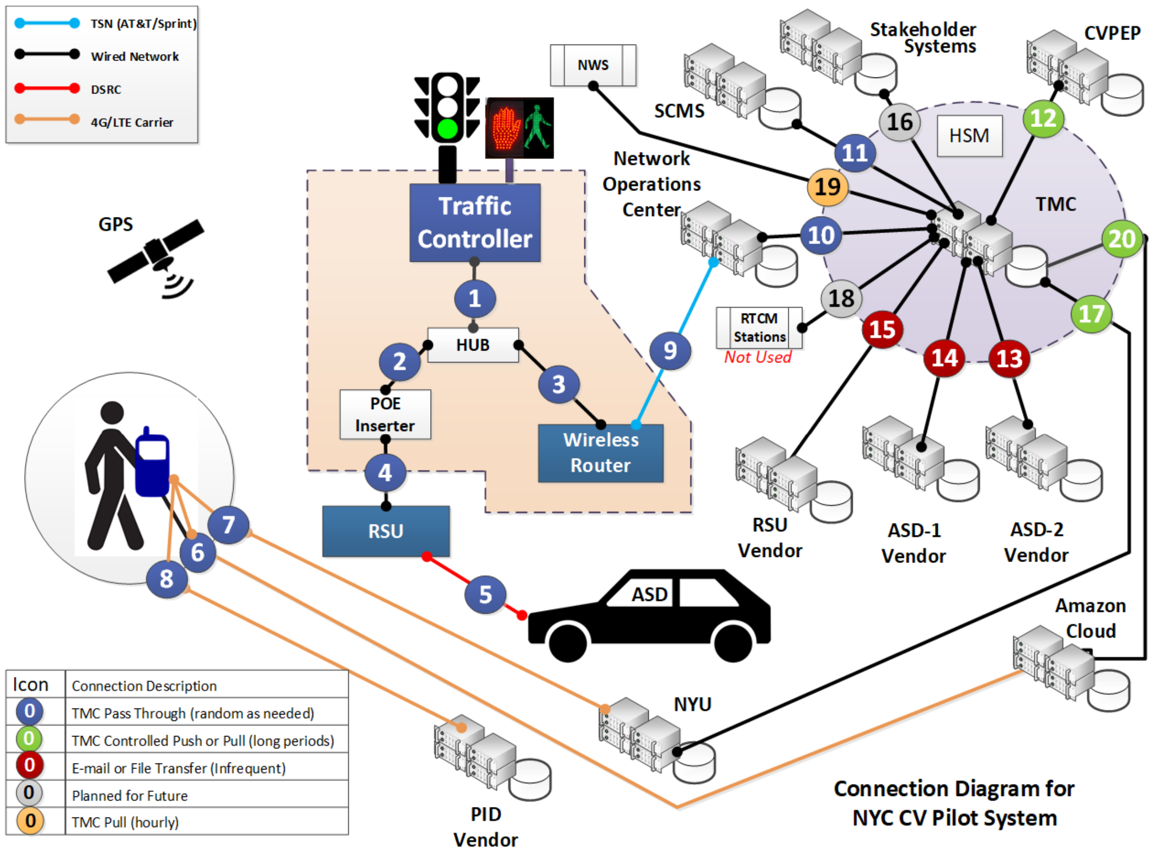
A set of prototype Personal Information Devices (PID), otherwise known as smart phones, have been procured to assist visually impaired travelers when crossing the street. The devices are loaded with the SmartCross application, and their locating system is augmented with additional positioning information from an external device.

1.1.4 Pedestrian Detection Devices

Infra-red video technology is installed to monitor the crosswalks at ten intersections. Information about pedestrians occupying the crossing is sent to the traffic signal controller and then to ASDs for use in alerting drivers to potential conflicts.

1.1.5 Back-office Servers

The back-office CV servers are shown in Figure 2 along with their connections to other system devices and external services. These servers manage the operation of the RSUs, provide security certificates for some of the RSU broadcast messages, and collect and process the data uploaded from the ASDs.



(Source: NYCDOT 2/22/2018)

Figure 2. NYC CVPD Physical Architecture

1.2 Connected Vehicle Data Collection

The NYC CVP collects data from both the vehicles and the fixed infrastructure to assess the benefits of the deploying the technology. The central system also collects data to track the health and operation of the various CV devices; this data is used to track the operation of the devices and identify device or system failures to support troubleshooting and remediation.

1.2.1 ASD Sourced Data

Vehicles collect information about the operation in system status logs, firmware inventory (over-the-air), travel locations (breadcrumbs), sightings of other equipped vehicles and infrastructure (Radio Frequency or RF), and safety application data (events) for assessing the system's performance.

1.2.2 RSU Sourced Data

The roadside units collect sightings of vehicles (RF), and vehicles entry into geo-fenced zones for determining travel times. Additionally, the roadside units collect the vehicle stored data and forward it to the back-office systems for analysis.

1.2.3 PID Sourced Data

The personal information devices collect data about intersection maps, signal displays, and the pedestrian's use of the crosswalk. This data is collected on the PID and then sent to the back-office servers for analysis.

1.2.4 Data Obfuscation and Aggregation

To protect the privacy of individuals, the collected data is obfuscated to hide the specific time and place of the activity. The data is aggregated for research purposes and measuring performance. Details about the data obfuscation and aggregation are available in the project documentation starting with the Concept of Operations and through the various project plans and design materials.

1.2.5 Data Export

Obfuscated data is periodically exported to two external repositories. One repository supports the project's evaluation by an independent organization (Secure Data Commons – SDC). The other repository supports connected vehicle researchers from external organizations (ITS DataHub).

2 Concepts and Application Analysis

This section provides a brief status summary of the project's connected vehicle applications. As the project's performance evaluation is incomplete at the time of this transition plan's preparation, the information is anecdotal and subject to revision based on the final performance evaluation report.

2.1 Working Applications

The connected vehicle applications listed in Table 1. Working CV Applications demonstrate acceptable performance and do not exhibit significant anomalies.

Table 1. Working CV Applications

Application	Full Name	Issues
EEBL	Emergency Electronic Brake Light	None
FCW	Forward Collision Warning	None
LCW	Lane Change Warning	None
IMA	Intersection Movement Assist	None
RLVW	Red Light Violation Warning	None
SPDCOMP	Speed Compliance	None
CSPDOMP	Curve Speed Compliance	None
SPDCOMPWZ	Work Zone Speed Compliance	None
OVC (Limit)	Oversize Vehicle Clearance – Height Limit	None
EVACINFO*	Evacuation Information	None

Note: While the EVACINFO performed in testing, its utility to provide emergency information should be evaluated further especially considering technology limitations of the C-V2X technology.

2.2 Partially Working Applications

The following connected vehicle applications in Table 2. Partially Working CV Applications exhibited anomalies that produced inconsistent performance thereby preventing their evaluation. Issues encountered with each application are listed below.

Table 2. Partially Working CV Applications

Application	Full Name	Issues
BSW	Blind Spot Warning	False alerts in heavy traffic are excessive The BSW application is disabled in the vehicle configurations. The application has reported events while disabled. The cause of reporting despite being disabled has been investigated and a root cause has not been identified.
VTRFB	Vehicle Turning Right in Front of Bus	Bus availability and operations in project are inadequate to evaluate performance
PEDSIG	Pedestrian Signal	Location accuracy insufficient to evaluate the performance of the application
PEDINXWLK	Pedestrian in Crosswalk	This application worked for perpendicular crosswalks but appeared to be unreliable for parallel crosswalks.

2.3 Removed Applications

The following application in Table 3. Removed CV Applications proved challenging to deploy.

Table 3. Removed CV Applications

Application	Full Name	Issues
OVC (Prohibit)	Oversize Vehicle Clearance – Prohibited Turn	Difficulty preparing an adequate and uniform TIM to describe the prohibited vehicle movement

3 Plans for Post-Phase 3

This section outlines NYCDOT's plan for operating the CVP system after completion of its agreement with USDOT. The dominate driver of this plan is the Federal Communications Commission (FCC)'s Docket 19-138 First Report and Order (FRO) published May 3, 2021. The FRO's requirements will be discussed with respect to system operation and then the plan going forward. The assumptions necessary for plan implementation will be presented followed by timelines and administrative considerations (roles, responsibilities, financial agreements). The impacts of the plan on various system components will then be discussed.

It is important to keep in mind the USDOT goals for the CV pilot projects while reviewing the plan presented below. NYCDOT undertook this project, contributing City matching funds, with the intent to be a leader in the deployment of a sustainable connected vehicle infrastructure and being able to benefit from the anticipated safety improvements offered by this technology.

The following is an excerpt from the USDOT CV Pilot Program Web Site:

The Connected Vehicle (CV) Pilots intend to accelerate the deployment of interoperable connected vehicle technologies by:

- Spurring innovation among early adopters of connected vehicle application concepts.
- Encouraging partnerships among multiple stakeholders required to deploy and manage connected vehicle concepts.
- Demonstrating the potential safety, mobility and environmental benefits associated with connected vehicle deployments.
- Creating sustainable momentum for nationwide deployment of connected vehicle technologies

3.1 FCC's First Report and Order Compliance

The FCC's Docket 19-138 First Report and Order declares Dedicated Short Range Communication (DSRC) technology obsolete and requires the use of Cellular Vehicle-to-Everything (C-V2X) technology going forward. This decision renders the USDOT and NYCDOT's investment of $23.1M null and void. While the project has produced significant data and lessons learned with respect to DSRC-based CV safety and operations, its value is arguable as the data collection is based on technology that the FCC has declared obsolete. Additionally, the FCC's roadmap for migration to C-V2X does not include funding and leaves many unresolved technology issues as standards are currently unpublished (as of September 2021), engineering data and documented experience is unpublished, and the existing/proposed Out-of-Band Emissions (OOBE) regulations may limit the viability of using C-V2X messaging for safety applications.

The FCC's FRO requires that DSRC vacate the lower 45 MHz of the DSRC spectrum by July 2, 2022 and certified as such. Because the NYCDOT project utilizes four of the channels in the spectrum space to be vacated, it requires extensive re-engineering and testing to compress its usage into the remaining 30 MHz as well as obtaining additional communications media/bandwidth (e.g. WiFi, LTE/4G, 5G) to address the deployment needs which are beyond the ability of the 30 MHz to support. Again, funding for these efforts is not budgeted nor appropriated thereby precluding these activities within the regulatory deadlines.

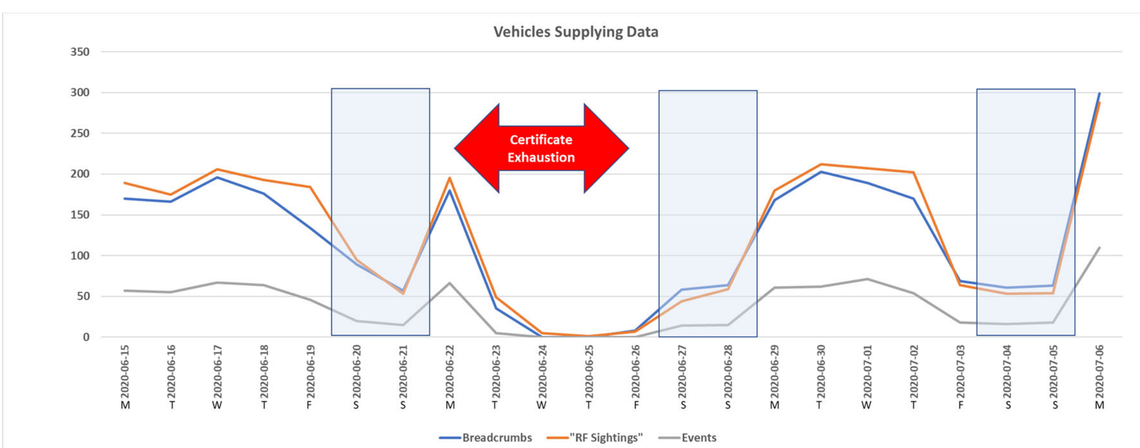
3.2 Transition Plan

This section discusses the NYC CVPD project's operational transition after the completion of the contract between the NYCDOT and USDOT scheduled for completion on December 31, 2021.

3.2.1 Transition Plan Overview

In consideration of the requirements and administrative regulations put forth by the FCC's Docket 19-138 First Report and Order, the NYC CVPD project will shut down after fulfillment of its USDOT Connected Vehicle Pilot contract. Therefore there are not any concepts, applications, governance framework, agreements, key documents, and equipment to be maintained as elements of routine operational practice after the completion of Phase 3 as defined in Phase 3: Maintain and Operate (Amendment 8) or December 31, 2021 (Amendment 7), whichever occurs first, per NYCDOT's agreement with USDOT.

This shutdown will be facilitated via the DSRC device's need for security certificates to enable DSRC broadcasting. The process of updating IEEE 1609.2 certificates on the DSRC devices will be interrupted thereby preventing new active certificates from being loaded onto the devices. When a device no longer has valid and currently active security certificates it will cease to broadcast DSRC messages. The devices utilize up to two batches of certificates which are valid for one week each. Therefore, when the updating process is disrupted, the device will be unable to obtain new certificates and cease transmitting after approximately two weeks. Assuming the update process is disabled on January 4, 2022 the devices will cease transmitting approximately January 18, 2022. This concept has been demonstrated when a software update to the SCMS Local Certificate Chain File (LCCF) file caused the DSRC devices to cease transmitting in August 2020 as shown in Figure 3. Certificate Expiration Example below.



(Source: NYCDOT 7/6/2020)

Figure 3. Certificate Expiration Example

Several techniques will be available to verify that the devices are no longer transmitting. First, the USDOT Kapsch tool can be used to listen for DSRC messages during a drive through areas equipped with RSUs. The same tool can be used to monitor the transmission of Basic Safety Messages (BSMs) in fleet terminal areas such as Rikers Island, Harper Street, and 34-02 Queens Blvd. System users can also verify that RSU transmission counters cease to increment though the RSU's remote user interface. Following verification that DSRC messages have ceased, NYCDOT can certify that the lower 45 MHz of the spectrum has been vacated per the FCC's regulations.

Additional actions will be necessary to decommission the CVP system. All existing leased equipment will require terminating leases and returning the leased equipment to its owner. Daily scheduled processes that aggregate data and forward data to external repositories (e.g. SDC, ITS DataHub) will be terminated. Final data backups will be made and archived. NYCDOT has no plans for recovery of DSRC field devices or their peripherals (Power of Ethernet supplies, antennas, cabling) as the salvage value will not begin to address the labor expenses of such recovery. Note that DSRC equipment removal may occur during the performance of other maintenance activities and such removed equipment will be scrapped.

3.2.2 Assumptions

The key assumption for this plan is that there will not be any regulatory, legislative, or judicial event to over-rule or stay the existing FCC FRO. While there are many ex parte contributions to the docket and currently outstanding regulatory and judicial actions pending, the FCC has not shown any acknowledgement of the USDOT's and others positions regarding the spectrum. The FCC's actions thereby reinforce this assumption's validity.

As NYC has substantial sunk costs for the purchase, deployment, and operation of the existing DSRC based equipment, its financial budgets have not programmed the significant funding necessary to re-engineer and deploy the interim configuration for temporary operation required by the FCC FRO. Budgeting for temporary "work-arounds" is difficult to justify in an environment where there is competition for limited funds to repair fixed assets such as roadways and bridges. Additionally, speculating on deploying a C-V2X system when the pre-requisites are not yet in place to enable such an effort poses significant risk to the City's investment and potential for re-work as the situation evolves.

To maintain the status quo following the completion of the USDOT contract requires ongoing monthly operational costs for nebulous benefits to the City. Such costs include ~$17,000 per month (certificates, Abstract Syntax Notation One (ASN.1) compiler, Hardware Security Module (HSM) signing appliance, Traffic Safety Network (TSN) data transport) for ongoing services and leases, and labor for maintenance support and administration (estimated at $50,000/month) of vehicle and intersection equipment. These costs do not acknowledge the expenses involved with necessary device security re-enrollments, replacement devices, and other engineering efforts for migration to comply with the FCC FRO.

3.2.3 Institutional Models

As the fleet is owned by New York City and the Metropolitan Transportation Authority, the institutions do not pose any issues with implementation of the transition plan.

3.2.4 Financial Agreements

NYC needs to address relationships with a series of outside vendors as the system is shutdown. These vendors provide the infrastructure detailed in Figure 2. NYC CVPD Physical Architecture. In Table 4. Vendor Agreements Summary below, the various vendors and their supplied components are listed along with a preliminary assessment as to their potential supply of goods and services for a future C-V2X implementation.

Table 4. Vendor Agreements Summary

Vendor	Component	Need	C-V2X Need*
ISS	Certificate generation	Provide security certificates for CV devices	Yes
ISS	TMC Authority	Provide system to securely sign TMC managed MAP & TIM messages	Yes
Siemens	RSU	Provide device repairs and troubleshooting	Conditional
Danlaw	ASD	Provide device repairs and troubleshooting	Conditional
CodeOn	ASD & RSU	Provide license for OTA encoding	Yes
OSS / Nokalva	ASN.1 Compiler	Provide license for ASN.1 Compiler for TMC system to decode messages	Yes
Microsoft	SQLServer Software	Database server license	Yes
Oriux	ASTC Firmware	X.509 certificate enabled controller firmware.	Yes
Harman (f.k.a. Savari)	Personal Information Device Location Augmentation Device	SmartCross application and its connection to an external Radio Technical Commission for Maritime Services (RTCM) enabled location augmentation device. Actual performance of this application does not warrant on-going independent operation.	No
Secure Data Commons	Secure Data Storage & Processing	USDOT contractual requirement to share data securely with the Independent Evaluation team.	No

Vendor	Componen t	Need	C-V2X Need*
ITS DataHub	Data Storage & Sharing	Data sharing with ITS community	No
Tableau	Tableau Server Software	Dashboard Presentation	No

*In the table above, the following describes the entries under the C-V2X column.

- Yes: Required for operation using C-V2X communications
- No: Not required for operation using C-V2X communications – was necessary to fulfill CVP contract requirements
- Conditional: Not required – may be necessary to fulfill requirements based on the adopted Concept of Operations

3.2.5 Roles and Responsibilities

NYCDOT IT staff will be responsible for closing the certificate renewal path through the proxy server in the Traffic Management Center (TMC). NYCDOT staff will monitor the ISS data portal to ensure that the devices do not receive certificate updates. NYCDOT will also monitor the infrastructure and certify that the lower 45 MHz have been cleared. NYCDOT staff will also monitor the FCC Universal Licensing System to ensure that the existing NYC DSRC licenses are migrated to the upper 30 MHz channels (180, 182, 184, and 183) as this preserves NYC's rights to the spectrum should funding become available to rebuild/redeploy the system using C-V2X technology as required by the FCC FRO.

3.2.6 Timeline

The schedule for terminating operations is summarized in Table 5. Timeline ConstraintsTable 5 below. It includes the FCC framing actions as well as direct actions required by NYC and events that will occur automatically due to expiration dates established by prior events.

Table 5. Timeline Constraints

Item	Date	Event	Actors
1	May 3, 2021	FCC First Report & Order published in Federal Register	FCC
2	July 2, 2021	FCC First Report & Order effective date	FCC
3	Dec 31, 2021	SCMS discontinues providing CVP certificates Cause: USDOT-ISS contract termination date	USDOT ISS
4	Jan 4, 2022	NYCDOT IT disables proxy server that enables DSRC devices to connect to the SCMS for certificate updates.	NYCDOT

Item	Date	Event	Actors
5	Jan 4, 2022	ISS TMC Authority (SCMS appliance in TMC) shutdown preventing distribution of signed MAP and TIM messages.	NYCDOT ISS
6	Jan 18, 2022	All DSRC devices are without active certificates will stop transmitting DSRC messages.	FCC NYCDOT
7	Jan 28, 2022	NYC RSU device security enrollments begin expiring - Note that any continued operation requires re-enrollment and RSU firmware changes to move to the upper 30 MHz.	NYCDOT Siemens ISS
8	Jan 31, 2022	ISS TMC Authority (SCMS appliance in TMC) lease expires, and devices returned to ISS.	NYCDOT ISS
9	Feb 4, 2022	NYCDOT verifies all DSRC devices are silent and certifies DSRC operations on the lower 45 MHz are terminated	NYCDOT FCC
10	June 12, 2022	NYC ASD device security enrollments begin expiring – Note that any continued operation requires ASD firmware changes to re-enroll devices. Additional ASD firmware changes are necessary to move DSRC to the upper 30 MHz.	NYCDOT Danlaw ISS
11	June 28, 2022	NYC RSU device security enrollments 50% expired	NYCDOT Siemens ISS
12	July 2, 2022	Abandon lower 45 MHz (Channels 172, 174, 176, 178) required. Temporary use of all upper 30 MHz (Channels 180, 182, 184) is permitted but requires software changes to ASD and RSU as well as testing to verify alternative approaches for existing operations.	FCC NYCDOT
13	Aug 29, 2022	NYC ASD device security enrollments 50% expired	NYCDOT Danlaw ISS
14	Dec 20, 2022	NYC ASD device security enrollments 100% expired	NYCDOT Danlaw ISS
15	Jan 25, 2023	NYC RSU device security enrollments nearly 100% expired (note: 5 replacement RSUs expire in Sept-Nov 2024)	NYCDOT Siemens ISS
16	May 10, 2023	OSS Nokalva ASN.1 compiler license expires	NYCDOT OSS
17	July 2, 2023	Discontinue All DSRC transmissions	FCC NYCDOT

Item	Date	Event	Actors
18	Nov 30, 2024	NYC RSU device security enrollments 100% expired.	NYCDOT Siemens ISS

3.3 NYC CVPD Subsystems

This section discusses the subsystems and resources within the existing system and the resources necessary for standing up a C-V2X based system in the future. This section does not address the development of an interim DSRC based system using only the upper 30 MHz. As noted earlier, the costs associated with the software modifications, ongoing operation, and system testing to continue the current operation, and the effort necessary to access the vehicles which do not respond to the automated update processes is not warranted since all equipment must be decommissioned by July 2, 2023 regardless.

3.3.1 Aftermarket Safety Devices (ASDs)

The current devices have been supplied by Danlaw. These devices only support DSRC communications and are currently programmed to use six of the seven DSRC channels. They would have to be re-programmed (new device firmware) to comply with the FCCs FRO to utilize the upper 30 MHz for continued use of DSRC.

Another issue with these devices is that their current device enrollments certificates will begin expiring in June 2022. Without an update to their current security libraries to accommodate re-enrollment and processing of Local Chain Configuration Files (LCCF), the devices will cease to transmit as their enrollment expires.

However, the existing devices do not and cannot support C-V2X technology; hence the existing devices would need to be removed and replaced to support C-V2X operations. This necessitates that all vehicles be brought to an installation site(s) for replacement; further, it is unclear if the current antenna configuration will be reusable for C-V2X operation. This will require investigation, evaluation, and testing.

In addition, the C-V2X technology does not have sufficient bandwidth to support the safety application messages along with the support services provided through unicast IP exchanges necessary on a single 20 MHz channel. The overall system needs to be re-designed to support the use of traditional cellular communications (4G, LTE,5G) or Wi-Fi which requires an additional radio and carrier services. These are some of the issues that would be worked out during some future C-V2X replacement system design project if and when the necessary funding becomes available. However, such efforts are beyond the scope of the current project.

3.3.2 Roadside Units (RSUs)

The current devices have been supplied by Siemens. These devices only support DSRC communications and are currently programmed to use six of the seven DSRC channels. They would have to be re-programmed to comply with the FCCs FRO. Another issue with these devices is their current security credentials as the device enrollments begin expiring in January 2022. Without an update to their current security libraries to accommodate re-enrollment, the devices will cease to transmit as their enrollment expires.

Siemens has indicated that the units can be rebuilt (at the factory) to support C-V2X; however, given that many of these were installed in 2019, Siemens has recommended that the units be replaced with new devices configured and tested for C-V2X operation. Either approach requires that field crews (bucket truck and electricians) remove the existing devices and install updated devices.

3.3.3 Personal Information Devices (PIDs)

The ten prototype personal information devices and their location augmentation devices do not use DSRC communications and can be repurposed following the system shutdown.

3.3.4 Traffic Management Center (TMC)

The back-office CV facilities will be shutdown following the termination of certificate services and a two-week period (i.e. data retention period) to collect data remaining on the vehicles. A final data backup will be performed to preserve the project’s data.

Any future deployment of C-V2X technology would re-instantiate the TMC security appliance to be used to sign the TIM, MAP, and other similar messages. Re-installation would require a contract for the acquisition of security credentials to support continued operation.

All other software at the TMC will need minor modifications to accommodate the deployment of C-V2X technology. However, as alternate media would be needed for support services (i.e. firmware updates, data collection and certificate distribution to the ASDs), this would require additional software design, development, and testing.

3.3.5 Performance Monitoring System

As the final data is collected, obfuscated, and exported, it is anticipated that the final data exports will be transmitted to the external repositories towards the end of January 2022. Following these exports, the computing systems can be taken out of service.

3.3.6 Security Credential Management System

With the expiration of the agreements for security credentials at the end of 2021, access by the ASDs and RSUs to certificates will be shut down by disabling the existing proxy server in the TMC. Additionally, the TMC Authority that signs the MAP/TIM messages will be taken out of service. Activities will be coordinated to return the device to its vendor to preserve the security information it contains.

3.3.7 Data Collection / Retention

See the actions described in Section 3.3.34 Traffic Management Center (TMC). Note that obfuscated event data released by the project will be retained on the ITS DataHub for a minimum of five years in accordance with the **ITS DataHub Records Disposition Manual**, National Archives and Records Administration (NARA0 schedule number **DAA-0406-2014-0003**.

3.3.8 Location Augmentation

The existing system utilizes a technique to improve the location accuracy of the ASDs using triangulation from the RSUs. A replacement mechanism would have to be incorporated to address the need demonstrated by the project.

3.4 Future Considerations

This project required extensive data collection to enable evaluating the operation and performance of the system and its devices to an extent never before attempted. However, in order to provide all of the above, the overall system design became very complex relative to the simple approaches necessary for the basic safety operations. This section addresses the concepts addressed and a concept for consideration when implementing C-V2X technology. The NYC CVPD design incorporated many leading-edge concepts; these included:

- practical data collection,
- weekly security certificate downloads,
- RF data collection, and
- over-the-air (OTA) software updates using a broadcast technique.

The system used a wireless carrier network, FirstNet, between the TMC and the RSUs, and used the data collected to monitor vehicle travel times. This project also deployed in-vehicle audio warning messages with monitoring and included a connection to the vehicle's CAN bus. Finally, this project pioneered the concept of addressing the location accuracy issues in the dense urban environment with a unique approach developed by Cohda to use time of flight signal timing from RSU transmissions. All of this was deployed using only the DSRC spectrum space (6 channels) as originally designated by the FCC and deployed the 1609.2 security provisions, as well as the 1609 standards for channel switching and message structure. To protect the connected vehicle security, the project extended the security perimeter to include other traffic control devices. Three communication links among the traffic signal controller, the TMC, and the roadside unit were addressed by these changes. The project was driven by the USDOT requirements for data collection and analysis and the understanding that change was inevitable – hence the provisions for OTA software updates.

This was a large-scale deployment of over 3000 municipally owned vehicles. It is important to note that the project initially planned to deploy the CV technology into the taxi fleets which provide services primarily in Manhattan. The system design was based on typical taxi fleet operation with RSUs deployed at entry and exit locations surrounding Manhattan since most of the taxi fleet support facilities are in Queens. The large-scale introduction of Uber, Lyft, and other For Hire Vehicles (FHV) services decimated the taxi industry with public outcry, suicides, and bankruptcies related to financing the Medallions necessary to provide taxi services within the city. As a result, the initial promise by the Taxi and Limousine Commission to support the CV project with appropriate incentives evaporated, and the project evolved to deploy using available City fleets. These City fleets have significantly different usage characteristics which has affected the operations and supports systems designed primarily for the taxi fleets.

Since the start of the project (October 2015), similar projects and further studies have led to the concept of simplified deployment. Security certificate top-offs are not necessary if the devices are fully preloaded with years of certificates as long as a fully operational mis-behavior detection system exists, and a certificate revocation support infrastructure exists. In addition, it has become evident that data collection is not needed for the "normal" operation of the safety applications. Many of the vehicle and device manufacturers have developed customized IP mechanisms to communicate with their devices for the collection of statistical operating data (health) and management of software updates and management of security certificates.

Thus, a CV project could be deployed in almost a "cookbook" manner without the extensive data collection required for the pilots. If the OBU has an IP address and application which supports proprietary vendor exchanges for software updates and data collection – but with standards for security certificate management and safety messages, the complexity of the system is greatly reduced. As the industry matures it is only necessary that the vehicles broadcast their basic safety messages to achieve all of the safety benefits, without the extensive data collection and analysis that was developed for the NYC pilot project.

Hence, to deploy the C-V2X technology, it is not necessary to design custom data collection mechanisms and design for device software updates and security management as these can be left to the device vendors. Thus, the responsibility of the infrastructure owner is only to purchase and install an RSU, connect it to a network accessible from the TMC, configure the MAP message content, implement the RTCM support, update the traffic controllers to support the SPaT information to the RSU, and implement the connections necessary to support the security credentials required to sign and authenticate the messages. The typical traffic management system already has the mechanisms to manage and monitor the traffic controllers and adding the RSU as a similar device is relatively straight forward.

It is hoped that as various trials and test installations using C-V2X technology are published, the vendors will use this information to develop production quality and cost-effective devices for both Original Equipment Manufacturer (OEM) and aftermarket deployment. NYCDOT deployed the largest DSRC based CV system with many lessons learned. It is hoped that the C-V2X trials will obviate the need to undertake the type of development efforts that proved to be necessary for the NYC CVPD project. However, NYCDOT found that although there had been a decade of trials, demonstrations, proof of concept, and pilots of the DSRC CV technology prior to the initiation of the New York City CVPD, it took years of effort to bring that technology to successful deployment in a large-scale urban setting. With appropriate funding, NYCDOT is prepared to work closely with USDOT as a site for the trials and testing of large-scale urban C-V2X based connected vehicle infrastructure and system deployment.

4 References

1. U.S. Department of Transportation. “Connected Vehicle Pilot Deployment Program Phase 1, Concept of Operations (ConOps) - NYCDOT” 2016 https://rosap.ntl.bts.gov/view/dot/30881

Appendix A. List of Acronyms

Table 6 below provides a list of the acronyms used in this Comprehensive Transition Plan (CTP) document.

Table 6. Acronym List

Acronym	Meaning
AO	Agreement Officer
AOR	Agreement Officer Representative
ASD	After-market Safety Device
ASN.1	Abstract Syntax Notation One
ASTC	Advanced Solid-State Traffic Controller
CAN	Controller Area Network
ConOps	Concept of Operations
CTP	Comprehensive Transition Plan
CV	Connected Vehicle
C-V2X	Cellular Vehicle to Everything – based on SAE J3161 which is still unpublished
CVPD	Connected Vehicle Pilot Deployment
DR	Dead Reckoning
DSRC	Dedicated Short Range Communications based on IEEE 802.11
FCC	Federal Communications Commission
FHV	For Hire Vehicles
FRO	First Report & Order
GNSS	Global Navigation Satellite System
HSM	Hardware Security Module
ITS	Intelligent Transportation Systems
LCCF	Local Certificate Chain File
MHz	Mega Hertz
NARA	National Archives and Records Administration
NYCDOT	New York City Department of Transportation
OBU	On-board Unit
OEM	Original Equipment Manufacturer

Acronym	Meaning
OOBE	Out-of-Band Emissions
OTA	Over-the-Air
PID	Personal Information Device
RSU	Roadside Unit
RTCM	Radio Technical Commission for Maritime Services
SDC	Secure Data Commons
TMC	Traffic Management Center
TSN	Traffic Safety Network
USDOT	United States Department of Transportation

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