Connected Vehicle Pilot Deployment Program Independent Evaluation:

Financial and Institutional Assessment—New York City

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Research Report—August 23, 2022
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16. Abstract

This report presents the financial and institutional evaluation conducted by the Texas A&M Transportation Institute (TTI) Connected Vehicle Pilot Deployment (CVPD) Evaluation Team of the New York City (NYC) CVPD. The purpose of the financial evaluation was to assess the changes in the financial settings, frameworks, models, elements, and associated impacts from the planned and implemented connected vehicle (CV) deployments along with an evaluation of the likelihood that the NYC pilot site achieved financial sustainability, including identifying the key factors that influence financial sustainability and identifying key metrics for measuring and evaluating the achievement of financial sustainability, particularly due to changes in the underlying financial and business inputs. The purpose of the institutional evaluation was to assess the organizational changes that stem from the NYC CVPD, including the systematic evaluation of the effects of institutional changes in NYC to identify potential strategies to minimize institutional risk. Six factors were the target of the institutional evaluation: (a) governance, (b) public partnerships, (c) private partnerships, (d) organizational efficiency, (e) legislation, (f) industrial organization. The TTI CVPD Evaluation Team also worked to identify to what extent the NYC CV Pilot site was able to address identified institutional risks.

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Chapter 1. Introduction

This report provides the results of the financial and institutional evaluations of the New York City (NYC) Connected Vehicle Pilot Deployment (CVPD). The financial evaluation assessed the changes, if any, in the financial settings, frameworks, models, elements, and associated impacts from the planned and implemented connected vehicle (CV) deployments and to evaluate the likelihood that the NYC CVPD achieved financial sustainability, including the identification of the key factors that influence financial sustainability and the key metrics for assessing the potential for financial sustainability, particularly due to changes in the underlying financial and business inputs. The institutional evaluation assessed the organizational changes that stemmed from the NYC CVPD, including the systematic evaluation of the effects of institutional changes in NYC to identify potential strategies to minimize institutional risk. Six factors were the target of the institutional evaluation:

- Governance
- Public partnerships
- Private partnerships
- Organizational efficiency
- Legislation
- Industrial organization.

Summary of the New York City Connected Vehicle Pilot Deployment

Located primarily in the Manhattan area and along Flatbush Avenue in Brooklyn (see Figure 1), the NYC CVPD focused on the deployment and assessment of applications that used 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, the New York City Department of Transportation (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 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.

Source: New York City Department of Transportation, 2022.

Figure 1. Map. NYC CVPD Deployment Corridors.

The NYC CVPD intended to support the following specific V2V and V2I applications:[1]

- **Forward Crash Warning—**This application alerts drivers in the event of an imminent rear-end crash with a remote vehicle ahead.
- **Emergency Electronic Brake Lights—**This application alerts drivers of stopped or hard-breaking vehicles ahead of time to avoid a crash safely.
- **Blind Spot Warning—**This application alerts drivers when a remote vehicle is traveling in the adjacent lane near the CV and issues an alert to avoid sideswipe crashes.
- **Lane Changing Warning—**Similar to the Blind Spot Warning application, this application alerts drivers to conduct a lane change when another vehicle is in the adjacent lane in the same direction of travel.
- **Intersection Movement Assist—**This application alerts the driver attempting to cross or turn when it is not safe to enter the intersection.
- **Vehicle Turning Right in Front of Bus Warning—**This application alerts a bus operator if a remote vehicle attempts to pull in front of the bus to make a right turn.
- **Speed Compliance—**This application alerts drivers when they exceed the posted regulatory speed limit.
- **Curve Speed Compliance—**This application alerts drivers that are approaching a curve that they are exceeding the recommended advisory speed.
- **Speed Compliance in Work Zones—**This application alerts drivers that they are exceeding the regulatory speed limit of a designated work zone.
- **Red Light Violation Warning—**This application provides an alert to the driver of impending red-light violations.
- **Oversize Vehicle Compliance—**This application alerts commercial vehicle operators when their vehicle exceeds the height-restriction of roadway infrastructures, such as bridge or tunnel clearances.
- **Emergency Communications and Evacuation Information—**This application provides travel and evacuation information alerts to drivers during emergency events.
- **Pedestrian in Signalized Crosswalk—**This application alerts drivers to the presence of pedestrians crossing at a signalized intersection.
- **Mobile Accessible Pedestrian Signal System—**This application informs a visually impaired or audibly impaired pedestrian of the signal status and provides orientation to the crosswalk to assist in crossing the street.

NYCDOT completed the Planning and Concept Development phase (Phase1) of the deployment in August 2016 and began the transition to the Design, Build, and Test phase (Phase 2) in September 2016.[2] The NYC CVPD Team started deploying RSUs in January 2019 and completed the deployment of RSUs in October 2020. Installation of the OBUs began in April 2019. NYC's COVID-19 restrictions in place in 2020 delayed full implementation until after the start of the Operations and Maintenance phase (Phase 3), which began January 1, 2021. At the start of 2021, the NYC CVPD Team had equipped over 2,150 vehicles. The deployment did not reach its target installations until August 17, 2021. [3]

Organization of Report

The Texas A&M Transportation Institute (TTI) CVPD Evaluation Team organized this report into the following chapters. The titles of each chapter and the major topics contained therein are:

- **Chapter 2. Financial Factors**—This chapter identifies the factors that had the potential to influence the financial outcomes of the pilot deployment and documents the assessment of the financial factors for the NYC CVPD.
- **Chapter 3. Institutional Factors—**This chapter provides an overview of the information and data provided by the NYC pilot site to conduct the financial evaluation as well as how the TTI CVPD Evaluation Team collected them. This chapter also describes the process that the TTI CVPD Evaluation Team used to perform the financial evaluation and reports the overall results of that analysis.

Chapter 2. Financial Factors

The purpose of the financial evaluation was to assess whether the NYC CVPD achieved financial sustainability based on the planned and implemented deployments. For the purposes of this assessment, the TTI CVPD Evaluation Team defined financial sustainability as achieving net revenues sufficient to operate and maintain the CV applications over a seven-year period without additional CV federal grant money after the pilot deployment program ends at the site.

As stated previously, the focus of the NYC CVPD was to improve the safety of travelers and pedestrians in support of the city's *Vision Zero* initiative.(1) The goal of the pilot was to reduce crash frequency and severity, manage vehicle speeds, and assess the potential for deploying CV technologies in a dense urban environment. Originally, the TTI CVPD Evaluation Team was tasked with applying quantitative and qualitative evaluation methodologies to conduct before-and-after performance assessments; cost-benefit assessments of the demonstration; assess user acceptance/citizen satisfaction of the demonstration; document lessons learned, challenges, and approaches for mitigating, addressing, and/or overcoming them; estimate total impacts, costs, and return-on-investment of the demonstration; and assess how well the initiative in NYC managed to bring to the table and utilize institutional partners.

The TTI CVPD Evaluation Team originally proposed as part of the financial and institutional evaluation plan to utilize a four-step process to meet the objectives of this task.(4) However, because of deployment delays and the COVID-19 pandemic, TTI's evaluation transitioned from the intended quantitative analysis to a qualitative analysis supported by financial-related data and qualitative information related to funding and finance as collected by the NYC Deployment Team and the Evaluation Team. Therefore, TTI's qualitative analysis on the financial data that were provided, along with the lessons learned, can be applied in deployments and operations of other CV deployments in the future.

Because of the limited availability of financial information from the sites, the TTI CVPD Evaluation Team was unable to perform any qualitative financial analysis or modeling associated with the NYC deployment. However, as part of the stakeholder evaluation interview process, key stakeholders were asked to provide insight into the financial factors impacting the long-term sustainability of the deployment.(5) Interviews on financial and institutional topics were conducted with the NYC CVPD deployment team: 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.

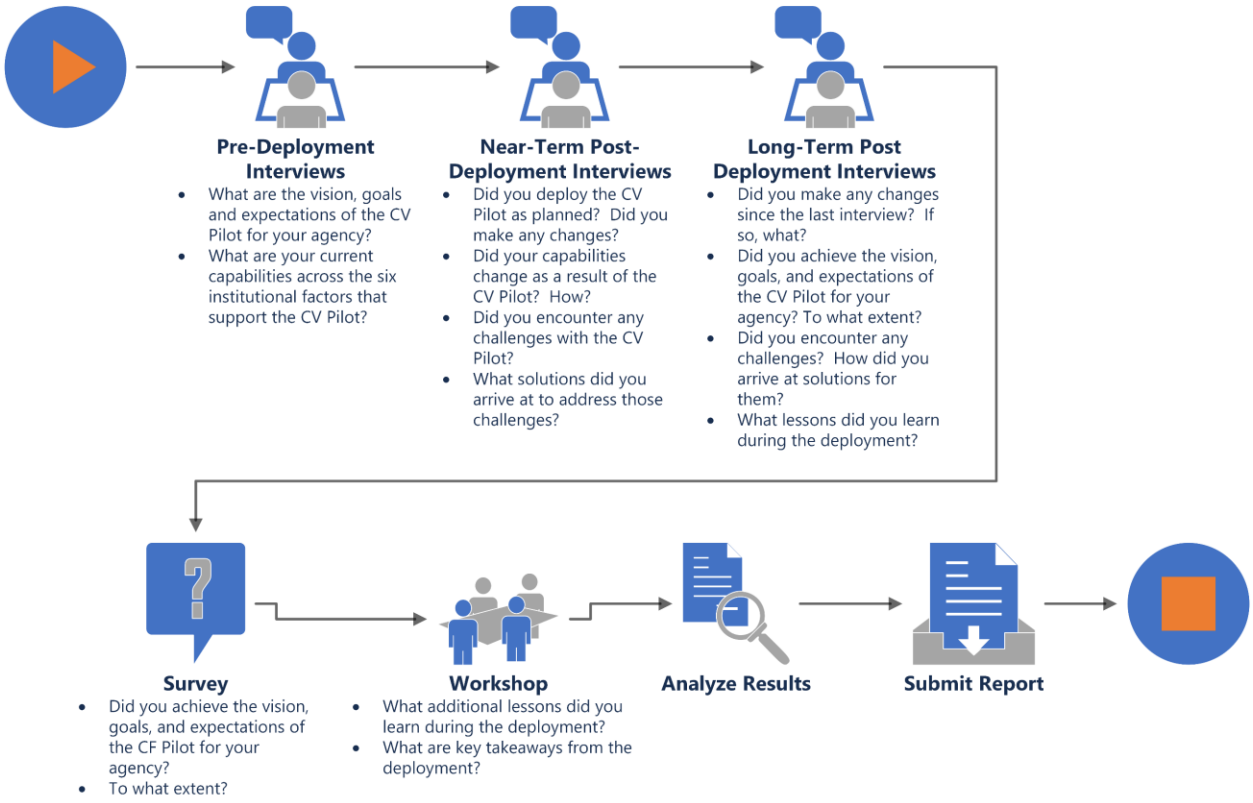
All interviews were conducted by telephone in October 2020, and each took about 45-60 minutes to complete; this was about 12 months later than originally planned. Their responses reflect the activity, adaptation, and learning leading up to operations and maintenance phase of the deployment.

As the deployment progressed, the NYC CVPD Team reported encountering several unexpected obstacles that potentially impacted the long-term financial stability of the deployment. The TTI CVPD Evaluation Team asked several critical key stakeholders to highlight some of the greatest factors impacting the financial stability of the deployment. The following provides a summary of these responses:

- Several individuals reported that the biggest financial impact to the deployment was the Federal Communications Commission's (FCC's) decision to reduce the available spectrum dedicated to CV technologies. The reduction in channel allocations, coupled with the National Highway Traffic Safety Administration's (NHTSA's) decision not to push forward with rulemaking on the use of CV technologies in vehicles, significantly changed the marketplace for CV technologies. Because of changes in the marketplace, the NYC CVPD reported experiencing difficulties in obtaining equipment and support from some technology vendors. In addition, there were sustainability impacts in that NYC DOT was reconsidering long-term plans to expand the deployment of the CV technologies after the pilot.
- Several NYC Stakeholders reported that NYC's contracting process impacted the schedule and project implementation. In interviews, several stakeholders mentioned that NYCDOT's procurement policies contributed to delays in initiating the deployment. The procurement processes of most government entities (not just NYCDOT) are based on "tried and true" technologies, not "bleeding edge" technologies like that deployed in the pilot. Procuring technologies at the scale required by the deployment required special procurement and contractual processes, and it took a while for NYC personnel to identify an appropriate procuring practice that they could use to secure the technologies. In the end, NYCDOT settled upon using a "negotiated procurement after a demonstration" approach for procuring the dedicated short-range communications (DSRC) equipment. NYC personnel did not have any previous experience using this procurement approach, which caused additional delays in getting the equipment procured. One stakeholder estimated all the administrative approval needed to use this approach added 18 months to the procurement timeline. Future deployments may want to consider procuring the equipment as a professional or technical services as opposed to a technology or device procurement.
- Several stakeholders expressed concern over the future scalability of the deployment. In interviews with the NYC CVPD stakeholders, one individual indicated, "We were able to implement 250 RSUs, but NYC has more than 13,000 intersections. To put the technology in all the intersections in the city would be a huge fiscal challenge. At one point, NYC had contemplated equipping more intersections as part of a capital program to rehabilitate several of the arterial roadways, but these changes in the deployment environment and the uncertainty of the communication may have altered those plans.
- The COVID-19 pandemic is having a long-term impact on the future viability of expanding the NYC CVPD. NYC was hit especially hard by the COVID-19 pandemic and the City's mitigation responses, and restrictions extended well past that experienced in other communities. The financial impact of the COVID-19 response is likely to have lasting effects on the NYC economy as the city continues to deal with financial and social issues generated by the pandemic. While NYCDOT made a commitment to operate and maintain the deployment through the evaluation periods, future support and expansion of the deployment may represent a fiscal challenge for NYCDOT given other priorities and limited resources within NYC.

Chapter 3. Institutional Factors

As illustrated in Figure 2, the TTI CVPD Evaluation Team broke down the institutional evaluation into a series of activities throughout the deployment period in an effort to extract critical information related to the institutional impact the deployments had in the region.[6] The overall intent was to establish a baseline or starting point for agencies prior to deployment, to identify the vision anticipated by the agencies after deployment, to assess to what extent the agencies achieved that vision, to learn how their capabilities and readiness changed as a result of the deployments, and to document the lessons learned throughout the entire deployment.



Source: Texas A&M Transportation Institute, 2022.

Figure 2. Diagram. Institutional Evaluation Framework.

The first phase in the framework was to collect a broad baseline understanding of the vision, goals, and expectations that the agency had for the CVPD. These elements of the project helped establish the metrics against which the agency could measure overall success and progress related to the CV deployment. Related to these elements, the TTI CVPD Evaluation Team worked with the agencies to identify their capabilities across the six institutional factors of governance, public partnerships, private partnerships, organizational efficiency, legislation, and industrial organization.

The second framework phase was intended to assess the near-term deployment to determine if the agencies deployed the CV technologies as planned and whether any changes were necessary throughout the initial deployment process. This phase also examined how agency capabilities might have changed as a result of the deployment and documented any challenges that arose and how the agency identified and implemented solutions to those challenges.

The third framework phase took a longer look at the deployments to determine if the agencies met the overall vision, goals, and expectations of the CVPDs. This phase documented any changes executed since the previous phase and described any challenges agencies encountered and how they were addressed. Finally, this phase worked to summarize any lessons learned during the deployment that could benefit other agencies considering CV technology deployments.

The fourth and fifth framework phases further examined the extent to which the deployments achieved the regional vision, goals, and expectations along with more detailed lessons learned and key takeaways. All the results from each phase were analyzed to establish the overall evaluation of institutional issues associated with the CV deployments.

NYCDOT was the principal project champion for this deployment and as such played a leadership role in the deployment. The NYC deployment was not a public-private partnership. NYCDOT was the prime contractor to the U.S. Department of Transportation (USDOT) and provided project oversight for the deployment. NYCDOT was supported by several subcontractors to NYC (or subcontractors to subcontractors).

For the deployment manager, the goal of the deployment was to enhance traffic safety to further NYC's *Vision Zero* initiative. To others, it was also being a part of the team working with NYCDOT 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 NYCDOT, and their support of NYCDOT in the CV Pilot was a natural progression. The technical vendors wanted to prove themselves (and their technology) in the Vehicle-to-Anything (V2X) space.

There was consensus among the deployment stakeholders that the organizational culture supported the deployment. The stakeholders were committed to completing the deployment and making the deployment work. One stakeholder commented, "NYCDOT 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 the things that they committed to doing is success."

Cooperation and Collaboration

Collaboration played a critical role in the success of the deployment. The NYC CVPD Team followed an extensive system engineering process to identify and mitigate as many deployment issues as possible, but still some existed. When these issues arose, the stakeholders had to band together and mutually identify solutions to make the deployment work as intended.

Outreach was another critical element of the deployment. The NYC CVPD Team conducted a lot of outreach activities at the beginning of the deployment. They produced a lot of good videos and conducted many demonstrations of the technology. Some sessions were open to people not directly involved in the pilot, such as different agency folks, owners of vehicles, and city planning personnel. Attendees were invited to get information and ask questions. The NYC CVPD Team used this as a way to gain acceptance and buy-in for future CV deployments. Different members of the deployment team also

participated in conferences to share what they were doing. NYCDOT conducted press releases and interviews to get information out about the pilot. Towards the end of the deployment, outreach was curtailed because of COVID-19.

Recommendations for Future Consideration

The following provides some general recommendations for consideration by future deployers to foster cooperation and collaboration among internal and external stakeholders.

- Foster collaborations with internal stakeholders (other departments) and external stakeholders. This might include developing a forum whereby stakeholders can meet regularly to discuss potential CV deployment activities.
- Update existing Regional ITS Architecture to reflect the data flows and devices installed and future planned deployments.
- Consider updating and refining communications, marketing, and outreach materials to reflect the current state and future planned deployments. The update should include information on the measured benefits from past phases and the anticipated schedule of deployment for each deployment phase.

Influencing Factors

The impacts of COVID-19 on the general economy of NYC have altered the priorities among decision-makers. Currently, funds have been allocated to maintain and operate the current deployment. Expansion of the deployment is still unclear and depends on several external factors, such as the following:

- Remaining uncertainty associated with the FCC's decision to reallocate a portion of the V2X communication spectrum for other purposes.
- The ability (and resources needed) to scale the deployment from 350 RSUs to over 13,000 intersections in the NYC area.

Some stakeholders mentioned the level of maturity of the applications to be an issue. From their perspective, "deployment ready" meant that components and applications were readily available on the market. In reality, the NYC CVPD Team expended a considerable amount of resources and effort getting the technology ready for deployment.

Several stakeholders cited privacy requirements as being a policy challenge. One person attributed this challenge to the fact that the CV industry was immature and meeting the agreed-upon privacy policy requirements (i.e., protecting personally identifiable information) was difficult. The NYC CVPD Team expended a lot of time and effort in figuring out how to process data, sanitize them, and obfuscate them to prevent any personal identified information from being exposed. Several stakeholders mentioned that the privacy requirement made the recruitment of fleets for the installation of aftermarket safety devices (ASDs) difficult. Several of the intended participating fleets wanted the data on their drivers (as a quid pro quo for participating), which NYCDOT could not provide.

Recommendations for Future Consideration

Issues with standards was also cited as a reason the technology was not deployment ready. The National Highway Transportation Safety Administration (NHTSA), ITS JPO, and other agencies may want to work with standard development organizations (SAE, ITE, AASHTO, etc.) to standardize the functional and

performance requirements of the applications to ensure interoperability across potential vehicle platforms and jurisdictions. USDOT may also want to work with these organizations to develop standardized testing procedure to ensure that application achieve a minimum performance standard. Future deployers may also want to develop requirements specifying the use of standardized applications in their deployments.

Policy/Legislative Changes

Most of the stakeholders agreed that the deployment was generally well-received by policy decision makers; however, some questioned the need for continuing to support the deployment given the uncertainty surrounding the V2X communications spectrum.

The NYC CVPD Team discussed several policy changes that had a significant impact on the development. Prior to initiating the CVPD, NYCDOT believed (as did many others) that NHTSA was on the verge of mandating V2V communications in all vehicles to support safety applications. This would have led to widescale deployment of CV applications in vehicles; however, the proposed rulemaking did not happen. As a result, many potential stakeholders no longer saw the value in equipping their vehicles.

Many stakeholders cited the change in spectrum allocation in the 5.9 GHz band as a significant policy change that impacted the deployment. This policy change significantly altered the V2X communications ecosystem and marketplace. Some stakeholders feared that the decision might cause larger original equipment manufacturers to delay adopting the technology for several years, creating a lack of interest among device suppliers and application developers.

Recommendations for Future Consideration

Because of the FCC's change in the DSRC spectrum, future deployers will need to consider replacing the current DSRC-based devices with Cellular Vehicle-to-Everything (CV2X) technology. This would include replacing the RSU at each intersection and the OBU in the deployment fleet. Future deployers will need to develop specifications, requirements, and equipment selection criteria to support the procurement of CV2X technologies to replace the DSRC unities in the field. Future deployers should also consider conducting comparison testing of the various CV2X technologies applying the testing and procurement lesson learned from their deployment. Future deployers may also want to consider narrowing the deployment focus to those applications likely to have the greatest chance of improving safety and mobility in the near-term while other applications mature.

The need for policies or standards to address interoperability of CV systems was also raised. To achieve fully interoperable deployments, the industry should begin thinking about the standards that need to be adopted. These standards should go beyond just the sharing of data and should include how the applications function and perform under different operating conditions. As security certifications are needed nationwide to allow applications to function across state lines, USDOT may want to facilitate and explore how security credentials can be shared interstate. The USDOT may want to conduct an analysis of other industry sectors to examine how credential systems may be shared across states and regions and to identify approaches they use to leverage information share.

Organizational and Technical Challenges

Nearly all interviewees indicated that the commitment of the external stakeholders changed significantly over the lifespan of the project. Originally, the pilot had commitments from the taxi industry, a private commercial delivery company, and a transit service provider to serve as users of the technology. As a result, the initial project planning resulted in a more robust deployment than what was achieved. The NYC CVPD Team cited a number of potential reasons for this change in commitment by some of the external stakeholders. For the private fleet vehicles, uncertainty about the DSRC spectrum made it difficult for some stakeholders to invest in installing the devices in their fleet.

Another cited reason for the change in stakeholders was the lack of incentives for the private sector to participate. Private sector stakeholders wanted access to the performance data to monitor the drivers; however, the deployment's privacy requirements prevented NYCDOT from allowing this to occur. The change in the vehicle-for-hire marketplace was also cited as a reason for the lack of participation by private fleet operators. The economic impacts of competition with Transportation Network Companies and the reduction in passengers due to COVID-19 changed the vehicle-for-hire ecosystem. The pilot was trying to recruit taxis because they were starting to fight for their survival. Now, a handful of taxis have ASDs installed—all pre-COVID.

The lack of participation by public transit stakeholders was primarily due to the impact of the COVID-19 pandemic. The COVID-19 pandemic significantly altered public transit usage and availability in NYC. This market is just now only beginning to recover.

In terms of technical challenges, many stakeholders cited accuracy with positioning systems as being the most significant technical challenge. One stakeholder noted, "None of the applications work if you can't pinpoint location." The lack of positioning accuracy was due in part to NYC's geography, which is more complex than other pilots, with urban canyons. The team did some work to improve the location accuracy (via RSU triangulation method); however, more work is needed to overcome this technical challenge. Failure for applications to work is often rooted in not being able to get an accurate position. NYC made strides in improving location accuracy in urban canyons, but the issue has not totally resolved.

Getting the over-the-air software updates to vehicles through DSRC was a challenge. The CVs were more dispersed than expected; not as many vehicles as desired were roaming the city. The updates were hindered by low-level bugs, such as in internet protocol drivers. Vendors bought libraries, but the libraries had bugs in them (e.g., OBU was not throwing away corrupted packets). The team also found interference between RSUs to be another source of issues with over-the-air updates. The team needed to prioritize different data communications over DSRC (e.g., data upload, Basic Safety Messages (BSM), security credential management communications). It was difficult to manage prioritizing one kind of communication over another.

There was consensus among the stakeholders that the current CV applications were not mature enough for widespread deployment. Getting the technology ready for deployment was resource intensive. Issues with standards was also cited as a reason the technology was not deployment ready.

The pilots identified gaps in standardization, but these gaps have not been fully resolved yet. Other deployments need standards for messages, data dictionaries, etc. so they end up borrowing the pilot deployment specs. As standards are developed, standards and specifications will likely deviate from those used in the CVPD.

Several individuals mentioned that many of the applications were not truly deployment ready, and the NYC CVPD Team invested a considerable amount of time and resources in making the technology "work" for the deployment. Future deployers should be aware that the steep learning curve to get the technology operational can lead to cost overruns and delays, and plan accordingly.

Recommendations for Future Consideration

To equip every intersection requires a significant investment. Future deployers may want to consider developing a phased deployment plan for equipping other key intersections and corridors of regional significance with CV technologies the deployment over multiple years. This would require future deployers to develop an investment plan for the program identifying the general funding levels, resource needs, and funding sources to support a sustainable program by major function over a 5- or 10-year period.

Future deployers may also want to consider developing a programmatic approach to expanding the system beyond the deployment boundaries. Other suggested actions that future deployers may want to consider include the following:

- Developing a staffing plan to address the additional maintenance needs required to insure the as the system expand, adequate maintenance personnel as available to maintain the deployment in a good state of repair.
- Developing processes for managing digital libraries associated with deployment intersections. This would include integrating digital libraries as part of an asset management system whereby digital configuration and MAP information can be retained and managed.
- Establishing process and procedures for monitoring and tracking the life cycle of deployed devices and applications.
- Developing performance baselines that could be used to assess future deployments.
- Developing a method for prioritizing the order of deployment for these criterial intersections.
- Developing a comprehensive staffing plan to address the additional maintenance needs required to insure the operations.

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