Connected Vehicle Pilot Deployment Program Independent Evaluation

Stakeholder Acceptance & User Satisfaction—New York City (NYC)

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16. Abstract

This report presents the stakeholder acceptance and user satisfaction evaluation conducted by the Texas A&M Transportation Institute independent evaluation team of the New York City (NYC) Connected Vehicle Pilot Deployment (CVPD). The purpose of the evaluation was to assess whether and how the NYC CVPD achieved the vision; goals; and desired mobility, environmental, and public agency efficiency impacts. In addition, the information gathered from stakeholders included observations and experiences pertaining to anticipated or potential challenges (e.g., technical, institutional, and financial), adopted solutions, and lessons learned. The results are intended to be of benefit to the long-term sustainability of the CV-deployed applications and to other entities seeking to deploy CV applications.

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Executive Summary

The Intelligent Transportation Systems Joint Program Office selected New York City (NYC) as one of three locations to serve as Connected Vehicle Pilot Deployment (CVPD) sites. The NYC Department of Transportation (NYCDOT) led the deployment. Located primarily in the Manhattan area and along Flatbush Avenue in Brooklyn, the primary objective of the NYC CVPD was to develop and demonstrate the use of vehicle-to-vehicle, vehicle-to-infrastructure, and infrastructure-to-pedestrian communications to improve safety, part of NYCDOT's Vision Zero goal to eliminate traffic-related fatalities and reduce crash-related injuries and damage throughout the city.

For this deployment, the NYC CVPD Team equipped a total of 3,000 city-owned fleet vehicles with aftermarket safety devices running the following applications as part of its NYC CVPD:

- Speed Compliance (SPDCOMP).
- Curve Speed Compliance (CSPDCOMP).
- Speed Compliance in Work Zone (SPDCOMPWZ).
- Forward Collision Warning (FCW).
- Emergency Electronic Brake Light Warning (EEBL).
- Blind Spot Warning (BSW)/Lane Change Warning (LCW).
- Intersection Movement Assist (IMA).
- Red-Light Violation Warning (RLVW).
- Vehicle Turning Right Warning (VTRW).
- Pedestrian in Signalized Crosswalk Warning (PEDINXWALK)
- Mobile Pedestrian Signal System (PED-SIG)
- Oversized Vehicle Compliance (OVC)
- Emergency Communications and Evaluation Information (EVAC)
- CV Data for Intelligent Transportation Signal System (I-SIGCVDATA).

The NYC CVPD Team also installed 457 roadside units (RSUs) at intersections in Manhattan, on the Brooklyn Bridge and along Franklin D. Roosevelt Parkway on the east side of Manhattan. United Parcel Service was enlisted as an original participant in the early stages of the project but disengaged prior to the deployment phase.

The CVPD evaluation included both stakeholder acceptance and user satisfaction researches. The Stakeholder Acceptance Research was designed and conducted by the Texas A&M Transportation Institute (TTI) CVPD Evaluation Team. The User Satisfaction Research was designed and implemented by the NYC CVPD Team.

A robust assessment of stakeholder acceptance of the NYC CVPD was not possible because the NYC CVPD Evaluation Plan [3] was not implemented in its entirety due to time constraints imposed by the occurrence of certain events (i.e., Covid-19, diminishing economic well-being of taxi industry, dedicated short-range communication spectrum uncertainties). The TTI CVPD evaluation team conducted pre-deployment interviews with stakeholders involved in the NYC CVPD about one year later than expected in October 2020.

The NYC CVPD was perceived by all stakeholders as being very challenging for all involved; most importantly, the CV technology was not deployment-ready. Three key technical challenges were identified: (1) CV technology not ready for deployment, (2) locational accuracy, and (3) over-the-air software updates. Thus, while success of the pilot was originally defined as achieving the safety goal of crash reduction, with mounting challenges the definition of success morphed into simply getting the deployment components to work. Also, as the numbers of deployed vehicles reduced from 10,000 to 8,000 to 3,000 due to some stakeholders dropping out of the pilot, there was doubt that the required data would be obtained from the number of deployed vehicles and RSUs to determine safety impact. Procuring technology at the scale of the pilot required special procurement and contractual processes, which caused contract delays and other procurement challenges. Overall, the learning curve in terms of deploying the CV technology in a dense urban environment and overcoming the many challenges brought a feeling of accomplishment to the NYC CVPD Team.

Research with end users was implemented according to plan.[2] The NYC CVPD Team collected user survey data from fleet drivers and from pedestrians with visual impairments. The sample sizes for these surveys were small. There were 24 pedestrians and 81, 19, and 161 drivers in the pre-deployment, early post-deployment, and late post-deployment survey, respectively. Drivers were neither satisfied nor dissatisfied with the CV applications. Common concerns were distractions, false alerts, and too many alerts. The most useful alerts to improve safety were SPDCOMP and FCW. These were also the two alerts that the drivers reported hearing the most. As for the pedestrians, most were positive in their overall impression for the PED-SIG application. The majority of participants thought the application is easy to use. Half of the participants reported feeling much safer using the PED-SIG application compared to not using it.

Chapter 1. Introduction

The purpose of the Stakeholder Acceptance and User Satisfaction evaluation was to assess whether and how the New York City Connected Vehicle Pilot Deployment (NYC CVPD) achieved the vision; goals; and desired mobility, environmental, and public agency efficiency impacts. In addition, the information gathered from stakeholders included observations and experiences pertaining to anticipated or potential challenges (e.g., technical, institutional, and financial), adopted solutions, and lessons learned. The results are intended to be of benefit to the long-term sustainability of the CV-deployed applications and to other entities seeking to deploy CV applications.

The primary goal of the NYC CVPD was to demonstrate how CV technologies and applications could potentially help the NYC Department of Transportation (DOT) advance its Vision Zero Program to "eliminate traffic related deaths and reduce crash related injuries and damage to both vehicles and infrastructure."[(1)] Applications tested include the following:

- Speed Compliance.
- Curve Speed Compliance.
- Forward Collision Warning.
- Electronic Emergency Break Light Warning.
- Blind Spot Warning/Lane Change Warning.
- Intersection Movement Assist.
- Red-Light Violation Warning.
- Curve Speed Compliance.
- Vehicle Turning Right Warning.
- Pedestrian in Signalized Crosswalk Warning.
- Mobile Pedestrian Signal System.
- Oversized Vehicle Compliance.
- Emergency Communications and Evacuation Information.
- CV Data for Intelligent Transportation Signal System.

The stakeholder acceptance/satisfaction data collection for the NYC CVPD included both qualitative interviews with stakeholders designed and conducted by the Texas A&M Transportation Institute (TTI) CVPD evaluation team and surveys with end users of the CV applications designed and conducted by the NYC CVPD Team, with assistance from the Volpe Center. The qualitative interviews examined contextual issues for the deployment; provided perspectives on vision, goals, and desired impacts; and identified concerns and challenges in advance of the start of the CV pilot. The surveys allowed for the quantification of outcomes (both desired and not desired) from a broader group of end users. End users included drivers of city fleet vehicles, some bus operators, and pedestrians with visual impairments.

Taken together, these data collection activities were used to assess the outcomes of the CV Pilot and provide strategic and operational recommendations (and lessons learned) for subsequent activities.

NYC Connected Vehicle Pilot Deployment

The Intelligent Transportation Systems Joint Program Office selected NYC as one of three CVPDs. NYCDOT led the deployment. Located primarily in the Manhattan area and along Flatbush Avenue in Brooklyn (see Figure 1), the NYC CVPD focused on developing applications using vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and infrastructure-to-pedestrian communications to improve safety as part of its Vision Zero goal to eliminate traffic-related fatalities and reduce crash-related injuries and damage throughout the city.[1] As part of their deployment, NYCDOT installed onboard units (OBUs) with embedded safety applications in approximately 3,000 city vehicles. The original concept included equipping United Parcel Service (UPS) vehicles; however, UPS disengaged prior to the deployment phase. NYCDOT also installed over 450 roadside units (RSUs) in Manhattan and along Flatbush Avenue in Brooklyn to provide CVs with signal phase and timing (SPaT) information from the traffic signal system. The NYC CVPD Team also installed RSUs at strategic locations, such as bus depots, fleet vehicle storage facilities, river crossings, and airports, to facilitate the downloading of evaluation data and the uploading of application updates.

The primary goal of the NYC CVPD was to demonstrate how CV technologies and applications could potentially help NYCDOT advance its Vision Zero Program to “eliminate traffic related deaths and reduce crash related injuries and damage to both vehicles and infrastructure.”[1] As a result, the NYC CVPD focused on applications targeted to improve safety. The NYC CVPD Team identified mobility as a secondary but intertwined goal of the deployment. The NYC CVPD Team hypothesized that reducing the number of crashes (and their severity) and managing speeds could also improve mobility. Fewer crashes would result in less crash-related delays. Likewise, fewer stops may result in fewer crashes, particularly rear-end crashes.[2]

The NYC CVPD Team identified seven Use Cases targeting NYCDOT’s goals for the deployment. Table 1 provides a summary of the Use Cases identified for the NYC CVPD. Table 2 provides a brief description of the applications deployed in each Use Case.

For this deployment, the NYC CVPD Team equipped a total of 3,000 city-owned fleet vehicles with aftermarket safety devices (ASDs).[2] Originally, the NYC CVPD Team planned to deploy ASDs in pay-for-hire taxi cabs (yellow cabs) that traverse the midtown area, but delays in deployment due to privacy concerns and the changing pay-for-hire rideshare market in the midtown area did not make this a viable option. The NYC CVPD Team also enlisted UPS as an original participant in the early stages of the project, but they also disengaged prior to the deployment phase. As a result, the NYC CVPD switched their deployment to city-owned fleet vehicles. Various agencies use these vehicles to conduct the daily business of the city. Some equipped vehicles were pool vehicles available to agency staff on an as-needed basis, while other vehicles were assigned to individual staff members. While some users could use their vehicles to commute to and from work, most participants used their vehicles for work-related trips. In most cases, drivers used the vehicles to make point-to-point, work-related trips while other drivers were required to follow fixed routes. Appendix A shows the types of vehicles where the NYC CVPD Team deployed onboard devices.

Source: New York City Department of Transportation, 2022

Figure 1. Map—NYC CVPD Deployment Corridors

Table 1. Use Case Descriptions for the NYC CVPD

Use Case Number	Use Case	Use Case Focus	Description
1	Manage Speed	Safety and Mobility	Because excessive speed is a contributing factor in many crashes and fatalities, NYCDOT identified managing speeds to operate within safe limits to improve on the safe operations of the city's roadways. The NYC CVPD Team deployed three different applications aimed at managing the operating speed of equipped vehicles under different conditions: • Speed Compliance (SPDCOMP). • Curve Speed Compliance (CSPDOMP). • Speed Compliance in Work Zones (SPCOMPWZ).

2	Reduce V2V Crashes	Safety	The goal of NYCDOT's Vision Zero Program is to reduce the number of fatalities and injuries on roadways, including V2V crashes. To reduce V2V crashes, the NYC CVPD Team deployed the following applications:
			• V2V applications including the following:
			  ○ Forward Collision Warning (FCW).
			  ○ Emergency Electronic Brake Light Warning (EEBL).
			  ○ Blind Spot Warning (BSW)/Lane Change Warning (LCW).
			  ○ Intersection Movement Assist (IMA).
			• Red-Light Violation Warning (RLVW).
			• Vehicle Turning Right in Front of Bus Warning (VTRW).

3	Reduce Vehicle-to-Pedestrian Crashes	Safety	Because of NYC's heavy pedestrian and bicycle environment and its history of frequent vehicle-to-pedestrian collisions, many of which result in fatalities, NYCDOT wanted to assess CV technologies as a potential strategy for assisting and protecting pedestrians at intersection crossings. As part of the deployment, the NYC CVPD Team deployed two different pedestrian-oriented applications: • Pedestrian in Signalized Crosswalk Warning (PEDINXWALK). • Mobile Pedestrian Signal System (PED-SIG).
4	Reduce V2I Crashes	Safety	Because of the frequency and costs associated with vehicle strikes to bridges, NYCDOT identified a need to reduce the potential for V2I crashes. The NYC CVPD identified the Oversize Vehicle Compliance (OVC) application to address low clearance issues for oversized vehicles and enforce related truck route restrictions.

Use Case Number	Use Case	Use Case Focus	Description
5	Inform Drivers of Serious Incidents	Mobility	As the traffic manager and roadway infrastructure owner, NYCDOT needs to provide notification to drivers of areas to avoid and why. The NYC CVPD Team developed the Emergency Communication and Evaluation Information (EVAC) application to inform drivers of serious incidents.
6	Provide Mobility Information	Mobility	NYCDOT identified a need to develop reliable alternatives for providing travel time data for use in the adaptive traffic signal system. The NYC CVPD Team identified the CV Data for Intelligent Traffic Signal System (I-SIGCVDATA) application to augment NYC's existing toll tag technology for producing linked travel time information.
7	Manage System Operation	Operations	NYCDOT identified a need to manage and track the performance and operations of the deployed CV technologies. The NYC CVPD Team developed a series of system reports, databases, and management tools to support the day-to-day management and assessment of CV system operations.

Source: Texas A&M Transportation Institute based on information contained in reference 2, 2022

Table 2. Summary Description of NYC CVPD Applications

Application	Use Case	Description
Speed Compliance	1	This application notified drivers when their speed exceeded the posted speed limits. Using a zero-tolerance approach, any travel speed above the posted speed limit triggered a warning to the driver to reduce their speed to the posted speed limit. The speed limits were transmitted to the vehicle's ASD via MAP messages broadcast from the system RSUs along all study corridors. The city's default regulatory speed limit was 25 mph.
Curve Speed Compliance	1	This application was deployed to inform CVs that they were approaching a sharp curve with a reduced advisory speed limit, thereby allowing the drivers to reduce vehicle speeds prior to the curve. The advisory curve speed limit was delivered to the vehicle's ASD via a traveler information message (TIM) broadcast from nearby RSUs for a predefined geofenced area approaching the curve. The application was deployed along selected on-ramps to the Franklin D. Roosevelt Parkway in Manhattan.
Speed Compliance in Work Zone	1	This application was deployed to provide CVs that were approaching a reduced speed work zone with information on the zone's reduced speed limit and warn the drivers if their speed was above the work zone's speed limit. The geofenced work zone area and its reduced speed limit were delivered to the vehicle's ASD via TIMs broadcast from nearby RSUs. In all cases deployed in Phase 3, the defined work zone speed limit was set to 15 mph, 10 mph below the default regulatory citywide 25 mph speed limit.
Forward Collision Warning	2	This application warned the driver of the host vehicle of an impending rear-end collision with a remote vehicle ahead in traffic in the same lane and direction of travel.
Electronic Emergency Brake Light Warning	2	This application enabled equipped vehicles to broadcast a self-generated emergency brake event to other surrounding CVs. Upon receiving such event information, the host vehicle receiving that message determined the relevance of the event and provided a warning to the driver, if appropriate.
Blind Spot Warning/Lane Change Warning	2	These two related applications aimed to warn the driver of the host vehicle during a lane change attempt if the blind spot zone into which the host vehicle intended to switch was (or would soon be) occupied by another CV traveling in the same direction.
Intersection Movement Assist	2	This application warned the driver of a host vehicle when it was not safe to enter an intersection due to a high probability of collision with other remote CVs (usually at stop sign–controlled or uncontrolled intersections).

Application	Use Case	Description
Red-Light Violation Warning	2	This application was deployed to warn drivers of potential red-light violations. The application enabled a CV approaching an RSU-equipped signalized intersection to receive information regarding the signal timing and geometry of the intersection. The application used the speed and acceleration profiles of the host vehicle along with current signal timing and geometry information to determine if it appeared likely that the vehicle would enter the intersection in violation of a red traffic signal. If the violation seemed likely to occur, the application provided a warning to the driver. The application operated on the host vehicle's ASD by processing received MAP and SPaT messages broadcast from RSUs connected to signalized intersections.
Vehicle Turning Right Warning	2	This application was deployed to determine the movement of CVs near a host transit vehicle stopped at a transit stop. The application provided an indication to the transit vehicle operator that a nearby CV was pulling in front of the transit vehicle. The application was intended to help transit vehicle operators determine if the area in front of the vehicle was occupied before it pulled away from the transit stop. (This application was deployed in limited conditions and primarily under testing conditions.)
Pedestrian in Signalized Crosswalk Warning	3	This application was deployed using pedestrian detection equipment (dedicated field-mounted infrared camera) to inform RSUs at equipped intersections of the presence of pedestrians within a defined crosswalk at signalized intersections. When pedestrians were detected, nearby CVs were notified via RSU broadcasted SPaT (to define active pedestrian detection) and MAP messages (to define geometry and crosswalk details). Using this information, the host vehicle's ASD warned the driver of the pedestrian presence as appropriate given the vehicle's trajectory.
Mobile Pedestrian Signal System	3	This custom smartphone application provided pedestrians with information regarding the geometry conditions and active signal state of the pedestrian signals (WALK/DON'T WALK) at signalized intersections. The application functioned by receiving both MAP and SPaT messages via a cloud-based infrastructure and a location augmentation device to provide more detailed location data than those provided by the native smartphone platform.
Oversized Vehicle Compliance	4	This application was deployed to inform drivers of connected trucks and other commercial vehicles of pending low clearance conditions based on the height of the equipped vehicle. The application functioned on the host vehicle's ADS by receiving TIMs broadcast from nearby RSUs that defined a geofenced region ahead of low-height clearance conditions and warned drivers when it entered the region of a potential bridge-strike. (This application was deployed in limited conditions during the pilot.)

Application	Use Case	Description
Emergency Communications and Evacuation Information	5	This application was deployed to help transmit information from NYC's Office of Emergency Management (OEM) and NYCDOT's Office of Emergency Response to CVs near or within affected areas during defined incidents and events. The vehicle's ASD warned drivers of events with a custom message upon entering a geofenced area of concern, as defined by a TIM broadcast from a nearby RSU. (This application was deployed under test conditions only with test messages during the deployment. No true emergency messages were broadcast during the evaluation period.)
CV Data for Intelligent Transportation Signal System	6	This application used data from RSUs to monitor CV movements to provide RSU-to-RSU travel time data for use in other NYCDOT systems (specifically, the Midtown-In-Motion adaptive traffic signal system). The intent of this application was to determine if CV technology could provide comparable travel times to existing toll tag technology used by NYCDOT's Adaptive Control Decision Support System. The RSUs monitored and reported when equipped vehicles entered defined areas (usually the intersection "box") and reported those individual sightings back to NYCDOT's Traffic Management Center (TMC). Additional software in the TMC then matched the sightings received from different RSUs to compute RSU-to-RSU travel link travel times.

Source: Texas A&M Transportation Institute based on information contained in reference 2, 2022

Organization of Report

The TTI CVPD evaluation team has organized this report into the following chapters. The titles of each chapter and the major topics contained therein are:

- **Chapter 2. Assessment Approach**—This chapter describes the approach that the TTI Team used to assess stakeholder and user acceptance of the NYC CVPD.
- **Chapter 3. Stakeholder Acceptance**—This chapter provides the results of the interviews conducted as part of the TTI independent evaluation.
- **Chapter 4. End User Satisfaction**—This chapter describes the results of the user satisfaction surveys conducted by the NYC CVPD Team as part of their assessment of the deployment.
- **Chapter 5. Summary of Findings**—This chapter provides an overall summary of the results for stakeholder acceptance and user satisfaction across all evaluation activities.

Chapter 2. Assessment Approach

For this evaluation, a *stakeholder* is defined as an entity/agency that is directly responsible for planning, designing, operating, and/or maintaining one or more of the systems or technologies associated with NYC CVPD or that financially or institutionally influence the decision making and sustainability of the deployment. Examples of stakeholders include city and/or state DOTs, transit agencies, private fleet operators, etc. Stakeholders differ from end users. For this evaluation, *end users* are those individual vehicle operators in whose vehicles the equipment is installed and that receive information from applications that might influence their travel behavior on any given trip. Examples of end users include vehicle operators, pedestrians, transit vehicle operators, etc.

The stakeholder acceptance evaluation was designed as a multipronged approach for data collection that included qualitative interviews, an online survey, and a virtual workshop[3], with the intention of providing a panoramic view of the stakeholders' perceptions, from different viewpoints and through diverse research lenses. While the TTI CVPD Evaluation Team designed pre- and post-deployment interviews with deployment managers, deployment team members, operating agency staff, and policy makers, as well as a small online survey with fleet managers and supporting agency staff and a workshop with all stakeholders[4], due to time constraints and other issues summarized in the *Connected Vehicle Pilot Deployment Program, Phase 3 Evaluation Report—New York City*[2], only the pre-deployment interviews were completed. The surveys with end users of the applications were designed and conducted by the NYC CVPD Team, and the end user surveys targeted vehicle operators (i.e., of city fleet vehicles) and pedestrians with visual impairments. These surveys were carried out as intended.

Stakeholder Evaluation Design

Six categories of stakeholders were the target of the acceptance/satisfaction information gathering activities as part of the NYC CVPD. These stakeholder groups are:

- Deployment managers.
- Deployment team members.
- Operating agencies.
- Fleet operators.
- Supporting agencies.
- Policy makers.

Table 3 provides descriptions of these stakeholders. The TTI CVPD Evaluation Team selected these stakeholders to interview because of their integral roles in the deployment's planning and implementation. They were expected to have the most practical data on challenges, solutions, and lessons learned. The deployment managers coordinated the pilot deployment, the deployment team members developed

applications and troubleshot solutions, and the operating agencies were directly involved in the day-to-day operations of the pilots.

Table 3. Stakeholder Group Types

Stakeholder Category	Agency/Entity
Deployment manager	• NYCDOT
Deployment team members	• TransCore • Cambridge Systematics • KLD Engineering • Security Innovations • New York University, University Transportation Research Center
Operating agency system managers	• Metropolitan Transportation Authority (MTA) NYC Traffic Management Operators • NYC Department of Information Technology
Fleet owners/operators	• NYC Department of Sanitation • NYC Taxi and Limousine Commission *(planned)* • UPS *(planned)* • Taxi Garage Operators *(planned)* • MTA • NYC Transit
Supporting agency managers	• New York State Truck Motor Association • NYC Fire Department • NYC Police Department • Pedestrians for Accessible and Safety Streets Coalition
Policy makers	• Mayor's Office • NYC Council

Source: Texas A&M Transportation Institute, 2017

The CVPD Program's Stakeholder Evaluation Plan[3] prescribed that the TTI CVPD evaluation team conduct multiple data collection activities with knowledgeable persons at the deployment managing agency, and with deployment team members, operating agencies, and policy makers. The objectives of these activities were to gather in-depth information on vision, goals, and desired impacts; anticipated or potential challenges; and desired outcomes. Table 4 shows the planned and actual data collection methods used to collect stakeholder acceptance information. Unfortunately, because of time constraints and other issues, the TTI CVPD evaluation team was unable to conduct any post-deployment data collection activities. Also, no interviews with policy makers were conducted.

Table 4. Data Collection Method by Stakeholder Type

Stakeholder Type	Pre-deployment Interviews	Near-Term Post-Deployment Interviews[1]	Long-Term Post-Deployment Interviews[2]	Online Survey[2]	Stakeholder Workshop[3]
Deployment managers	Completed	Planned	Planned	NA	Planned
Deployment team	Completed	Planned	NA	NA	Planned
Operating agency system managers	Completed	NA	Planned	NA	Planned
Fleet owners/operators	NA	NA	NA	Planned	NA
Supporting agency managers	NA	NA	NA	Planned	NA
Policy makers	Planned	NA	Planned	NA	NA

Notes
1 To be performed 2–3 months after activation
2 To be performed 9–12 months after activation
3 Planned to be performed at the conclusion of post-deployment evaluation period

Stakeholder Interview Guide

A semi-structured interview format was used for the qualitative interviews. In semi-structured interviewing, a guide is followed, with questions and topics that must be covered. An interviewer has some discretion about the order in which questions are asked. However, the questions are standardized, and probes are provided to ensure that the researcher covers the correct material. This kind of interview collects detailed information, which is needed for the stakeholder assessment, but in a way that is consistent yet conversational. While pre- and post-deployment interview guides were developed, only the pre-deployment interview guide was used. It is presented in Appendix B. Table 5 presents an overview of the interview topics and examples of questions within each topic area. It was anticipated that many of the questions were pertinent to all stakeholder types, but to target the interview and to reduce burden on the interviewees, interviewees were advised to answer only those questions for which they felt comfortable and knowledgeable in answering.

Table 5. Sample of Topic Areas and Sample Questions for Pre-deployment Interviews

Topic Areas	Sample Questions
Vision and goals	What is your agency's goal(s) in participating in the CV pilot? What constitutes "success" for your pilot deployment?
Policy challenges	Are there any specific policy or political issues that had to be addressed to deploy the CV applications?
Institutional challenges	Did you encounter institutional issues associated with the deployment team members, partners, or stakeholders?
Culture	Does the organization as a whole support the CV pilot?
Collaboration	What types of formal processes have been put in place to facilitate collaborative planning/programming among CV pilot stakeholders?
Financial issues	Is there a shared commitment among stakeholders as to the financial stability of the CV pilot and how to achieve it? Are you familiar with the long-term plan for funding/financing the CV pilot?
Business processes	In a typical DOT-centric manner, the pilots would be organized such that the public sector is expected to assume responsibility for the infrastructure aspects of the system and the private sector the installation of the vehicle equipment. Was this general structure followed? To what extent are your business processes changing because of deploying the pilot?
Performance measures	What impacts did you foresee when your agency decided to participate in the CV pilot?
Systems and technology	What do you think are the most significant technical or technology-related challenges related to the CV pilot? What kinds of security challenges did you face?
Workforce development	Are sufficient people trained to manage, operate, and maintain the CV system through both in-house work and outsourcing? If in-house staff, were these individuals added on to units with the existing structure and staffing, or was a CV-specific operational unit developed?
Outreach	What outreach activities, if any, has your agency planned to engage other stakeholders, policy makers, or the public in the CV deployment?

Source: Texas A&M Transportation Institute, 2022 (4)

Stakeholder Analysis

Originally, the TTI's approach outlined in the Stakeholder Evaluation Plan [4] included qualitative syntheses of the pre- and post-deployment interviews (i.e., individual interviews were synthesized for anonymity), along with trend analysis of stakeholder perceptions across time periods. However, because of timing issues associated with this evaluation, TTI was only able to conduct the analysis of stakeholder opinions based on pre-deployment interviews.

End User Evaluation Design

For this evaluation, end users' assessments of the CV applications' performance were desired in addition to the passively collected system performance measures. The NYC CVPD team, led by NYCDOT, gathered users' feedback on the deployed technologies through a series of online surveys with operators of vehicles with installed CV technology as well as a more limited capture of feedback from visually impaired users of a Mobile Accessible Pedestrian Signal System (PED-SIG) application.

Driver Survey Design

Driver surveys were planned with three broad groups of vehicle operators who had CV equipment installed in their vehicles—taxi drivers, MTA bus drivers, and NYC government fleet drivers, with taxi drivers envisioned as the major fleet participants. However, due to economic issues of the taxi industry (caused by the growth of ridehailing services in the city and impacts of Covid-19 pandemic on travel behavior) and the constraints on offering incentives for taxi participation, the targeted fleets transitioned away from taxis to focus on NYC Department of Citywide Administrative Services vehicle fleets and MTA/NYC Transit buses. The user surveys were administered to the drivers through these employers.

The plan was to conduct three sets of surveys—(a) initial pre-deployment survey, (b) early stage post-deployment survey, and (c) late stage post-deployment survey. Initial pre-deployment survey was intended to establish baseline conditions and to gather demographic information about the survey respondents. Early stage post-deployment was to capture early deployment experiences and initial feedback from end users. Late stage post-deployment was to gather information as to whether or not the pilot deployment met its goals and objectives from the end users' perspectives.

The driver survey instrument had four parts. The plan was to ask Part 3 questions in the early and late post-deployment iterations (see Instrument in Appendix D).

1. Vehicle Usage: Questions about the drivers' typical vehicle usage and driving patterns when driving for work in NYC.
2. User Attitude/Perception: Questions regarding perceptions and attitudes towards CV technology and about the perceived safety of driving for work in NYC in general.
3. User Experience: Questions about drivers' experiences with the active CV applications warnings provided to the drivers (not collected in the pre-deployment survey).
4. Demographics: Questions to help identify basic demographics of the respondents.

PED-SIG User Research Design

The PED-SIG application was developed to assist pedestrians with vision disabilities in safely navigating crosswalks at signalized intersections. The version of PED-SIG deployed was a custom smartphone application that provided the pedestrian with information regarding the signalized intersection geometric conditions as well as the active traffic signals' state-of-the-pedestrian signals (walk/do not walk). To ensure that this app provided appropriate functionalities with an intuitive and accessible design, the plan was to

introduce the app to 24 pedestrians with low or no vision, having diverse travel habits, mobility needs, and independence levels, including:

- A variety of mobility assistance mechanisms, from companions, guide dogs, and long canes to vision aids and global positioning system (GPS) navigation or other assistive phone apps.
- Pedestrians who were born with a vision disability as well as those who had lost their sight over time or later in life.
- Pedestrians with co-existing disabilities, such as deafness and blindness.

The NYC CVPD Team recruited volunteer participants with vision disabilities to participate in field tests where the pedestrian interface devices (PIDs) that ran the PED-SIG application were given to participants to be used "in the real world," accompanied by at least one Institutional Review Board–certified NYC CVPD team member to ensure their safety. Recruitment of participants was done through local and national organizations working with blind communities. Such organizations identified possible participants. Then, one-on-one conversations were held with each volunteer to provide an in-depth explanation of what the app does and what the field tests would entail, as well as answering any of their questions.

Six (6) predefined routes, each made up of two crosswalk crossings, were chosen to test the utility, accuracy, and connectivity of the PID, as well as to gauge the participants' experiences through multiple CV-equipped intersections.

Two survey instruments were developed to be implemented during the field tests (see Appendix E). The initial survey was designed to establish baseline conditions for study participants. The survey included a few key demographic questions, self-ratings of mobility and travel proficiency, and questions about assistive technology usage in navigating city streets. The post-deployment surveys collected feedback on participants' perceptions and experiences with the PED-SIG application during the field test and suggestions for improving the application. The survey includes an additional set of questions on attitudes, perceived impact on participants' safety and mobility, institutional issues (e.g., privacy), and other relevant topics.

Driver and Pedestrian Survey Analysis Approach

The planned analyses of both the driver and pedestrian survey data were to produce descriptive statistics, such as frequencies, means, and medians of survey questions.

Chapter 3. Stakeholder Acceptance

The TTI CVPD Evaluation Team conducted pre-deployment interviews with deployment stakeholders that were involved in the NYC CVPD.[4] The objectives of the interviews were to gather in-depth information on vision, goals, and desired impacts; anticipated or potential challenges; and desired outcomes. All interviews were conducted by telephone.

Stakeholder Interview Response

A total of 19 individuals were identified by NYC to be interviewed for this evaluation. The TTI CVPD Evaluation Team sent email invitations to identified individuals to participate in the interviews. The invitation contained information about the study purpose, interview method, content, and duration. An informed consent document was included as an attachment. The participants who replied in the affirmative to the invitation were asked to provide their availability, after which a suggested date and time for the interview was communicated. Table 6 below presents the overall response that TTI received to the recruitment and interview processes.

Interviews were conducted with the NYC CVPD deployment team: NYCDOT, the deployment manager; the prime engineering consultant and subconsultants responsible for performance metrics and evaluation, user surveys, modeling and simulation, supporting system architecture design, and outreach; and the vendors responsible for providing Security Credential Management System (SCMS) services, supplying OBUs and RSUs, and providing the security engineering products as well as the security design and security analysis approach.

All interviews were conducted by telephone in October 2020, and each interview took about 45–60 minutes to complete. These interviews were about 12 months later than originally planned. Their responses reflect the activity, adaptation, and learning leading up to operations and maintenance phase of the deployment. Due to time constraints, no post-deployment interviews were conducted as part of this evaluation.

Table 6. Interview Participation Invitation Outcomes

Stakeholder Type	Invited	Declined	No Response	Scheduled	Completed
Deployment Manager (NYCDOT)	2	1	0	1	1
Deployment Team/Vendor	13	2	0	11	11
Operating Agencies	4	2	2	0	0
Total	**19**	**5**	**2**	**12**	**12**

Common Stakeholder Acceptance Themes

The themes identified below are synthesized from a summary of the 12 pre-deployment interviews with the NYCDOT deployment manager and deployment team consultants and vendors.

Change in Deployment Scope

At the start of Phase 1, stakeholders identified the main objective of the NYC CVPD as being *safety*, contributing to NYC's Vision Zero Initiative. The plan was to install CV technology in large fleets, along with deploying the supportive vehicle-to-everything (V2X) infrastructure, and to evaluate the benefits of the deployed CV system to NYC's Vision Zero Initiative. The project sought to acquire and deploy ASDs and RSUs that would communicate over a dedicated short-range communications (DSRC) network as well as deploy applications to provide drivers with alerts about identifiable safety situations. The deployment design requirements were identified collaboratively among the public and private organizations comprising the NYC CVPD Team. However, in implementation, so many operational, technical, fiscal, and policy challenges were faced that the main objective transitioned from gathering evidence of safety impacts to simply getting the deployment to work. One participant said, "This would entail getting the V2X infrastructure up and running and getting vehicles talking to each other."

The challenges led several deployment team members to question whether evidence of safety impacts could result. For example, the needed evidence would come from equipment installed in a large number of fleet vehicles. The original plan was to install equipment in 10,000 vehicles, which was subsequently reduced to 8,000 and then to 3,000 vehicles because many of the initial stakeholder organizations (such as the Taxi & Limousine Commission and UPS) dropped out. Several members of the NYC CVPD Team recognized that 3,000 instrumented vehicles might not be enough to determine impact unless the pilot deployment continued for a "very long time to reach statistical significance of impact." In the end, the NYC CVPD deployment team was able to implement about 450 RSUs, but this implementation is far less than what would be needed to evidence impact on safety since NYC has more than 13,000 intersections.

Given the NYC CVPD conditions at the time of the pre-deployment interviews, many stakeholders felt "just staying and finishing the project would, in itself, be success." One participant commented, "To deploy the system as planned would have been a huge technical and fiscal challenge."

CV Technology Not Deployment-Ready

In Phase 1, the NYC CVPD Team assumed that the CV technology would be deployment-ready. However, the general consensus at the time of the pre-deployment interviews was that the available technology was far afield from practical deployment. While many persons mentioned this, one person summarized the issue saying, "Ready for deployment means you can go out and buy components. In reality, devices were not available to do the job that had to be done." The NYC CVPD Team needed to unexpectedly do a lot of troubleshooting with the components to get them to function well. Another individual singled out the readiness of RSUs as not being ready for deployment, saying that the "RSUs that were delivered initially were an immature product. One can deal with that when deploying a few units—it is something else when there are 450." The lack of CV technology readiness led to cost overruns because of delays and the level

of effort that went into making the technology work. One stakeholder said, “The learning curve has meant a financial hit.” Yet, at the time of the pre-deployment interviews, the RSUs were collecting data over DSRC, and checks of unit efficacy were being done over-the-air.

As his closing thought, one of the interviewees discussed the “interaction of the pilot and mainstream deployment of V2X”:

> *“It’s taken 3 years for the industry to understand that standards are necessary; RSU specs are necessary. Maturity of the CV technology is still not there. Not a consensus yet on how to do this. We need consensus to figure out the future of CV so we’re all pulling in the same direction. People don’t seem to know what it takes to put a whole CV ecosystem to work. Pilots [such as the NYC CVPD] identify gaps in standardization that have not been fully resolved yet—a chicken and egg situation. Other deployments need standards for messages, data dictionaries., etc. So, they end up borrowing the pilot deployment specs. But as standards develop (e.g., SPaT, signal preemption), the specifications will deviate from what a CV pilot did. So, we may be in for a painful transition. Standards organizations are aware of it. But an industry can only move so fast.”*

Challenges of Deploying CV in a Dense Urban Environment

For many interviewees, the most technical challenge in the deployment was addressing GPS inaccuracy since the primary goal of the pilot was to improve safety. One participant commented, “None of the applications work if you can’t pinpoint location.” Specifically, the pedestrian and intersection movement assist applications were mentioned as having significant issues. The lack of GPS accuracy was due in part to NYC’s geography, which interviewees considered more complex than that encountered in other pilots, with its urban canyons. The team troubleshot to find a solution for the GPS inaccuracy (via RSU triangulation), using time of flight technology. RSUs have a known location; ASD time was set relative to the RSUs to improve location accuracy. But implementing this solution was challenging in itself. The universe of vehicles and their data architectures was very extensive. Detailed engineering was needed to properly ensure that they were getting the data needed—because of make, model, and year variations. Another person explained that using RSUs to triangulate was not a perfect solution because not enough RSUs could be installed to provide needed coverage. The person said, “Triangulating off of a roadside unit is not good enough because a city is constantly moving. Today the method could work fine but tomorrow there can be someone building scaffolding in front of the RSU. NYC or any environment is not static—[so RSUs] require constant maintenance and updating.”

At the time of the pre-deployment interviews, the NYC CVPD Team was trying to determine where RSUs could be positioned to capture as many vehicles as possible. The team was moving around a few mobile RSUs to figure out where the permanent ones should be installed.

Another identified challenge was trying to do all the uploads to the TMC via RSUs instead of other wireless technology. That this was a pilot with the need to collect research and development (R&D) data as well as support V2I communications created unforeseen complications. Not only were data being uploaded via RSUs to TMC for R&D purposes, but also vehicles needed to refresh software and firmware through RSUs

as well. RSUs were location specific, but vehicles were not. Vehicles would detach from RSUs without necessary software and firmware updates. The NYC CVPD Team did not know if this situation would be quite the same challenge in a real-world implementation (not R&D).

Getting new security certificates to the ASDs (to sign their messages) was a challenge. Those certificates came from SCMS, which was outside the DSRC network. On the other hand, ASDs were inside the network, which caused network management/security issues. NYC was using certificate top-offs on a weekly basis. Every Tuesday, ASDs would get their certifications updated for the following week and week after—a two-week period. Since there was no way for the deployment team to control where drivers would go during a given 2-week period, it was not possible to ensure that vehicles would pass by a predesignated RSU so certifications could be downloaded. Those vehicles with no updated certifications would not be "seen." So, it took a while for the NYC CVPD Team to recognize that some vehicles' certifications were not updated. A solution was eventually worked out. The NYC pilot did certification on the fly as the vehicle moved around, with periodic re-certification.

Importance of Reliable Vehicle Installations

The NYC CVPD Team trained installers and provided tools, but they did not perform the installations themselves. Vehicle installations were done by a combination of city and private contractors who routinely work on the vehicles (maintenance) through existing contracts. Over time, the NYC CVPD deployment team learned that vehicle installation was a weak link in the deployment process. A team member said, "We learned that we needed to perform more inspections and verification of installations than originally thought. There's not much time put into evaluating each individual installation because of the scale. We would have liked to have vehicles running around in test mode after the install." Every vehicle that was in the pilot was a government service vehicle. If taken off the road, then it would not be fulfilling its primary role. At the time of the pre-deployment interviews, the NYC CVPD Team was having to track down some of the vehicles to figure out how to get them operational.

Also, vehicle installations were delayed due to union issues. Certain contract items needed to be reviewed and negotiated, such as (1) when and where the devices were to be installed, (2) the number of shifts on which they could be installed, and (3) when and how inspections would occur. There were a number of different public fleets that were involved, and the requirements varied. The deployment team expected the process to take a long time, but it took much longer than expected.

Challenges Impacted Collaboration among the Deployment Team

CV is a recent technology, and the NYC CVPD Team wanted to be associated with its leading edge. The lead consultant and many of the subconsultants had long-standing relationships with NYCDOT. Their selection as deployment team members in support of NYCDOT in the CV Pilot reinforced their commitment to make things work—however challenging. The technical vendors wanted to prove themselves (and their technology) in the V2X space. There was a general sense among stakeholders that there was more collaboration at the beginning of the NYC CVPD than during the deployment itself. During the planning stages, there were lots of roundtable discussions with a goal of getting deployment team members and stakeholders to understand how the system components work together and to feel a sense

of ownership over the overall system design. The emphasis was on “making it right from the start to mitigate risk.” As one vendor said, “the supplier of RSU is a competitor. For the pilot, we all worked together to meet short-term goal of getting the pilot up and running and collecting data.”

However, after planning and moving into the more challenging system design and implementation phases, it became more difficult to identify a common goal. This lack of consensus was identified as a big institutional issue. The “complexity of the project undermined collaboration” as challenges mounted. NYCDOT had a perspective of risk mitigation. Many of the consultants and vendors on the team felt that mitigating risk is hard to accomplish with an R&D initiative. The consultants wanted a proof-of-concept showcase. The vendors’ priority was to prove their technology worked in a NYC context. For city fleets, their agency priorities came before the needs of the deployment. One city fleet staff member said, “The agency-side just wants to make sure that the pilot does not upset their day-to-day operations. So, the deployment team needed to be flexible and make it easy for them to participate (e.g., onsite installation in their shops).” Another city fleet staff member commented, “At the end, we are not coming from the same vision.”

Conflicts in Measuring the System Performance While Preserving Privacy

One person described this challenge as the fact that the CV industry was immature and meeting the privacy policy requirements (i.e., protecting personally identifiable information [PII]) set forth by NYCDOT were difficult. A lot of energy (i.e., time and effort) was put into figuring out how to process data, sanitize it, and obfuscate it to prevent any PII from being exposed. Another person said, “There was lots of discussion about obfuscation and privacy access.” In the pilot, information about the vehicle operators was “detached” from the other data being collected. NYC Information Technology (IT) engineered the process so that some of the event data were moved by location offsets—so one does not know where exactly in NYC the vehicle was. NYC IT was also doing intense data scrubbing to reduce disclosure risks. However, such data manipulations made accurate performance measurement more difficult.

Impact of National DSRC Policy Uncertainty

More than one person talked about the need for a DSRC mandate—and a direction—so the NYC investment in DSRC would be sustainable. They commented, “Right now, yes, everybody is supporting the project but the lack of a DSRC mandate affects the support of the project in general. There is doubt by some people (inside and outside of the agency) as to whether this is a worthwhile investment.” Another person said, “Some in the city are saying, ‘Why spend more if FCC will pull the rug out from under us?’” A person commented, “New York City was contemplating expansion of RSU installations with a capital program of rehabbing arterials. But things have changed.” One person speculated that Federal Communications Commission (FCC) spectrum issues also influenced commitment of external stakeholders. The person said, “UPS didn’t know if their investment in getting ASDs installed in vehicles was going to be sustained.”

Effects of NYCDOT Procurement Policies

For this pilot, NYCDOT was the prime contractor to USDOT. All others were subcontractors to NYCDOT (or subcontractors to subcontractors). Many people mentioned challenges that arose due to NYCDOT's procurement policies. Procuring at the scale of the pilot required special procurement and contractual processes. As one person said, "One thing for spending $100k; something else for a couple of million."

The perception among the consultants and vendors was that NYCDOTs' procurement policies are focused on procuring tried technologies and not the "bleeding edge" technologies needed for a pilot such as this one. Several people mentioned delays in getting the proper contract mechanisms in place. One person said, "It took a while to identify the right contract mechanism (which ended up being a 'negotiated procurement after a demonstration'). Then it took a lot of time to get contracts in place because none of the pertinent NYCDOT staff had used the identified contract mechanism before or even knew it existed." One interviewee estimated that contracts were delayed by more than 18 months because all the "downtown" people needed to sign off. One subconsultant indicated that their contract was piecemeal—in 3-month increments—because NYC tapped into a previous engineering services contract. The subconsultant said, "This has caused piecemeal subcontracts and delays in payment."

The contractual process also impacted the schedule and the project implementation, in general. One person commented, "Making sure that the procurements were cost-effective and, at the same time, that the units would work in a large-scale deployment took a lot of time and effort." For example, there were challenges in getting the contract for RSUs after it was learned that the existing units on the market were not up to what was needed. So, a new RSU vendor had to be found, and then there were challenges in getting that vendor under contract.

The ways in which the procurements were done was also a problem. Relating to the purchase of RSUs, one person explained that it was a purchase order for 550 units with some provisioning for onsite support. The purchase order did not include all of the effort to make sure everything worked. The person said, "They were going for lowest price."

Shifting of Planned Versus Actual Performance Measurement

The NYC CVPD Team planned to implement performance measures that would provide proof that the CV technology was able to help the city's drivers and pedestrians to resolve traffic or safety issues. According to one interviewee, "the CV pilot was focused on mitigating accidents." This comment is the reason one key metric was the number of vehicle sightings (where one ASD-equipped vehicle encounters another ASD-equipped vehicle so there would be the opportunity for messages to occur). The person said, "We were trying to get a considerable number of interactions between vehicles." The deployment team wanted indicators that would "provide evidence of a difference."

Performance measures were identified in the design phase with uncertainty as to whether the required data would be available to populate the performance matrix. For example, in Phase 1, the team planned specific items based on warnings that would make travel safer, such as limiting red light running and wanting to avoid as many accidents as possible. A team member shared, "We defined a number of different events (warnings to the driver) and made sure we had a rolling mechanism that would capture the

time-based events up to and after the event. It was important that we collected the right data and got it up to TMC." Another team member said, "At the beginning there was going to be a lot of instrumented vehicles. Then we lost the taxis. Now I'm not sure we'll have enough data."

Unforeseen Exogenous Factors (Black Swan Events)

A *black swan* is an unpredictable event that is beyond what is normally expected of a situation and has potentially severe consequences. Black swan events are characterized by their extreme rarity. All interviewees mentioned the unforeseen negative impacts of several black swan events (i.e., Covid-19 pandemic, financial implications for taxi industry, spectrum issues). The general perception was that such influences caused not only extensive schedule delays and raised costs, but also caused external stakeholder commitments to change over the lifespan of the project. One interviewee commented, "Originally, the pilot had commitments from the taxi industry, a private commercial delivery company, and the MTA to participate. The private commercial delivery company bowed out early. The initial planning included much more robust deployment in taxis and buses than what has been achieved."

In terms of the taxis, it was mentioned that the lack of participation was influenced by the changing taxi marketplace (i.e., economic impacts of competition with transportation network companies and the reduction in passengers due to Covid-19). One person said, "The pilot was trying to recruit taxis as they were starting to fight for their survival. Now, a handful of taxis have ASDs installed—all pre-COVID." One person mentioned that early in the design phase, NYCDOT held ongoing dialogue with the taxi/limousine commission in NYC about mandating the taxis to participate in the pilot. But it learned that taxis are independent contractors so they cannot be mandated.

With MTA and buses, the lack of participation was primarily due to Covid-19's impact on public transit. One person said, "MTA has vastly different priorities right now. The pilot has installed ASDs in only a small number of buses. Some installations were pre-COVID, and some have happened recently."

Due mostly to complications from Covid-19 pandemic restrictions in place in 2020, installations of CV equipment in fleet vehicles were incredibly delayed. The equipped vehicle fleet was not fully operational at the beginning of the Phase 3 deployment period (January 1, 2021). At the start of 2021, there were just over 2,150 completed vehicle installations. CV vehicle installations continued through 2021 until the full 3,000 fleet size was achieved on August 17, 2021.

One person mentioned that people are just beginning to realize the significant financial issues that exist for state and local governments due to the Covid-19 pandemic. The person asked, "Will the project survive? There are fiscal challenges for NYCDOT. NYCDOT has made investments to run the pilot, RSUs, staff training equipment to manage system in TMCs." Another person commented, "I wonder. What is the commitment from NYCDOT going forward?"

Chapter 4. End User Satisfaction

With the assistance of the Volpe National Transportation Systems Center, the NYC CVPD Team developed driver feedback surveys to solicit user satisfaction related to four different areas:

- The drivers' typical vehicle usage and driving patterns when driving for work in NYC.
- User perceptions and attitudes about both CV technology and about the safety of driving for work in NYC.
- User experiences with the CV applications while driving (only collected in post-deployment surveys).
- Limited demographic data about the respondents.

The NYC CVPD Team compared the results of these user surveys to see if user perceptions changed over time or after exposure to the CV technology.

Driver Survey Responses

The NYC CVPD Team attempted to collect driver perception data at three periods: pre-deployment, early in the post-deployment period, and late in the post-deployment period.[2] The responses to three surveys varied greatly:[2]

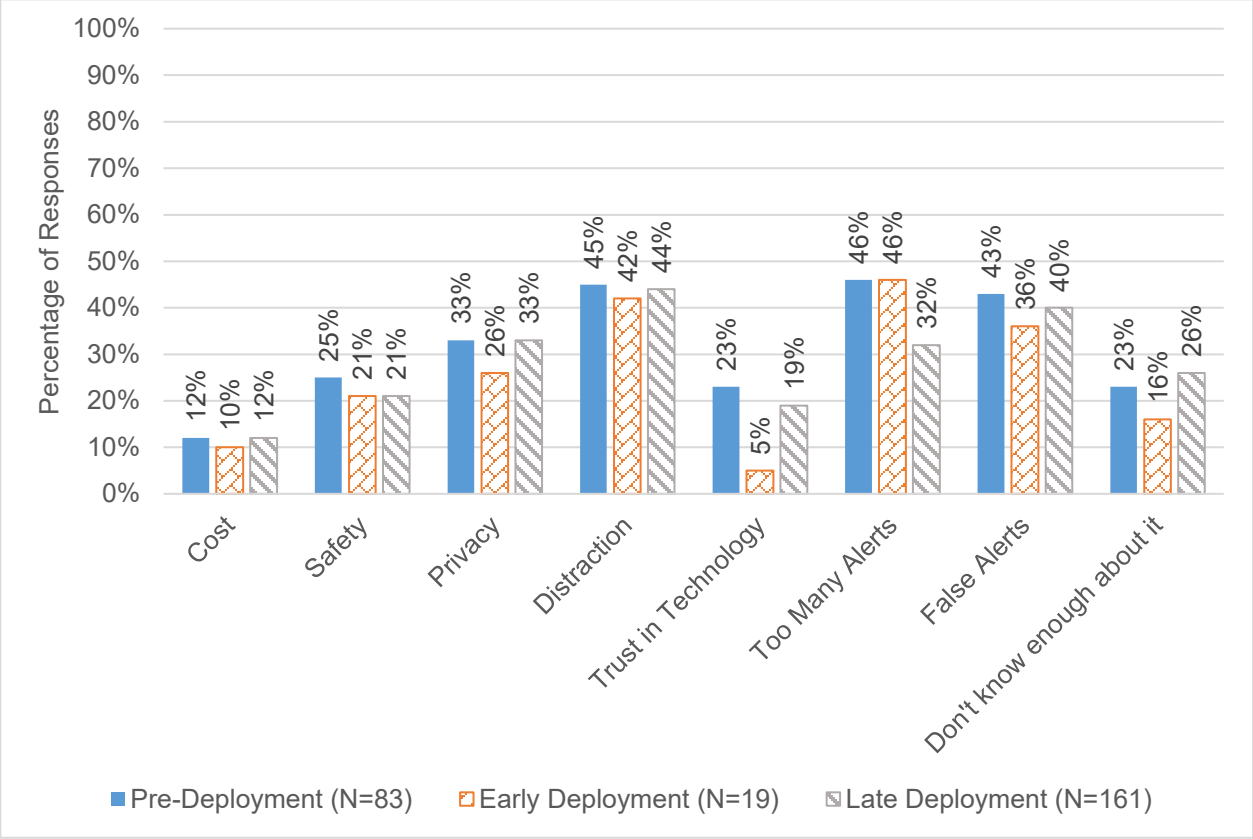
- Pre-deployment: Eighty-three (83) responses.
- Early post-deployment: Nineteen (19) responses.
- Late post-deployment: One hundred sixty-one (161) responses.

The surveys were implemented through the drivers' employers, and so the NYC CVPD Team had no direct contact with the participating drivers to ascertain the survey universe and to provide incentives to encourage responses. The team reported that efforts were taken to encourage drivers to complete each of the three surveys through messages from the various fleet and department management.[2] But the NYC CVPD Team could not ensure or determine after the fact whether individual respondents completed all three waves of the survey. Thus, it was not possible to compare changes in perceptions and attitudes over time. Furthermore, the NYC CVPD Team was not able to correlate survey responses to the CV technology operating mode (active or silent) in the post-deployment survey.[2]

Driver Perceptions/Attitudes

Figure 2 shows user responses to questions regarding the user's perceptions of CV technology. The most frequently identified concerns were distractions, false alerts, and too many alerts with CV technology.

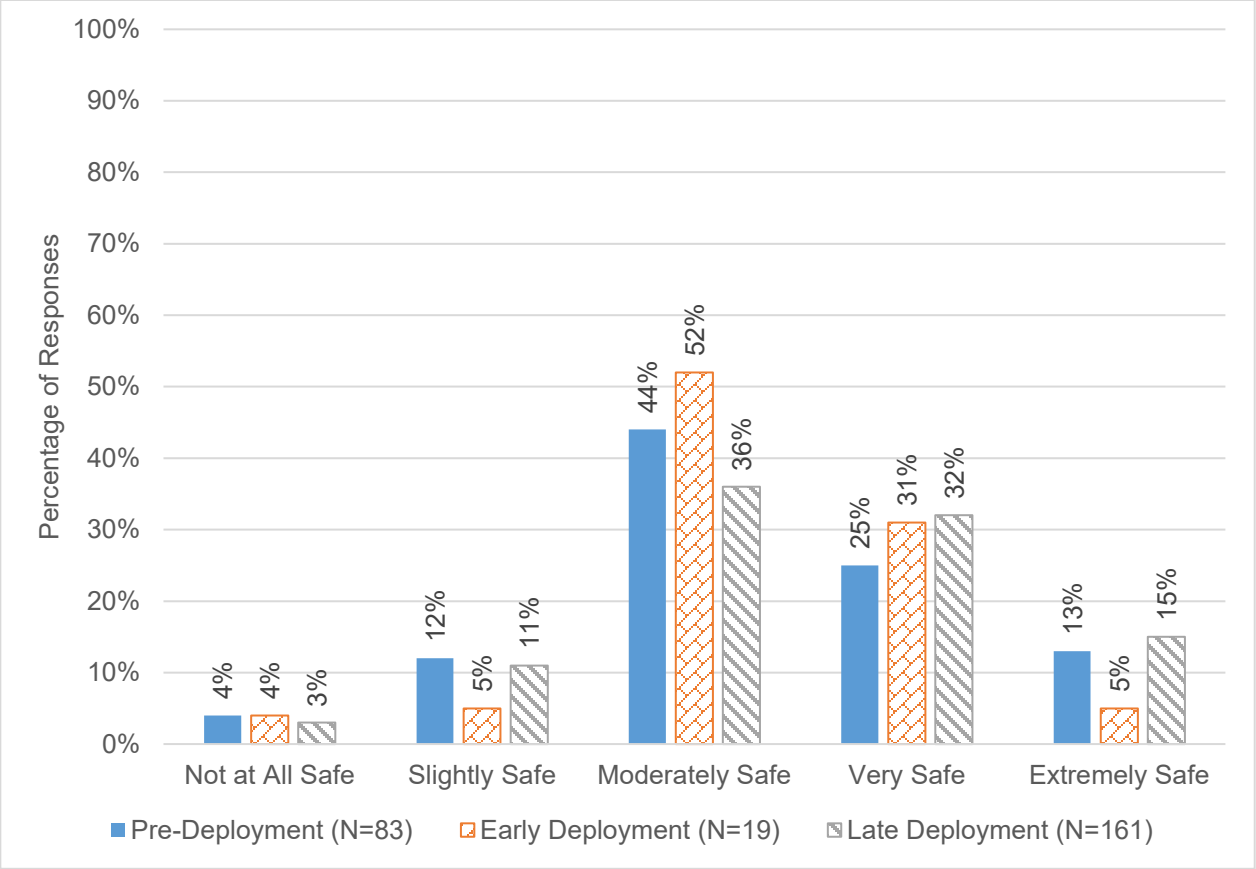
Concerns about distractions and false alerts stayed steady through the pre-deployment survey to the post-deployment survey. On the other hand, perceptions of too many alerts were much lower in the post-deployment survey. Interestingly, about 25 percent of respondents in the late post-deployment survey responded that they did not know enough about it to provide concerns. Findings for the early post-deployment survey are presented in the following graphs; however, the small sample size makes these findings exceptionally unreliable. Thus, they are not discussed in the text.



Source: New York City Department of Transportation, 2021

Figure 2. Respondents' Concerns about CV Technology Systems

Figure 3 shows user responses to the questions about perceptions of the level of safely driving in NYC before and after the deployment. Figure 3 shows that most of the users felt relatively safe driving in the city for work. The proportions for feeling very safe or extremely safe were higher in late post-deployment than pre-deployment. These results may be related to the lower numbers of vehicles on the road during the Covid-19 pandemic, when the late post-deployment survey was conducted.

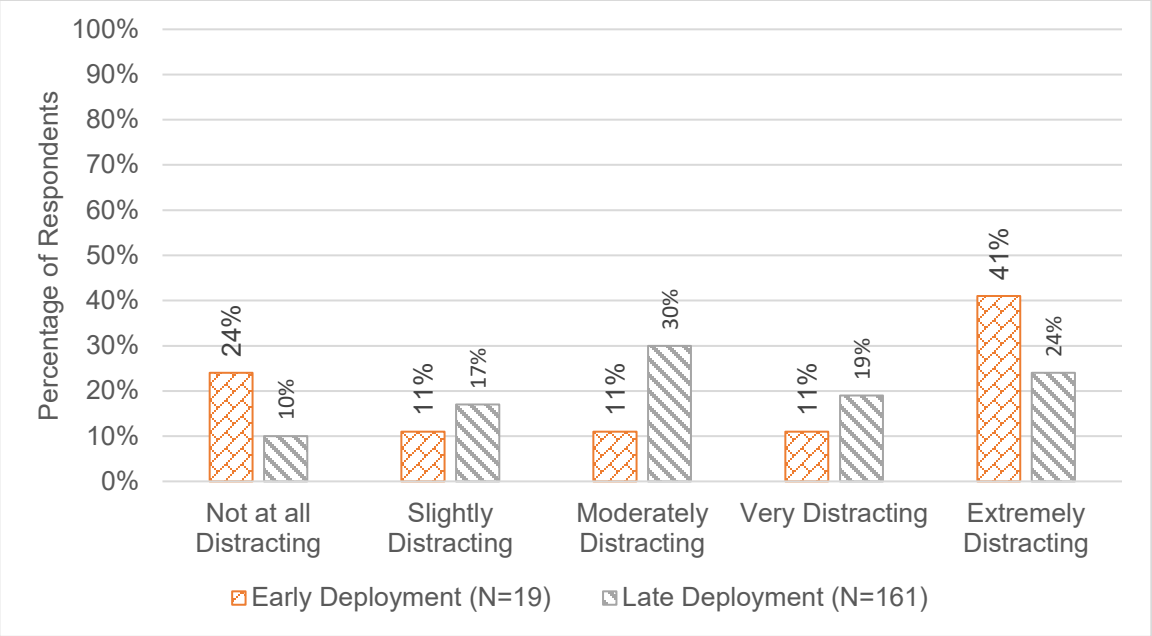


Source: New York Department of Transportation, 2021

Figure 3. Perceived Level of Safe Driving in NYC for Work

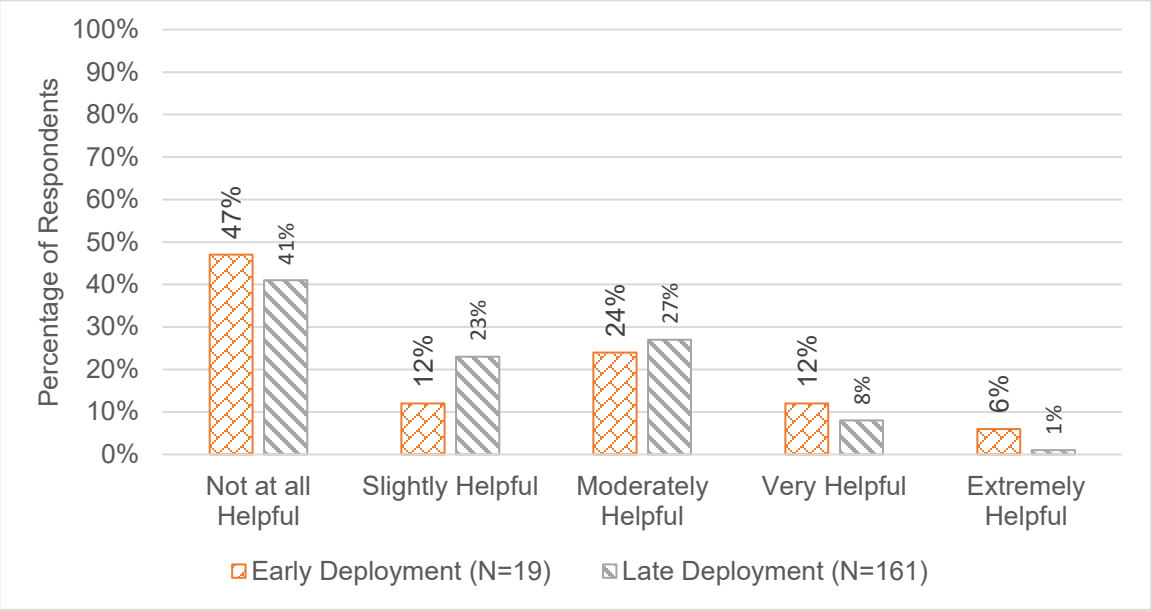
CV User Experiences

Feedback on the respondents' experiences with the CV applications while driving was solicited in the post-deployment surveys. More respondents in the late post-deployment survey found them distracting than non-distracting (Figure 4), and most did not find them to be useful (Figure 5).



Source: New York Department of Transportation, 2021

Figure 4. Respondents' Opinions on if Alerts Are Distracting



Source: New York Department of Transportation, 2021

Figure 5. Respondents' Opinions on if Alerts Are Helpful

When asked about which applications the drivers recalled hearing (Figure 6), the most commonly reported alerts were FCW and SPDCOMP. A minority of respondents reported that they could not tell them apart, that they could not recall receiving them, or that they heard no warnings.

Finally, when drivers that responded that they had heard alerts were asked about their overall satisfaction with the CV applications and alerts that they were exposed to (Figure 7), most were indifferent, with more citing dissatisfaction than satisfaction.

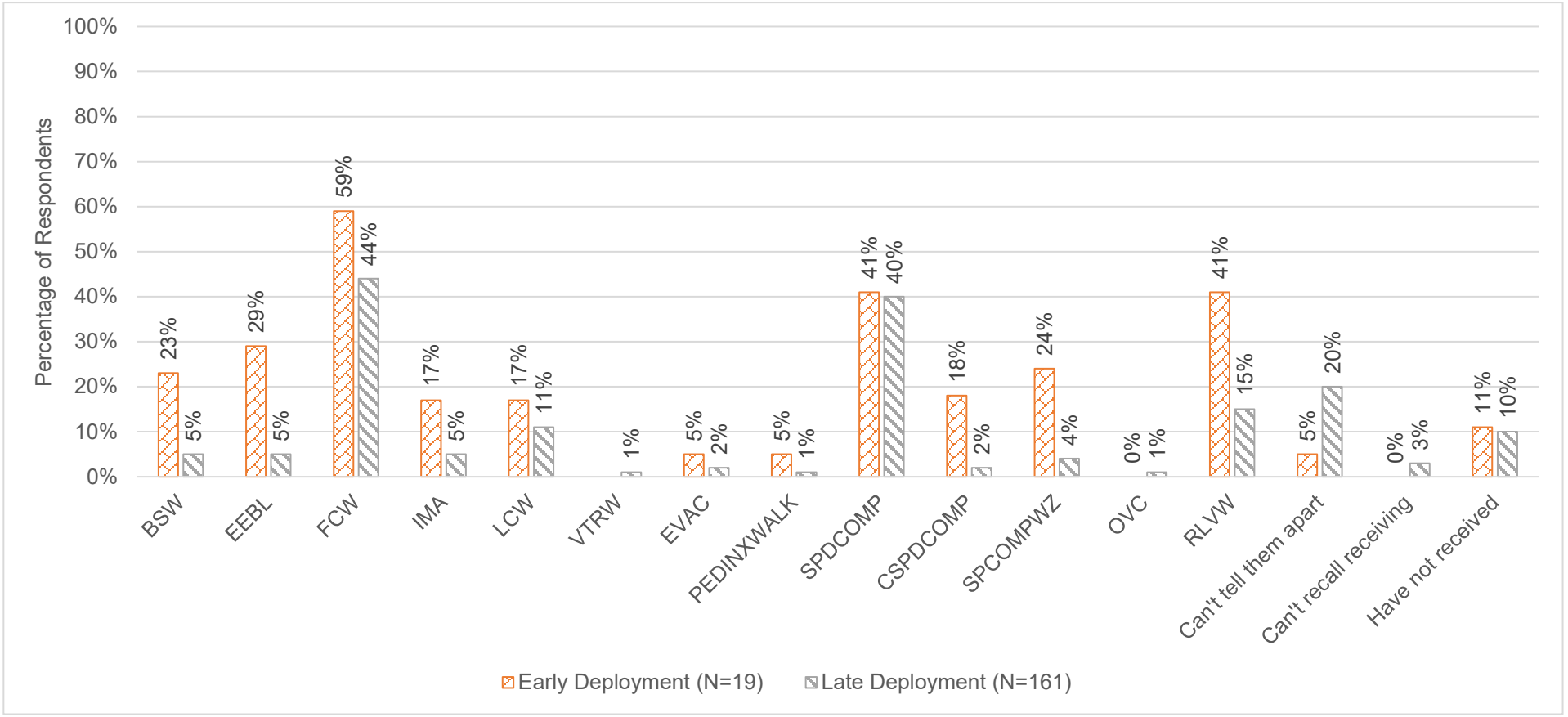
Of those respondents indicating the CV applications were helpful (Figure 8), the SPDCOMP application was identified most as being helpful.

Summary of Driver Perceptions

The NYC CVPD Team reported the following key findings from their user satisfaction surveys:[2]

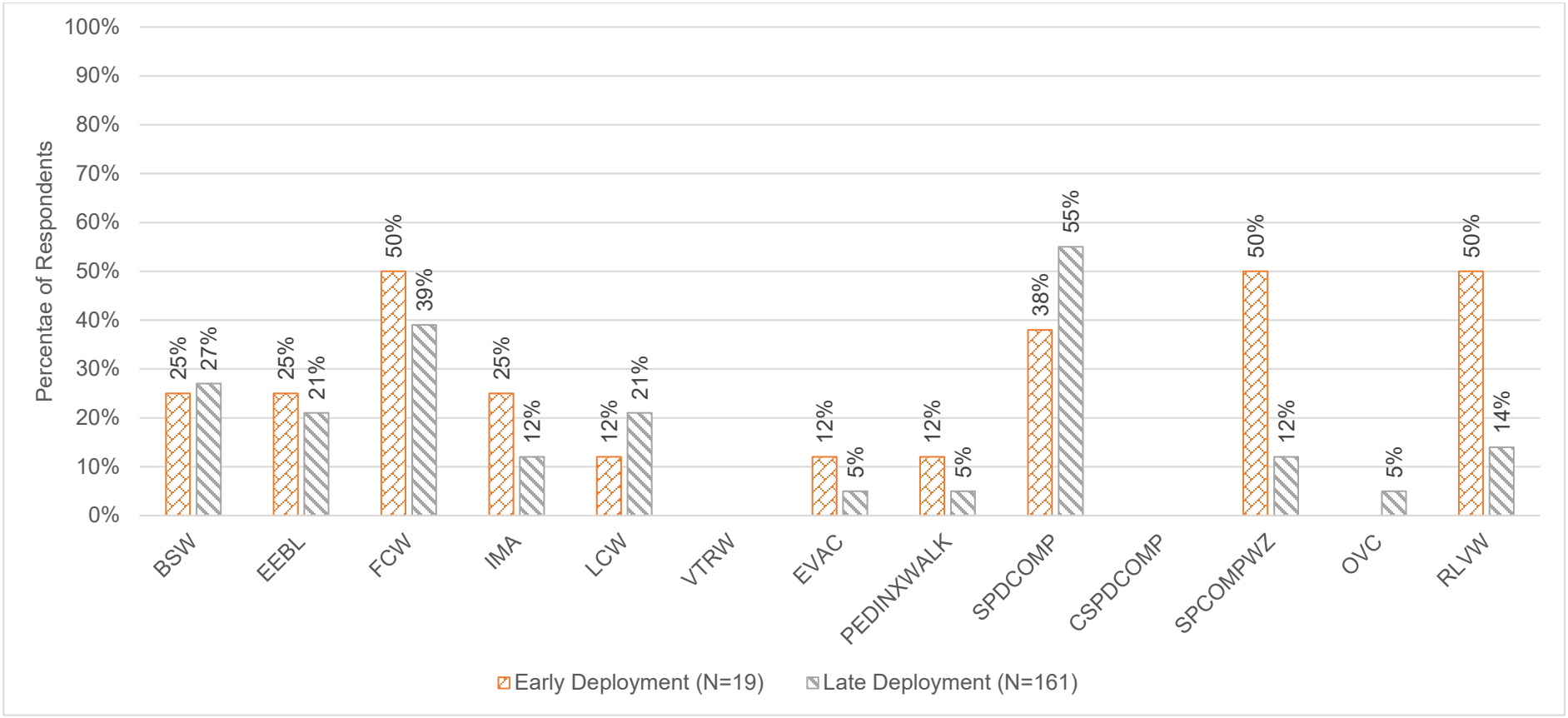
- Common concerns with the CV technology were distractions, false alerts, and too many alerts. Concerns about distractions and false alerts stayed steady through the pre-deployment survey to the post-deployment survey.
- The most useful alerts to improve safety were SPDCOMP and FCW—alerts that the drivers reported hearing the most.
- Most drivers were indifferent to (i.e., neither satisfied nor dissatisfied with) the CV applications and alerts to which they were exposed.

The NYC CVPD Team did not report user perceptions of the effectiveness or the efficiency of the applications to improve mobility, public agency efficiency, and the environment.



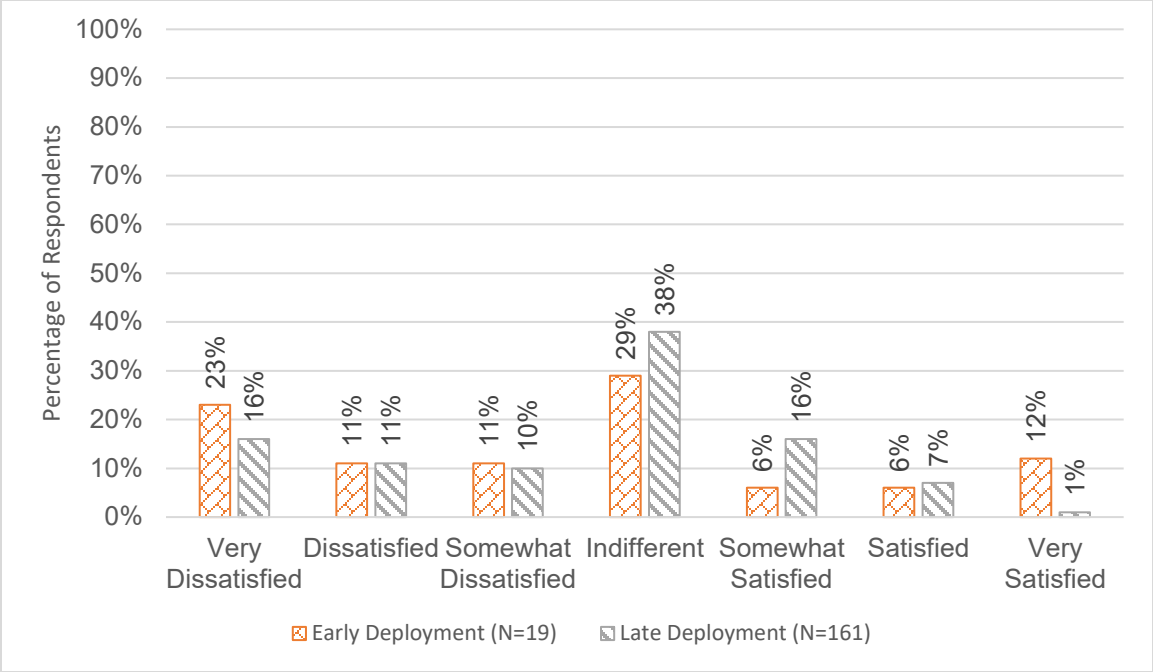
Source: New York Department of Transportation, 2021

Figure 6. Alerts Recalled Hearing



Source: New York Department of Transportation, 2021

Figure 7. Alerts Helpful in Driving More Safely



Source: New York Department of Transportation, 2021

Figure 8. Overall Satisfaction with CV Technology

PED-SIG User Perceptions

The CVPD Team also collected user feedback data on the PED-SIG application. The NYC CVPD Team collected field data and user perception data from 24 visually impaired participants.(2) The focus of this assessment was on ease-of-use, user experience, application functionality, and user perception of safety. Because of the small sample, the results are reported here in a qualitative manner.

Most post-field test respondents were positive in their overall impression for the PED-SIG application (i.e., ratings of good, very good, or excellent). The main problems experienced when using the PED-SIG application were:

- Inaccurate location information.
- Slow responses.
- Inaccurate orientation.

Nearly all participants felt they were given sufficient time to cross the intersection, and more than half of them felt they stayed oriented on the crosswalk when using the PED-SIG application. The majority of participants also thought the application is easy to use. Most participants strongly or somewhat agreed that they felt more confident in their ability to cross a signalized intersection with the application than with other assistive technologies they had used before. Half of the participants reported feeling much safer using the PED-SIG application compared to not using it. About a third felt slightly safer.

Chapter 5. Summary of Findings

Stakeholder Acceptance

A robust assessment of stakeholder acceptance of the NYC CVPD was not possible because the evaluation plan in its entirety was not implemented due to time constraints imposed by the occurrence of certain black swan events (i.e., Covid-19, diminishing economic well-being of taxi industry, DSRC spectrum uncertainties). The TTI CVPD evaluation team conducted pre-deployment interviews with deployment managers, deployment team members, operating agency staff, and policy makers that were involved in the NYC CVPD about one year later than expected in October 2020.

The following lists the key findings from these interviews:

- While the NYC CVPD faced many challenges and hurdles, the team was able to develop a fully completed CV system on a large-scale, on NYC infrastructure, with over 450 RSUs and 3,000 vehicles deployed. They addressed the different design requirements and the development of new technology with both public and private entities.
- Universally among stakeholders, the deployment was perceived as being very challenging for all involved; the CV technology was not deployment-ready. A considerable amount of troubleshooting and fiscal resources were required to get the CV ecosystem up and running.
    - Three big technical challenges were identified: (1) CV technology not ready for deployment, (2) locational accuracy, and (3) over-the-air software updates.
- Success of the pilot was originally defined as achieving the safety goal of crash reduction; however, the NYC CVPD Team realized that accurate and reliable evidence of safety impacts would not be possible due to the low number of deployed vehicles and RSUs. The definition of success morphed into simply getting the deployment components to work.
    - While performance measures were identified in the design phase, there was doubt that the required data would be obtained from the number of deployed vehicles and RSUs to determine impact.
    - In October 2020, the FCC chairman announced his plans regarding the breaking up of the 5.9 GHz band, which was reserved for transportation safety communications (DSRC). This created an ongoing policy challenge for the NYC CVPD Team as not just the NYC CVPD but future V2X implementations were based on DSRC spectrum availability. This brought into question the sustainability of V2X implementations in NYC.
    - Procuring technology at the scale of the pilot required special procurement and contractual processes. The NYCDOT procurement policies were not flexible to accommodate these requirements. There were both delays in getting the consultant and vendor contracts in place and challenges with the format of the purchase orders issued (e.g., for units of technology only without consideration of level of effort required to make the equipment work).
    - An institutional challenge was related to the stakeholder participation. Stakeholder commitments changed over the lifespan of the project. Originally, the pilot had commitments from the taxi

industry, a private commercial delivery company, and the MTA to participate. The private commercial delivery company bowed out early. The initial planning included much more robust deployment in taxis and buses than had been achieved.

- There was lack of consensus among stakeholders on whether consensus existed as to goals, expectations, and priorities. While collaboration started strong in the design phase (Phase 1), it tapered off during Phases 2 and 3 as the conflicting goals and priorities of stakeholders surfaced. This team was comprised of academic–private–public entities. Each had a different perspective on moving forward as challenges mounted.
    - Financial challenges surfaced. One source of financial challenge was the Covid-19 pandemic, which had negative impacts for the private sector but also for state and local governments. The loss of the taxi fleet (due to their economic situation among other issues) was a really big issue for being able to measure impact. There were also a lot of cost overruns because of delays and solving technical challenges. The learning curve in terms of deploying the CV technology in a dense urban environment meant a financial hit for NYC CVPD team members.

End User Satisfaction and Perceptions

The NYC CVPD Team collected user survey data from fleet drivers and from pedestrians with visual impairments. The sample sizes for these surveys were small. There were 24 pedestrians and 81, 19, and 161 drivers in the pre-deployment, early post-deployment, and late post-deployment survey, respectively.

Drivers were neither satisfied nor dissatisfied with the CV applications. Most drivers were indifferent to them. Common concerns were distractions, false alerts, and too many alerts. Concerns about distractions and false alerts stayed steady through the pre-deployment survey to the post-deployment survey. The most useful alerts to improve safety were SPDCOMP and FCW—alerts that the drivers reported hearing the most.

As for the pedestrians, most were positive in their overall impression for the PED-SIG application. The main problems experienced when using the PED-SIG application were that the location information provided was not accurate. Nearly all participants felt they were given sufficient time to cross the intersection, and more than half of them felt they stayed oriented on the crosswalk when using the PED-SIG application. Most participants also thought the application is easy to use. Half of the participants reported feeling much safer using the PED-SIG application compared to not using it.

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Appendix A. NYC CVPD Vehicle Fleet

Agency	Passenger Cars	Pickups and Trucks	Vans	Buses	Vehicle Installations
NYC Dept. of Transportation	Yes	Yes	Yes	No	1,238
NYC Dept. of Parks and Recreation	Yes	Yes	Yes	No	511
NYC Dept. of Corrections	Yes	Yes	Yes	Yes	259
NYC Dept. of Environmental Protection	Yes	Yes	Yes	No	159
NYC Dept. of Homeless Services	Yes	No	Yes	No	100
NYC Taxi and Limousine Commission	Yes	Yes	Yes	No	98
NYC Human Resources Administration	Yes	No	Yes	No	86
NYC Dept. of Citywide Administrative Services Fleet	Yes	No	No	No	78
NYC Dept. of Education	Yes	Yes	Yes	No	78
NYC Dept. of Buildings	Yes	No	No	No	69
NYC Administration for Children's Services	Yes	Yes	Yes	No	65
NYC Dept. of Housing, Preservation, and Development	Yes	No	No	No	48
NYC Dept. of Health and Mental Hygiene	Yes	Yes	Yes	No	45
NYC Dept. of Design and Construction	Yes	No	No	No	38
NYC Office of Chief Medical Examiner	Yes	Yes	Yes	No	29
Metropolitan Transit Authority Bus & New York City Transit	No	No	No	Yes	14
NYC Emergency Management	Yes	No	No	No	12
NYC Dept. of Consumer Affairs	Yes	Yes	No	No	12
Anheuser-Busch InBev	No	No	Yes	No	10
NYC Dept. of Information Technology and Telecommunications	Yes	No	No	No	9
NYC Dept. of Probation	Yes	No	No	No	6
NYC CVPD Team Vehicle	No	Yes	No	No	1
Taxi Limousine Commission (Yellow Cabs)	Yes	No	No	No	1
Totals	**1,662**	**967**	**269**	**102**	**3,000**

Source: New York City Department of Transportation, 2021.

Appendix B. Pre-deployment Interview Guide

The pre-deployment interviews elicited vision, goals, and expectations and provided information on financial and institutional preparedness. The TTI CVPD evaluation team executed these interviews just before activation of the test CV applications.

Preamble

Good morning [afternoon] and thank you for participating in this interview. I am [name], a member of the CV pilot deployment independent evaluation team. Our job is to assess the mobility, environmental, and public agency efficiencies associated with the CV pilot deployments. The USDOT ITS Joint Program Office is sponsoring this evaluation. The purpose of this interview is to gather information on the vision, goals, and expectations of the CV pilot and to gather information on financial and institutional preparedness before the deployment activation. We are conducting this interview under the human subjects' protection requirements of Texas A&M University's Institutional Review Board. The information that you provide in this interview is confidential, and we will not attribute responses to any specific individuals. As part of this interview, I will be asking a series of questions that pertain specifically to your perceptions and experiences regarding the planning, development, and upcoming implementation of the CV pilot applications.

Interview Questions

Role, Vision, and Goals

Questions to be asked of deployment managers, deployment team members, operating agencies, and policy makers:

1. What is your agency's role in the CV pilot deployment?
2. What is your role in the NYC CV pilot deployment?
    - Probe if not addressed: In what stage are you most involved? (planning, development, implementation, or all)
    - Probe if not addressed: In what specific activities are you most involved?
3. To the best of your knowledge, what are your agency's goals/reasons for participating in the CV pilot?
4. In your opinion, what constitutes success for your pilot deployment?
    - Probe: What are the positive outcomes that your agency is hoping will result from the CV pilot deployment?

Policy Challenges

Questions to be asked of deployment managers, deployment team members, operating agencies, and policy makers:

5. Are there specific policies or political issues that had to be addressed to deploy the CV applications?
    - Probe: How were they addressed? [note issue by issue]
6. Are there any policy issues that your agency still needs to address in the future regarding deployment of this type of technology?

Institutional Challenges

Questions to be asked of deployment managers, deployment team members, operating agencies, and policy makers:

7. Are there any specific institutional issues that surfaced during the planning for implementation?
    - Probe: What solutions were put forth to address these challenges? [note challenge by challenge] [do not ask policy maker]

Organizational Culture

Questions to be asked of deployment managers, deployment team members, operating agencies, and policy makers:

8. Does your organization as a whole support the CV pilot deployment?
    - If yes: In what way has this benefitted the deployment?
    - If no: What kinds of issues/concerns has this created for the deployment?

Collaboration

Questions to be asked of deployment managers, deployment team members, and operating agencies:

9. In your opinion, does consensus exist among the various stakeholders regarding CV goals, expectations, and priorities, or is each stakeholder participating in the pilot program according to its priorities?
10. To your knowledge, what types of formal processes have been put in place to facilitate collaborative planning/programming among CV pilot stakeholders?
11. How do key stakeholders participate in the decision process for CV system operations and management?
12. Moving into implementation, what kind of business processes and procedures have you enacted to facilitate your operational decision making?

Financial Issues

Questions asked of deployment managers, deployment team members, and operating agencies:

13. In your opinion, is there a shared commitment among stakeholders as to the financial stability of the CV pilot and how to achieve it?
    - If yes: What are the shared commitments (including cash contributions) from the various stakeholders? How were these shared commitments achieved?
    - If no: Discuss why not.
14. Are you familiar with the long-term plan for funding/financing the CV pilot?
    - If yes: Please describe.
15. Are you aware of the existence of a business plan or business planning process for the CV pilot?
    - If yes: Please describe.
16. Have projections for future market participation, revenue, and cost associated with the CV pilot been developed?
    - If yes: Can you provide detail on that process? Outcomes?
    - If no: Are there plans to do this in the future?

Business Processes

Questions asked of deployment managers, deployment team members, and operating agencies:

17. In a typical DOT-centric manner, the pilots would be organized such that the public sector is expected to assume responsibility for the infrastructure aspects of the system and the private sector the installation of vehicle equipment. Was this general structure followed?
    - If no: What structure was used?
18. Has the CV pilot program been reflected in the overall multimodal transportation and business plans of all participating public agencies?
    - Probe: Have multiyear budgets been developed for pilot implementation?
    - Probe: Is there a plan for ongoing operation of the CV deployment including actions defined and business models for expansion of the existing pilot and transition to support long-term deployment?
19. To what extent are your business processes changing as a result of deploying the pilot? Can you provide an example?

Performance Measures

Questions to be asked of deployment managers, deployment team members, operating agencies, and policy makers:

20. What impacts do you foresee when you (your agency) decided to participate in the CV pilot?
    - Probe: Specifically, on individual mobility, environmental, and efficiency impacts.

Questions to be asked of deployment managers:

21. Your agency identified a number of performance measures for monitoring performance of the deployment. How will these data be used during the pilot deployment?
    - Probe: Directly for after-action debriefings and improvements, displayed in dashboards, or only after the fact for overall evaluation purposes.
22. During the deployment, will these performance measures be reported internally to the deployment team only or externally as well?
23. In what way will performance measures be related to financial stability measures? In other words, used to support business decisions related to future CV pilot activities?

Systems and Technology

Questions to be asked of deployment managers, deployment team members, and operating agencies:

24. What do you think are the most significant technical or technology-related challenges related to the CV pilot?
    - Probe: How has your agency coped with the challenges? What kind of solutions has your agency put forth? [note challenge by challenge]
    - Probe: What kind of issues/challenges did you encounter with standards and specifications?
    - Probe: Do you feel the applications are mature enough for deployment?
    - Probe: If no, what needs to be done to solidify the applications?
25. What kinds of security challenges did you face in planning and implementing your deployment?
    - Probe: Does your system design address hacking and privacy concerns? Please explain.
    - If yes: Does the CV program include adequate infrastructure to ensure timely issuance of security certificates to participants?

Questions asked of deployment managers and deployment team members:

26. Does the system design incorporate maintenance monitoring for both vehicles and field equipment that permits rapid identification of system degradations or failures?
    - If yes: Is emphasis placed on seamless monitoring across jurisdictional boundaries?
    - If yes: How will you deal with maintenance issues of equipment installed on vehicles?
    - Probe: Who will maintain the field equipment?
    - Probe: Has your agency developed a maintenance management system that captures maintenance actions, cost, inputs, and outputs for both field equipment and vehicles?

Workforce Development

Questions asked of deployment managers and operating agencies:

27. Are sufficient people trained to manage, operate, and maintain the CV system through both in-house work and outsourcing?
    - Probe on any challenges encountered.
28. For the in-house staff, were these individuals added on to units with an existing structure and staffing, or was a CV-specific operational unit developed?
    - Probe: If added to an existing structure, do you foresee CV responsibilities being consolidated into an operational unit with a manager and defined budget?
29. How do you see staffing evolving to meet the demands of future technologies and a mix of modes?

Outreach

Questions asked of deployment managers and operating agencies:

30. What outreach activities, if any, has your agency planned to engage other stakeholders, policy makers, or the public in the CV deployment?

Final Question

31. Do you have any additional thoughts or concerns to share that may not have come up during the interview?

Appendix C. Pre-deployment Interview Summary

In October 2020, pre-deployment interviews were conducted with knowledgeable persons at the deployment managing agency, with deployment team members, and with operating agencies. A total of 19 individuals were interviewed. A summary of their individual interviews is presented here.

Role, Vision, and Goals

What is your agency's role in the CV pilot deployment?

Interviews were conducted with the NYC DOT, the deployment manager; the prime engineering consultant and subconsultants responsible for performance metrics and evaluation, user surveys, modeling and simulation, supporting system architecture design, and outreach; and the vendors responsible for providing SCMS services, supplying the onboard units and the roadside units, and providing the security engineering products as well as the security design and security analysis approach.

To the best of your knowledge, what are your agency's goals/reasons for participating in the CV pilot?

For the deployment manager, the goal was to enhance traffic safety to further NYC's Vision Zero initiative. To others, it was that reason plus being a part of the team working with NYC DOT to design and implement the "most ambitious CV pilot to date." CV was a new technology, and everyone wanted to be connected to the leading edge of the technology. The lead consultant and many of the subconsultants had long-standing relationships with NYC DOT and their support of NYC DOT in the CV pilot was a natural progression. The technical vendors wanted to prove themselves (and their technology) in the V2X space.

In your opinion, what constitutes "success" for your pilot deployment?

There were two different definitions of success, and both were mentioned by virtually all persons interviews.

- The first was **achieving the safety goal**–crash reduction. Related to that was verifying how much NYC could benefit from the deployed safety applications. Not that there was the expectation that all safety applications would perform at the same level of success. NYC has unique spatial environment and geographic layout so it was presumed that there would be variation in the effectiveness rates of the deployed safety applications.
    - A few of the interviewees were unsure if there could actually be evidence of safety impacts. The pilot will only instrument about 3,000 vehicles and that might not be enough vehicles to determine impact.

- One person suggested that the pilot might need to deploy for a very long time to reach statistical significance of impact.
- Another said that results of the use of the system will be difficult to detect because accidents among professional drivers (such as the fleets in which the equipment is installed) will be less frequent than average drivers. This makes it hard to see significant accident reduction.

- The second definition of success was **simply getting the deployment to work**, to function reliably. This would entail getting the V2X infrastructure up and running and getting vehicles talking to each other.
  - As one person said, NYC DOT has taken on an ambitious goal in terms of the size of the pilot--numbers of vehicles and RSUs. In terms of its scale, getting through the deployment and checking off all things that they committed to doing is success. Just staying and finishing the project would, in itself, be success.
  - Another person said: Can the NYC DOT and the team get a significant number of vehicles interacting in this challenging CV environment? Can they identify meaningful lessons learned for future CV deployments?

Policy Challenges

Are there specific policies or political issues that had to be addressed to deploy the CV applications?

Two national policy challenges were mentioned by several interviewees.

- A few persons mentioned that the biggest policy challenge was the fact that the NHTSA **mandate for V2V (DSRC) was never enacted**.
  - The benefits accrue when you have very high penetration of vehicle and enabled roadways, a mandate would have helped to achieve that.
  - This created also challenges in terms of making the city's investment in CV sustainable. A mandate would have been backup from a national level as the city takes on certain large-scale investment risks.
- More individuals mentioned the **Federal Communication Commission's (FCC) notice of proposed rulemaking** which would split the 5.9 GHZ band and reduce the amount of bandwidth that would be available for DSRC as a significant policy challenge.
  - A couple people were concerned that this decision might upset the whole V2X ecosystem, e.g., cause largest OEMs to delay by years implemented V2X communications, create lack of interest among suppliers of devices and services.

  - One person lamented that "DSRC is the only line of sight sensor for the vehicle. Even AVs need to be on a line-of-sight sensor. Radio communication is really important. FCC needs to get its act together and that USDOT needs to do more to combat this change."[1]
  - Another person asked the rhetorical question, "what if DSRC doesn't survive?" The pilot was an opportunity to test other communications not just DSRC. But NYC didn't do that. If DSRC doesn't survive, we wasted an important opportunity.

The need for policies or standards to address **interoperability of CV systems** was also raised.

- One person wanted to know, "What are the interstate norms for CV communications?" And he suggested that the industry needs to be thinking about the standards that need to be put in the security certifications to allow them to operate across state lines.

Other policy challenges were more focused on the NYC context. For example, the **privacy requirements** were also view as a policy challenge.

- One person described this challenge as the fact that the CV industry was immature and meeting the privacy policy requirements (i.e., protecting PII) set forth by USDOT were difficult. A lot of energy (time and effort) was put into figuring out how to process data, sanitize it, and obfuscate it to prevent any PII from being exposed.
- Another person mentioned that the lack of data retention due to fear of lawsuits meant that using the data for other research purposes will not be possible.
- Several people mentioned that the privacy requirement made recruitment of fleets for the aftermarket safety devices (ASDs) installation difficult. Several of the intended participating fleets wanted the data on their drivers (as a quid pro quo for participating), which NYC DOT could not provide.

Many people mentioned challenges that arose due to NYC DOT's **procurement policies**. Not just NYC DOT, but many government procurement policies are focused on procuring tried technologies and not the "bleeding edge" technologies needed for the pilot. Procuring at the scale of the pilot required special procurement and contractual processes. As one person said, "One thing for spending $100k; something else for a couple of million."

- Several people mentioned delays in getting the proper contract vehicles in place. That it took a while to identify the right contract mechanism, which ended up being a "negotiated procurement after a demonstration." It took a lot of time to get contract vehicles in place even after identifying the right procurement mechanism because none of the pertinent NYC DOT staff had used it before or even knew it existed. One interviewee estimated that procurement delayed more than 18 months because all the "downtown" people needed to sign off.
- The ways in which the procurements were done was also a problem. Relating to the purchase of RSUs, one person explained that it was basically a purchase order for 550 units with some

[1] USDOT has some active initiatives to assess the impacts of the FCC proposed change https://www.transportation.gov/research-and-technology/safety-band-testing-plans-and-technical-info

provisioning for onsite support. The purchase order did not include all of the effort to make sure everything worked. “They were going for lowest price.”

Are there any policy issues that your agency still needs to address in the future regarding deployment of this type of technology?

Two issues were mentioned.

- One person talked about the need for a DSRC mandate – and a direction – so their investment in DSRC is sustainable.
- Also, for national deployment of CV, a couple of people mentioned that there needs to be more development of the “applications.” That there has been miscommunication in the V2X industry for years concerning the application maturity, which were “talked about like they existed in some sort of specification.” But in reality, there is no standard specification. Until specifications exist, there will be no interoperability among deployments. New pilots will have to change identifiers as the industry specs out these applications.
- Another person mentioned that looking toward the future, he does not want “technology islands” where CV apps are only for that island.

Institutional Challenges

Did you encounter institutional issues?

Institutional issues were mitigated by the fact that “everyone was focusing on the safety end of things.” Deployment was all about safety. And the NYC deployment was not a public-private partnership. NYC DOT was the prime contractor to USDOT. All others were subcontractors to NYC (or subcontractors to subcontractors). That said, several people mentioned two institutional issues. And more people talked about the first one than the second one.

- The first was related to the **stakeholder participation**. There were challenges, as discussed by nearly all of the interviewees, because stakeholder commitments changed over the lifespan of the project. Originally, the pilot had commitments from the taxi industry, a private commercial delivery company, and the MTA to participate. The private commercial delivery company bowed out early. The initial planning included much more robust deployment in taxis and buses than has been achieved.
    - One person speculated that FCC spectrum issues influenced commitment of stakeholders. They didn’t know if their investment in getting ASDs installed in vehicles was going to be sustained.
    - Another pointed out that there were no incentives for the private sector to participate. They wanted access to the data to monitor the drivers. But the privacy requirements prevented NYC DOT from allowing this.
    - In terms of the taxis, the lack of participation was influenced by the changing taxi marketplace (i.e., economic impacts of competition with TNCs and the reduction in passengers due to COVID). The pilot was trying to recruit taxis as they were starting to fight for their survival. Now, a handful of taxis have ASDs installed – all pre-COVID.
- One person mentioned that early in the design phase, NYC DOT held ongoing dialogue with the taxi/limousine commission in NYC about mandating the taxis to participate in the pilot. But it learned that taxis are independent contractors so they cannot be mandated.

  - With MTA and buses, the lack of participation is primarily due to COVID impact on public transit. MTA has vastly different priorities right now. The pilot has installed ASDs in only a small number of buses. Some installations were pre-Covid and some have happened recently.

- The second institutional issue, mentioned by about half of interviewees, was **contractual** – processes required to make sure that large-scale CV procurement and deployment was implemented cost-effectively. That was a challenge given that this was an innovative technology that was deployed almost for the first time.
  - The contractual process impacted the schedule and the project implementation, in general. Making sure that the procurements were cost-effective and at the same time, that the units would work in a large-scale deployment took a lot of time and effort.
  - For example, there were challenges in getting the contract for RSUs after it was learned that the existing units on the market were not up to what was needed. So, a new RSU vendor had to be found and then there were challenges in getting that vendor under contract.

Have you encountered any union issues?

One person talked about union issues, where the biggest area of impact was ASD installation. There were schedule delays as certain contract items needed to be reviewed and negotiated, such as (1) when and where the devices were to be installed, (2) the number of shifts on which they could be installed, and (3) when and how inspections would occur. There were a number of different public fleets that were involved, and the requirements varied. The deployment team expected the process to take a long time, but it took much longer than ever expected.

Culture

Does your organization as a whole support the CV Pilot Deployment?

The deployment manager said that NYC supports the CV pilot deployment very much. But that this is dependent on "what goes next." Right now, yes, everybody is supporting the project but the lack of a DSRC mandate affects the support of the project in general. There is some doubt by some people (inside and outside of the agency) as to whether this is a worthwhile investment.

Collaboration

In your opinion, does consensus exist among the various stakeholders regarding CV goals, expectations, and priorities or is each stakeholder participating in the pilot program according to its priorities?.

Yes/no – there was lack of consensus among interviewees on whether consensus existed among various stakeholders as to goals, expectations, and priorities. Individual responses to the question are below.

- Yes. Collaboration was good. "The project manager did a very good job."
- Yes. As an example, "the supplier of RSU is a competitor." For the pilot we all worked together to meet short-term goal of getting the pilot up and running and collecting data.

- Not really. One individual identified two different stakeholder sets – supplier side and agency side. Supplier side wanted the technology to work and work as expected. Their goal was to see the pilot succeed from a technical perspective. Agency-side just wants to make sure that the pilot does not upset their day-to-day operations. At the same time, they would like to see that it makes a difference in driver safety.
- Yes/no. There were about 12 city fleets beyond DOT. These stakeholders were encouraged to participate by the main agency responsible for city fleets. But their agency priorities come first. So, the deployment team needed to be flexible with stakeholders and make it easy for them to participate (e.g., onsite installation in their shops).
- No. "Because of the complexity of this project." It was challenging to identify a common goal. For the vendors, they were not involved in the big picture; their priority was to make sure that the equipment worked.
- No. I wish there had been more strategic involvement from stakeholders to understand where the project is going. To be honest, there is no schedule. There was one two years ago, but nothing now. There is a lot of challenges on this project.
- No. This team was comprised of academic-private-public entities. Each has a unique perspective. The lack of consensus on objectives was a big institutional issue. At the end, we are not coming from the same vision. NYC DOT came at this from a perspective of risk mitigation. It is hard to do that with an R&D initiative.

To your knowledge, what types of formal processes have been put in place to facilitate collaborative planning/ programming among CV pilot stakeholders?

At the beginning there were more collaborative, frequent meetings but as the project needs changed so did the formal processes to facilitate collaboration, as discussed by different people below:

- In Phase 1 there were lots of roundtable discussions with a goal to get everyone to understand how the system components all work together; to get everybody to feel a sense of ownership over the overall system design.
- The fact that there were so many vehicles was a significant risk - if anything went wrong – it would be expensive to fix. So, the emphasis was on making it right from the start. Formal meetings were necessary to achieve that.
- There were twice-a-week meetings as we were experiencing issues. We would thrash through issues which led to joint troubleshooting. This happened to address early issues like the SCMS. Process worked well. Now we talk though data we are collecting with the city to facilitate the city being about to sustain the deployment after the pilot.
- There were regular meetings with stakeholders, especially during the planning stages. Delays have impacted the regularity of the meetings.
- More of an implementation process now (rather than design) so more people involved from NYC DOT and other city entities providing vehicles. So more of a working level than a managerial one and the meetings are more informal.
- We have established a project review panel to provide different input – updated on a monthly, quarterly basis. There was a hefty process that was developed to deal with the stakeholders to make sure they are always updated. We had meetings from the beginning. We have the website to support the project outreach and feedback from stakeholders and the public. We have formal driver training.

How do key stakeholders participate in the decision process for CV system operations and management?

The whole team participated in the requirements analysis to make the new CV system work with NYC systems. Key stakeholders had key input to design decisions during planning. But now during testing, management is primarily NYC DOT.

Financial Issues

In your opinion, is there a shared commitment among stakeholders as to the financial stability of CV pilot and how to achieve it?

Fiscal responsibility is partly NYC DOT and partly federal government funds. There are no other public agency stakeholders with fiscal responsibility. A few people discussed financial concerns:

- One mentioned that right now with impact of the pandemic, people are just beginning to realize the significant financial issues that exist for state and local governments.
- Another person said the city is overly concerned right now with some in city saying, “why spend more if FCC will pull rug out from under us.” Loss of taxis was a really big issue – from 8,000 vehicles to 3,000s vehicles.
- Another mentioned there were lot of cost overruns because of delays and solving technical challenges associated with R&D. There was a lot of effort to make the technology work – developing new units – OBUs, RSUs. The learning curve has meant a financial hit.
- One subconsultant indicated that their contract is piecemeal – by 3 months. NYC tapped into previous engineering services contract. This has caused piecemeal subcontracts and delays in payment.
- A vendor said, we supply the units. We’ve supplied all the units that we’re going to supply – If not enough vehicles or city ran out of money. I don’t know the whole picture.

Are you familiar with the long-term plan for funding/financing the CV pilot?

- Several challenges in the development a long-term plan for funding/financing the CV pilot were raised.
    - One individual said, at this point, we like to see the future of the spectrum; can we expand or not? One factor that was introduced this year was the pandemic. “That question will become clearer one year from now.”
    - Another mentioned scalability-- we were able to implement 250 RSUs, but NYC has more than 13,000 intersections. To put the technology in all of the intersections in the city would be a huge fiscal challenge.
    - Will the project survive? There are fiscal challenges for NYC DOT. NYC DOT has made investments to run the pilot, RSUs, staff training equipment to manage system in TMCs. “I wonder. what is the commitment from NYC DOT going forward?”
    - I’m skeptical; no resources; city dealing with a lot of issues right now.

Are you aware of the existence of a business plan or business planning process for the CV pilot?

Not really because we are faced with the stability of the spectrum. The requirement for a successful project is changing. NYC was contemplating expansion (RSU installation) with a capital program of rehab arterials. But things have changed.

Have projections for future market participation, revenue, and cost associated with the CV pilot been developed?

At this time, the funding is allocated to maintain and operate. Expansion is not clear – "will be clearer a year from now."

Performance Measures

What impacts did you foresee when you (your agency) decided to participate in the CV pilot?

The consensus among interviewees was that the NYC pilot is primarily focusing on safety aspects, and secondarily on the mobility aspects. The team is looking for proof that CV technology actually is able to help the city's drivers and pedestrians to resolve traffic or safety issues. While performance measures were identified in the design phase, whether or not the required data will be available is uncertain. This was evidenced in the individual responses to this question.

- In Phase 1, the team planned specific items based on warnings that would make travel safer, such as limiting red light running and wanting to avoid as many accidents or incidents, as possible. The team wanted indicators that would enable us to see a difference.
- From a data management/upload design, our objective was to make sure the vehicles captured the data needed for all sorts of performance measures. We defined a number of different events (warning to the driver) and made sure we had a rolling mechanism that would capture the time-based events up to and after the event. It was important that we collected the right data and got it up to TMC. Not sure if there is enough data.
- This is the reason one key metric is number of vehicle sightings (where one ASD-equipped vehicle encounters another ASD-equipped vehicle so there would be the opportunity for messages to occur). "We were trying to get a significant number of interactions between vehicles. Really excited because have seen the number grow from 5,000 a day to 15,000 a day."
- The CV pilot was focused on mitigating accidents. At the beginning there was going to be a lot of instrumented vehicles. "Now I'm not sure we'll see a big impact especially since we lost the taxis."

Your agency identified a number of performance measures to monitor performance of the deployment. How will these data be used during the pilot deployment?

The team's current focus is on providing information to the independent evaluator-- pushing data to the security data commons (SDC).

- One person mentioned working to improve the data flow from the vehicles back to the TMC – and up to the SDC. But they have not done a lot of SDC data uploads to date. Learning from the other pilots, they are doing all possible to automate data collection and performance metrics extractions. But it is too early to say how successful they will be. Some things, like crashes or how many vehicles are communicating, the NYC team is tracking on a daily basis.
- One person indicated that there was lots of discussion about obfuscation and privacy access. And another went into detail on how the pilot is detaching information about the vehicle operators from

the data being collected. NYC engineered the process so that some of the event data was moved by location offsets – so one does not know where exactly in NYC the vehicle was. NYC is also doing intense data scrubbing to reduce disclosure risks. The danger is still that a larger entity like Google could vacuum up and reconstitute data – post-trip location tracking.

- A fourth person talked about looking at system reliability. How to use CV vehicles as probes for travel time data collection.

During the deployment period, will these performance measures be reported internally to the deployment team only or externally as well? No

NYC is working on dashboard to share the data. It is now being shared informally.

In what way will performance measures be related to financial stability measures – in other words, used to support business decisions related to future CV pilot activities?

All performance measures are safety related; one mobility related. Not looking at financial performance.

Systems and Technology

What do you think are the most significant technical or technology-related challenges related to the CV pilot?

Three big challenges were identified (1) the CV technology was not ready for deployment, (2) the locational accuracy, and (3) over-the-air software updates.

- The **CV technology was not ready for deployment**. While many persons mentioned this, one person went into detail saying, "Ready for deployment means you can go out and buy components. In reality, devices were not available to do the job that had to be done." The available technology was nowhere near practical deployment, and in this person's opinion, this was compounded by the USDOT's desire to collect a lot of extraneous data compared to what was needed for the actual pilot deployment.
    - One individual singled out the readiness of RSUs, saying that the RSUs that were delivered were an undependable device – immature product. Pointing out, one can deal with that when deployment a few units – it is something else when there are 450. The NYC team needed to d0 things to the components to get them to function well. Now, the units are working, collecting data, over DSRC, and checks of unit efficacy are being done.
- Several people mentioned that the most technical challenge was the **GPS accuracy** since the primary goal of the pilot was to improve safety. "None of the applications work if you can't pinpoint location." Specifically, the pedestrian and intersection movement assist applications were mentioned as significant issues. The lack of GPS accuracy was due in part to NYC's geography which more complex than other pilots, with urban canyons.
    - The team did some work to improve the location accuracy (via RSU triangulation method). As one person explained the engineering tweak was to have the RSU and ASD using time of flight technology. RSUs have a known location; ASD time was relative to RSU to improve location accuracy. But there were challenges in implementing this solution. The universe of vehicles and their data architectures is very extensive. Detailed engineering was needed to properly ensure that they were getting the data needed – because of make,

model, year variations. One could have the same make, model, year but because of changes during the model year integration of vehicles was difficult.

- Another person explained that using RSUs to triangulate was not good enough to improve the GPS accuracy. They could not install enough equipment everywhere. Urban canyons are a significant problem for the GPS signals. It's an ongoing technical concern.
- A couple of people mentioned that USDOT (the COTR) produced a solution that involved having some datasets to supplement what one gets with GPS (a unicast ping back). Accuracy was close to about 70% - but still a problem because they were deploying safety applications. This person believes GPS accuracy will continue to be the most challenging technical issue in CV applications. NYC made headways. Now, anyone can take it and improve on it.
- One person described how getting the applications to work often has its root in not being able to get an accurate position, and that a policy issue is that the standard for positioning really only requires knowing a location 67% of time. But such standards do not meet the needs of safety applications. Location accuracy is better but not totally overcome. Triangulating off of a roadside unit is not good enough because a city is constantly moving. Today the method could work fine but tomorrow there can be someone building scaffolding in front of the RSU. NYC or any environment is not static – it requires constant maintenance and updating. This person suggested that with 5G, positioning off of cell towers should improve location accuracy because there will be thousands of cell towers in NYC but "we're not there yet."

- Getting the **over-the-air software updates** to vehicle through DSRC was a challenge. "You've got equipment in the field that has bugs that need to be updated. You need to push updates to those devices (OBUs) that don't impact privacy of the drivers. Everything has to just work." Different people identified specific challenges.
  - The team experienced challenges in pushing the updates to the devices, that is, producing a way of distributing firmware to 7-8,000 vehicles.
  - The updates were hindered by low-level bugs such as in IP drivers. Vendors bought libraries but the libraries had bugs in them, e.g., OBU was not throwing away corrupted packets. When team investigated, they found it was caused by interference by RSUs, so they needed to fix both channel and spatial diversity.
  - Because the RSUs were very close to each other, the team needed to use diverse channels to reduce interference. They could not have them alternating between channel A and channel B. Each had to be operating on a distinct service channel.
  - Relying on DSRC was more difficult than expected. The CVs are more dispersed than expected; not as many vehicles as desired roaming the city. The team needed to prioritize different data communications over DSRC, e.g., data upload, BSM, SCMS communications. It was difficult to manage prioritizing one kind of communication over another. Now it varies.
  - The team is trying to determine where RSUs can be positioned to capture as many vehicles as possible. They are moving around a few mobile RSUs to figure out where permanent ones should be installed.
  - Doing all the uploads via RSUs instead of other wireless technology was an engineering challenge. A lot of data was being collected that would not be in real deployment. Because vehicles are mobile, they are handed off to different RSUs. Not only were data being uploaded via RSUs to TMC for research purposes, but also when the vehicles needed to refresh software and firmware, they had to do through RSUs as well. The

RSU and its control by the TMC had to broadcast in a specialized way through RSUs while vehicles were detaching from RSUs because they are mobile. The team used a network coded-based approach with downloads starting and stopping. In the real world (not R&D), they don't know if situation would be quite the challenge.

- Securing the RSU connection to traffic controller to which it was attached to required secure, real-time status and data transfers between them like SPaT. The team specified a secure protocol for that to happen. Traffic signal controller needed significant to support to secure that as well.

- When it comes to technical challenges and solutions, all seemed to think that the CV pilots did accomplish an underlying goal – education.
- What's become clear is that all pilots are a technical challenge. We'll discover increasingly as apps become more sophisticated. Vehicles are going to be making decisions based on information they receive. That information has to be secure and reliable to be usable.

What kinds of security challenges did you face in planning and implementing your deployment?

The biggest security challenge was **getting new certificates to the devices** (to sign their messages). Those certificates came from SCMS which is outside the network. On the other hand, devices were inside the network. This caused network management/security issues as discussed below.

- NYC was using certificate top offs on a weekly basis. Every Tuesday ASDs get their certifications updated for the following week and week after. Since there was no way for the deployment team to control where drivers go, it was not possible to ensure that vehicles would pass by a predesignated RSU so certifications could be downloaded. Those vehicles with no updated certifications would not be "seen." It took a while for the team to recognize that some vehicles' certifications were not updated.
- The solution was sophisticated. NYC pilot did certification on the fly as the vehicle moved around, with periodic re-certification. NYC pilot was pressing the state of the art early in the planning stage since there was no misbehavior algorithm.
- NYC pilot has had two security incidents (1) certificate provider made a changes and vehicles ran out of certificates, and (2) certificate providers distributed a new file that was documented in the security system specification; however, the security library did not have capability of handling that. So, all vehicles ran out of certificates for two weeks. These incidents helped to identify a new issue that they will have deal with in the future, that is, certificate expiration dates, which currently expire in 2023.

Does the system design incorporate maintenance monitoring for both vehicles and field equipment that permits rapid identification of system degradations or failures?

- Yes – The NYC pilot team implemented a robust logging system – uploaded through RSUs. Each device sends up logs to the system and analyzing those logs can determine if there are issues. Nothing specific in the units that are related to diagnostics, but one can determine an issue by looking at the data. The team uses the event data to evaluate the performance measures of the applications: event itself and raw data on which that event was triggered (e.g., a false warning – red light warning when traffic controller green). All are collected in a rolling log as meta data.
    - Field equipment, yes. The team tracks RSU status back in TMCs. Maintenance of the RSUs has been more intensive than expected but manageable. The city's ITS group is responsible.

- Vehicles, yes. The team tracks who we communicate with – what version of firmware.
- We have learned that we needed to do more inspections and verification of installations. We put too much faith in the fact that installers would be professionally trained. Now, we're having to track down some of the vehicles to figure out how to get them operational. Expected to do all over the air but we can't get updates over the air. Everything is a service vehicle. If we take it off the road then it's not fulfilling its primary role.

Workforce Development

Are sufficient people trained to manage, operate, and maintain the CV system through both in-house work and outsourcing?

Sufficient people are trained now, but there is uncertainty about the future.

- The core can handle right now. The ability to keep the core growing and moving will be challenging as priorities change. Technology is changing so fast that it is difficult to focus on operating what you have and still keep up with the changes as they occur.
- 80% inhouse to NYC DOT; 20% outsourced. Hard to say if proportions will change. The in-house team is very capable. It's always good to have a private-public partnership to deal with something like that until its routine.
- Vehicle installation is a mixture of city and private contractors who routinely do work on the vehicles (maintenance). One weak point vehicle installation teams.
- We train and provide the tools but don't install. There's a lot of existing contracts for installations. There's not as much time put into testing each individual install because of the scale. We would have liked to have vehicles running around in test mode after the install

For the in-house staff, were these individuals added on to units with the existing structure and staffing or was a CV-specific operational unit developed?

Existing staff have added CV pilot to their responsibilities. The city's ITS group was already maintaining signals and equipment. Nothing new here. There was a team that was formed, and specialties were added because of the specific tasks required for CV.

How do you see staffing evolving to meet the demands of future technologies and a mix of modes?

Probably yes, so much turnover in technology that staffing has to stay nimble. Sure, city will do that. Folks will probably have to expand their skill sets as technology evolves.

Outreach

What outreach activities, if any, has your agency planned to engage other stakeholders. Policymakers, or the public in the CV deployment?

At the beginning there was a lot of outreach activities: A lot of good videos; lots of demonstrations of the technology. Some sessions were open to people not directly involved in the pilot, such as different agency folks, owners of vehicles, city planning personnel. They were invited to get information and ask questions and as a way to gain acceptance and buy-in for the CV pilot in the future. Different members of the deployment team have participated in conference to share what they are doing; press releases have gone out, and other things like that to get information out about the pilot. But over the past 6 months, because of COVID, outreach has been curtailed. We are learning some very unique things in this NYC environment. It is lighthouse project. The deployment team should be discussing lessons learned more. One phase 3 requirement is to hold the operational capability showcase. The deployment team will rely on USDOT and NYC DOT to make sure it gets coordinated.

Concluding Thoughts

Do you have any additional thoughts or concerns to share that may not have come up during the interview?

What is the accomplishment of this pilot? We were able to develop a fully completed system on a large-scale, on NYC infrastructure, over 450 RSUs, and almost 2000 vehicle deployed. We have addressed the different design requirements and the development of this new technology with both public and private entities –we have completed testing and are about to enter the evaluation period. This can be model for the rest of the country. We hope it is going to be the model as DSRC is still the first choice for CV deployment. It might be a success even if a certain safety application do not work.

The project has been pushed forward during a period with outside influences beyond anyone's control (pandemic, financial implications for taxi industry, spectrum issues). Just the fact that the pilot is achieving implementation is a tribute to the people working on it.

Everybody in the space is interested in what will happen with 5.9. uncertainty. It doesn't change or take away from CV pilot but that does have some considerations to think about for the future.

Project maturity – it's taken 3 years for the industry to understand that standards are necessary; RSU specs are necessary. Maturity of the CV technology is still not there. Not a consensus yet on how to do this. We need consensus to figure out the future of CV so we're all pulling in the same direction. People don't seem to know what it takes to put a whole CV ecosystem to work.

Interaction of the pilot and mainstream deployment of V2X. The pilots identified gaps in standardization but because the gaps have not been fully resolved yet – we're in a chicken and egg situation – other deployments need standards for messages, data dictionaries., etc. So, they end of borrowing the pilot deployment specs. But as standards are developed, SPaT, signal preemption specs will likely deviate from what CV pilot did. So, we may be in for a painful transition. Standards organizations are aware of it. But an industry can only move so fast.

Appendix D. Participant Surveys

ASD Driver Surveys:

Different sets of questions are asked depending on the time the survey is conducted: Pre-deployment survey: Parts 1, 2, and 4 only. Early-deployment survey: Parts 1 to 4. Late-deployment survey: Parts 1 to 4.

Part 1: Vehicle Usage

Note: These questions are asked in all surveys.

1) Where do you primarily operate the vehicle during a typical work week? (Select all that apply):
   a) Manhattan - Lower Manhattan (South of 14th St)
   b) Manhattan - Midtown Manhattan
   c) Manhattan - Upper East Side
   d) Manhattan - Upper West Side
   e) Manhattan - Upper Manhattan (North of 96th St)
   f) Brooklyn - Downtown Brooklyn
   g) Brooklyn - Outer Brooklyn
   h) Staten Island
   i) Queens - Long Island City
   j) Queens - LaGuardia Airport
   k) Queens - John F. Kennedy Airport
   l) Queens - Other
   m) Bronx - Southern Bronx
   n) Bronx - Northern Bronx

2) At what times of day do you typically operate during WEEKDAYS? (Select all that apply):
   a) AM Rush (6AM-9AM
   b) Mid-day (9AM-3PM
   c) PM Rush (3PM-7PM)
   d) Evening (7PM-12AM
   e) Other (12AM-6AM)

3) At what times of day do you typically operate during WEEKENDS? (Select all that apply):
   a) Daytime (7AM-7PM)
   b) Nighttime (7PM-7AM)
   c) N/A (Not Applicable)

4) Which agency owns the vehicle you drive for work?
   a) NYC Department of Transportation (DOT)
   b) NYC Department of Corrections (DOC)
   c) NYC Department of Environmental Protection (DEP)
   d) NYC Department of Homeless Services (DHS)
   e) NYC Department of Parks and Recreation (Parks)
   f) NYC Taxi and Limousine Commission (TLC)
   g) NYC Human Resources Administration (HRA)
   h) NYC Department of Citywide Administrative Services (DCAS)
   i) NYC Department of Design and Construction (DDC)
   j) NYC Department of Buildings (DOB)
   k) NYC Administration for Children's Services (ACS)
   l) Metropolitan Transit Authority – Bridges and Tunnels (MTA B&T)
   m) Metropolitan Transit Authority – Bus (MTA Bus)
   n) New York City Transit (NYCT)
   o) Other: _____

Q5 conditionally asked if Q4 response is NOT “NYCT” or “MTA”

5) What is the make/model* of the fleet vehicle you typically drive?
   (Select all that apply):

   a) Chevrolet Bolt
   b) Chevrolet Express
   c) Chevrolet Silverado
   d) Ford E350
   e) Ford Explorer
   f) Ford F150
   g) Ford F250
   h) For F350
   i) Ford F550
   j) Ford Fusion
   k) Nissan Leaf
   l) Ram 2500
   m) Toyota Camry
   n) Toyota Prius
   o) Rav4
   p) Other: _____

Q6 conditionally asked if Q4 response IS “NYCT” or “MTA”

6) What is the make/model* of the fleet vehicle you typically drive?
   (Select all that apply):
   a) New Flyer
   b) Nova Bus
   c) Orion
   d) Other _____

7) Do you typically drive the same vehicle, or do you drive different vehicles within common fleet?
   a) Typically same assigned vehicle
   b) Different vehicles within common fleet

8) What is the typical MINIMUM number of miles you drive your fleet vehicle per workday? _____ miles

9) What is the typical MAXIMUM number of miles you drive your fleet vehicle per workday? _____ miles

10) What is the typical MINIMUM number of hours you drive your fleet vehicle per workday? _____ hours

11) What is the typical MAXIMUM number of hours you drive your fleet vehicle per workday? _____ hours

12) What is the typical MINIMUM number of days you drive your fleet vehicle per work week? _____ days

13) What is the typical MAXIMUM number of days you drive your fleet vehicle per work week? _____ days

Part 2: User Perception/Attitude

Note: These questions are asked in all surveys.

1) Please indicate your level of familiarity with Connected Vehicles and Connected Vehicle applications:
   a) Very familiar (I've heard about many of the applications and understand how they work)
   b) Somewhat familiar (I've heard about some of the applications and understand how they work)
   c) Not too familiar (I've heard about some of the applications but don't know how they work)
   d) Not at all familiar (I had not heard of Connected Vehicles before this study and have no information about the applications)

2) Do you anticipate that drivers will benefit from the use of Connected Vehicle technologies?
   a) Yes
   b) No
   c) Don't know enough about the technology

3) Do you have any of the following concerns about the Connected Vehicle technology system? (Select all that apply):
   a) Cost (i.e., it will be too expensive for you to purchase for your own personal vehicle)
   b) Safety
   c) Privacy
   d) Distraction (i.e., the system will be distracting)
   e) Trust in the technology
   f) Too many alerts or warning
   g) False alerts or warning (i.e., when there is no real danger
   h) Other (please specify: _____)
   i) Don't know enough about the technology

4) Based on your perceptions when you are driving in the City for work, what is your likelihood of a crash or near-crash with a pedestrian or bicyclist?
   a) Extremely Likely
   b) Very Likely
   c) Moderately Likely
   d) Slightly Likely
   e) Not at all likely
   f) Not applicable

5) Based on your perceptions when you are driving in the City for work, what is your likelihood of a crash or near-crash with another vehicle?
   a) Extremely Likely
   b) Very Likely
   c) Moderately Likely
   d) Slightly Likely
   e) Not at all likely
   f) Not applicable

6) Based on your perceptions when you are driving in the City for work, what is your likelihood of a crash or near-crash by yourself (e.g., hit roadway barrier or off-road crash)?
   a) Extremely Likely
   b) Very Likely
   c) Moderately Likely
   d) Slightly Likely
   e) Not at all Likely
   f) Not applicable

7) In general, how safe do you feel when driving in the City for work (i.e., that you won't be involved in a crash)?
   a) Extremely safe
   b) Very safe
   c) Moderately safe
   d) Slightly safe
   e) Not at all safe
   f) Not applicable (Do not drive in the City for work)

Part 3: User Experience

Note: These questions are asked only in the early-deployment and late-deployment surveys.

1) How often do you hear the alerts?
   a) Many times per day
   b) Few times per day
   c) Few times per week
   d) Less than weekly
   e) Never

If Q1 response is “Never”, skip remaining Part 3 question

2) How would you rate the sound volume of the alerts?
   a) Much Too Loud
   b) Somewhat too Loud
   c) About right
   d) Somewhat too Quiet
   e) Much Too Quiet

3) Are the audible alerts distracting or not?
   a) Extremely distracting
   b) Very distracting
   c) Moderately distracting
   d) Slightly distracting
   e) Not at all distracting

4) Do you find the audible alerts helpful or not?
   a) Extremely helpful
   b) Very helpful
   c) Moderately helpful
   d) Slightly helpful
   e) Not at all helpful

5) Have the audible alerts affected how you drive in the City or not?
   a) The alerts have affected my driving
   b) The alerts have not affected my driving

Q6 conditionally asked if Q5 response is “The alerts have affected my driving”:

6) How would you define the effect on your driving?
   a) Very Positive
   b) Somewhat Positive
   c) Somewhat Negative
   d) Very Negative

Q7 conditionally asked if Q5 response is “The alerts have affected my driving”:

7) Please indicate the reason for your previous response:
   _____

8) Which of these warnings do you recall hearing?
(Select all that apply):
   a) Blind Spot Alert
   b) Emergency Brake Light
   c) Emergency Communications and Evacuation Information
   d) Forward Crash Warning
   e) Intersection Movement Assist
   f) Lane Change Warning
   g) Pedestrian Warning
   h) Reduce Speed
   i) Reduce Speed Curve
   j) Reduce Speed Work Zone
   k) Stop Height Restriction
   l) Stop Red Light
   m) Vehicle Turning Right in Front of Bus Warning n
   n) I have received warnings, but I cannot tell them apart
   o) I can't recall if I received warnings
   p) I have not received any warnings

9) Which three warnings do you recall hearing most often?
(Select up to three):
   a) Blind Spot Alert
   b) Emergency Brake Light
   c) Emergency Communications and Evacuation Information
   d) Forward Crash Warning
   e) Intersection Movement Assist
   f) Lane Change Warning
   g) Pedestrian Warning
   h) Reduce Speed
   i) Reduce Speed Curve
   j) Reduce Speed Work Zone
   k) Stop Height Restriction
   l) Stop Red Light
   m) Vehicle Turning Right in Front of Bus Warning
   n) I have received warnings, but I cannot tell them apart
   o) I can't recall if I received warnings\
   p) I have not received any warnings

10) Do you think any of the warnings have helped you drive more safely?
   a) Yes
   b) No

Q11 conditionally asked if Q10 response is "Yes":

11) Check all that have helped you drive more safely:
(Select all that apply):
a) Blind Spot Alert
b) Emergency Brake Light
c) Emergency Communications and Evacuation Information
d) Forward Crash Warning
e) Intersection Movement Assist
f) Lane Change Warning
g) Pedestrian Warning
h) Reduce Speed
i) Reduce Speed Curve
j) Reduce Speed Work Zone
k) Stop Height Restriction
l) Stop Red Light
m) Vehicle Turning Right in Front of Bus Warning

12) Overall, how satisfied or dissatisfied are you with the warning system?
a) Very dissatisfied
b) Dissatisfied
c) Somewhat dissatisfied
d) Indifferent
e) Somewhat satisfied
f) Satisfied
g) Very satisfied

Part 4: Demographics

Note: These questions are asked in all surveys.

1) How many years have you been driving for work in New York City?
a) 0-2 years
b) 3-5 years
c) 6-10 years
d) More than 10 years

2) What is your age?
a) 18-24
b) 25-44
c) 45-64
d) Older than 65

3) What is your proficiency with English?
   a) Fluent
   b) Good
   c) Limited
   d) None

Appendix E. PID Pedestrian Survey

Pre-Experiment Interview Protocol

The purpose of this pre-experiment interview is to understand the baseline conditions for study participants.

Demographic Information

1) Name: _____

2) What is your age:
   - 18-24
   - 25-44
   - 45-64
   - Older than 65

3) Which borough do you reside in?
   - Manhattan
   - Bronx
   - Brooklyn
   - Queens
   - Staten Island

4) Which of the following best describes your vision disability?
   - Partially-sighted or low vision
   - Blind
   - Totally blind

5) At what age did you develop a vision disability or become blind?
   - _____ years old
   - _____ visually impaired since birth

6) On average, how often do you cross a signalized intersection per day?
   - 6 or more intersections a day
   - 4 or 5 intersections a day
   - 2 or 3 intersections a day
   - Less than 2 intersections a day

Self-ratings: Technology

7) Have you participated in any orientation and mobility training?
   - Yes
   - No

8) Do you currently use a mobile phone?
   - Yes: iOS or Android
   - No

9) Do you currently use a mobile navigation assistant / Global Positioning System (GPS)?
   - Yes
   - No

10) Have you experienced an Accessible Pedestrian Signal before? These signals give you audio or tactile information about the state of the light at the intersection or the location of the crosswalks in addition to a light signal.
   - Yes
   - No

Navigation & Mobility

11) What is your preferred method of assistance while navigating to a destination (select only one)?
   - Long or white cane
   - Guide dog
   - Electronic travel aid (e.g., laser cane)
   - Personal navigation device / GPS on the phone
   - Asking other pedestrians I pass
   - Other (please specify_____

12) How often do you use each of the following methods of assistance while navigating to a destination?
   A. Many times per day B. Few times per day C. Few times per week D. Less weekly E. Never
   - Long or white cane: _____
   - Guide dog: _____
   - Electronic travel aid (e.g., laser cane): _____
   - Personal navigation device / GPS on phone: _____
   - Asking other pedestrians I pass: _____
   - Other (please specify: _____): _____

13) In general, how safe do you feel when you cross a signalized intersection?
   - Extremely Safe
   - Very safe
   - Moderately safe
   - Slightly safe
   - Not at all safe

14) How would you rate your proficiency in each of these travel skills? Are you well below average, below average, average, above average, or well above average*? [INTERVIEWER: REPEAT RESPONSE CATEGORIES AS NEEDED]*

	Well below average	Below average	Average	Above average	Well above average
General sense of direction					
Independent travel					
Signalized street crossings					

Post-Experiment Interview Protocol

The post-experiment interview aims to collect useful feedback on participants' perceptions and experiences with the Ped App after the field test is done. t includes an additional set of questions on attitudes, safety, and other relevant topics.

User Experience

1) How do you rate the Ped App overall?
   - Poor
   - Fair
   - Good
   - Very good
   - Excellent

2) Did you experience any of the following problems in using the Ped App? Select all that apply.
   - Slow response
   - Location information provided not accurate
   - Type of advisory provided (i.e., signal timing) not useful
   - Other. Please specify. _____

3) When using the Ped App, do you feel you have sufficient time to cross the intersection or not?
   - Yes
   - No
   - Don't know

4) When using the Ped App, do you feel you stay oriented within the crosswalk?
   - Yes
   - No
   - Do not know

5) For each of the following statements, please tell me whether you strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, or strongly agree.
[INTERVIEWER SHOULD REPEAT RESPONSE CATEGORIES AS NEEDED]

- The operation of the Ped App is easy to use.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
○	○	○	○	○

b) I am more confident in my ability to cross a signalized intersection with the CVP pedestrian application compared to other assistive technologies I have used before.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
○	○	○	○	○

6) Does the Ped App provide sufficient information through AUDIO to assist your intersection crossing?
   - Yes
   - No
   - Do not know

7) Does the Ped App provide sufficient information through VIBRATION to assist your intersection crossing?
   - Yes
   - No
   - Don’t know

8) For each of the following statements, please select the answer that apply. [INTERVIEWER SHOULD READ AND REPEAT RESPONSE CATEGORIES AS NEEDED]

- Alerts given by the Ped App are timely.

Always	Mostly	Sometimes	Never
○	○	○	○

- Alerts given by the Ped App are accurate.

Always	Mostly	Sometimes	Never
○	○	○	○

- Type of alerts (i.e., signal information) given by the Ped App are helpful.

Strongly Disagree	Somewhat Disagree	Neither agree nor disagree	Somewhat Agree	Strongly Agree
○	○	○	○	○

9) In general, how safe do you feel when using the Ped App in comparison with not using it?
- Much Safer
- Slightly Safer
- Same level of safety
- Slightly less safe
- Much worse

10) How would you rate your ability to easily navigate the pedestrian crosswalk when using the Ped App?
- Excellent
- Very Good
- Good
- Fair
- Poor
- Very Poor

11) Do you anticipate that pedestrians will benefit from the use of Ped App technologies?
- Yes
- No

12) Do you have any of the following concerns about the Ped App technologies? Check all that apply.
- Safety
- Privacy
- Trust in the technology
- Too many alerts or warnings
- False alerts or warnings (i.e., when there is no real danger)
- Distraction (i.e., the system will be distracting)
- Don't know enough about the technology
- Other (please specify: _____)
- No concerns

13) Do you have any suggestions for improving the Ped App?

_____
___

14) Would you recommend the Ped App to other prospective users? Please specify why or why not
- Yes
- No

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