



## Executive Briefing

### Connected Vehicle Pilot Deployment Program

#### Highlights

- In June 2018, the three Connected Vehicle Pilots successfully demonstrated cross-site over-the-air interoperability among six participating vendors.
- Following an intensive two-year period spent designing and building the connected vehicle systems, the CV Pilot sites are now in the final stages of preparation for full-scale deployment of roadside infrastructure and equipping of vehicle fleets.

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*This brief is based on past evaluation data contained in the ITS Knowledge Resources database at: [www.itskrs.its.dot.gov](http://www.itskrs.its.dot.gov) The database is maintained by the USDOT's ITS JPO Evaluation Program to support informed decision making regarding ITS investments by tracking the effectiveness of deployed ITS. The brief presents benefits, costs and lessons learned from past evaluations of ITS projects.*



## Connected Vehicle Pilot Deployment Program

### Introduction

Connected vehicles (CVs) are poised to transform our streets, communities, and personal lives. But first, we must tackle deployment challenges head on and provide interested regions with examples of success stories and champions. The U.S. Department of Transportation (USDOT) is taking on this challenge by investing in a regional pilot deployment program that is not only accelerating deployment but also uncovering what barriers remain and how to address them. This program will help ensure that this revolutionary technology can meet its fullest potential in the near future.

In September of 2015, USDOT selected New York City Department of Transportation (NYCDOT), Wyoming Department of Transportation (WYDOT) and Tampa Hillsborough Expressway Authority (THEA) as the recipients of a combined \$45 million in federal funding to implement a suite of connected vehicle applications and technologies tailored to meet their region's unique transportation needs. These pilot sites will help connected vehicles make the final leap into real-world deployment so that they can deliver on their promises of increasing safety and improving mobility. Moreover, these sites will lay the groundwork for even more dramatic transformations as other areas follow in their footsteps.

The sites are conducting the pilots in three Phases. Under Phase 1, the sites spent 12 months preparing a comprehensive deployment concept to ensure rapid and efficient connected vehicle capability roll out. This comprehensive concept included identifying specific performance measures, targets and capabilities associated with performance monitoring and performance management.

*Asked if this technology is the most exciting thing in his 30-year career, "I would definitely say so, definitely. This is game changing [1]."*

*– Mohamad Talas,  
NYCDOT*



## Introduction (continued)

In Phase 2, the sites embarked on a two-year phase of activity to design, build and test the nation's most complex and extensive deployment of integrated wireless in-vehicle, mobile device, and roadside technologies. In Phase 3, the tested pilot deployment applications and technologies will be placed into operational practice, where the safety, mobility and environmental impact of the deployment will be monitored and reported on a set of key performance measures.

The Wyoming CV Pilot will focus on the efficient and safe movement of freight through the I-80 east-west corridor, which is critical to commercial heavy-duty vehicles moving across the northern portion of our country. The **Wyoming Department of Transportation (WYDOT)** CV Pilot site focuses on the needs of the commercial vehicle operator in the State of Wyoming and will develop applications that use vehicle to infrastructure (V2I) and vehicle to vehicle (V2V) connectivity to support a flexible range of services from advisories including roadside alerts, parking notifications and dynamic travel guidance.



A member of the WYDOT installation crew installs the on-board units.

This WYDOT CV Pilot is expected to reduce the number of blow-over incidents and adverse weather-related incidents (including secondary incidents) in the corridor to improve safety and reduce incident-related delays. WYDOT will develop systems that support the use of CV Technology along the 402 miles of I-80 in Wyoming. WYDOT will equip around 400 vehicles, a combination of fleet vehicles and commercial trucks with on-board units (OBUs), at least 150 of which would be heavy trucks that are expected to be

regular users of I-80. In addition, of the 400 equipped-vehicles, 100 WYDOT fleet vehicles, snowplows and highway patrol vehicles, will be equipped with OBUs and mobile weather sensors.

The **New York City Department of Transportation (NYCDOT)** leads the New York City Pilot, which aims to improve the safety of travelers and pedestrians in the city through the deployment of V2V and V2I connected vehicle technologies. NYCDOT's planned deployment provides an ideal opportunity to evaluate connected vehicle technology and applications in tightly-spaced intersections typical in a dense urban transportation system and is anticipated to be the largest connected vehicle technology deployment to date. The NYCDOT CV Pilot Deployment project area encompasses three distinct areas in the boroughs of Manhattan and Brooklyn. Approximately 8,000 vehicles (comprising 3,200 taxis, 3,200 Department of Citywide Administrative Services (DCAS) vehicles, 700 Metropolitan Transportation Authority (MTA) buses, 700 NYCDOT fleet vehicles and 170 New York City Department of Sanitation (DSNY) vehicles) that frequent these areas will be outfitted with the CV technology. As a city bustling with pedestrians, the pilot will also focus on reducing vehicle-pedestrian conflicts through in-vehicle pedestrian warnings and an additional V2I/I2V project component that will equip approximately 100 visually challenged pedestrians with personal devices that provide audible alerts to orient them and assist them in safely crossing the street at signalized intersections.



NYC's mobile pedestrian application being tested at the confined *Safety City* lot in Manhattan.



## Introduction (continued)

The **Tampa Hillsborough Expressway Authority (THEA)** CV Pilot will employ innovative V2V and V2I communication technology to improve safety and traffic conditions in downtown Tampa. The pilot seeks to address peak rush-hour congestion in downtown Tampa, reduce the risk of collisions by detecting and warning wrong-way drivers before they get on the expressway, enhance pedestrian safety at signalized intersections, provide transit signal priority to help keep buses on schedule, and help to reduce conflicts with streetcars by deploying devices that enable them to communicate wirelessly with other connected vehicles and pedestrians. The THEA CV Pilot will employ Dedicated Short-Range Communication (DSRC) to enable transmissions among approximately 1,600 cars, 10 buses, 10 trolleys, 500 pedestrians with smartphone applications. To support this initiative, THEA will be working with their primary partners, The City of Tampa (COT), Florida Department of Transportation (FDOT) and Hillsborough Area Regional Transit (HART) to create a region-wide Connected Vehicle Task Force.



A driver of a Tampa-connected vehicle receives a side collision alert in the vehicle's rearview mirror.

## Best Practices

During the past two years, the CV Pilot sites have employed the systems engineering process and developed a concept of operations, high-level design, and detailed design and implementation plans. This experience has enabled the sites to encounter first-hand the challenges associated with the deployment of this technology, including, but not limited to:

- Updates to the standards and modifications to the device specifications.
- Deployment of the Security Credential Management System and changing requirements for its use (credential management services are now being supported by a commercial entity rather than USDOT).
- Development of Over-The-Air (OTA) firmware updates for the OBUs using DSRC.
- Development of a central data management system. Testing and tuning of V2V and V2I safety applications.
- Device certification by OmniAir Consortium (this has been a learning experience for the vendors since it has taken time to stabilize the testing procedures, test equipment, and test environment).
- Development of OBU installation procedures which varies by vehicle model and year.
- Obtaining FCC licensing for the 500+ RSUs being deployed by the three sites (NYC alone had to apply for more than 1,000 RSU licenses).
- Various procurement and installation contractual management issues due to the desire for multiple vendors, the required device development, and the uncertainty of specific vehicle installation procedures.
- Development of a testing environment—for the technology, the installation, and troubleshooting the radio frequency field conditions—which have experienced interference and GPS jamming.

Below the sites offer insights on how they overcame some of their most difficult technical challenges faced to date ([2019-00871](#)).

**If using Dedicated Short-Range Communications (DSRC), consider purchasing interference tracking equipment to detect potential interference from other users in the 5.9 GHz band that can compromise data exchange.**

The FCC originally allocated the 5.9 GHz band strictly for DSRC-based ITS applications. However, unbeknownst to THEA, in 2013, the FCC began allowing unlicensed devices to share the spectrum with primary users as long as they were not found to be interfering with the primary DSRC users.

During acceptance testing, THEA detected and tracked down an interference on their DSRC communication channels coming from a local amateur radio operator.



## Best Practices (continued)

While the HAM radio could not receive DSRC radio messages due to the far lesser range of DSRC, THEA's DSRC radio would receive the ham radio messages, causing the radio to consider the channel "busy" and not "clear to send". The additional signal on THEA's channels impacted the performance of their equipment in terms of data exchange and back haul speed, with testing indicating a degradation in data uploads by up to 50%. Upon review of these findings, Florida Department of Transportation, who operates the state-wide FCC licensing, ordered the amateur radio operator to vacate the channel. Through this experience, the THEA team learned that HAM Operators are "licensed" in the spectrum and thus should be approached as secondary, "licensed users" and not "unlicensed intruders". Due to the larger scale of the NYC deployment and thus the increased likelihood for interference, the NYC team invested in the purchase of sophisticated interference checking and RF spectrum analysis equipment.

**Assess vehicle OBUs' ability to monitor its position accurately in dense urban environments to determine whether a correction is needed.**

New York City is known for its "urban canyons" which provide a challenging environment for GPS technology that is often limited to open sky. The current standard (J2945/1) requires the vehicle to cease transmission if it loses GPS "lock," which is not practical in a dense urban environment. As a result, additional techniques were required in the OBUs positioning algorithms to provide the accuracy needed for many of the V2V and V2I safety applications to function properly. The NYC vendors were required to augment their location determination algorithms to include inertial navigation, map matching, tethering to the vehicle, and RSU triangulation. Preliminary testing indicated that this combination of supporting techniques, with the proper algorithms and tuning, will meet the applications' stringent location needs.

**Refine proper antenna placement to reduce communications interferences.**

The location of the antenna on the vehicle is critical to ensure continuous wireless communication without loss of

signal strength. The New York City and Tampa teams found that for light-vehicles, antennas mounted near the rear-center of the rooftop was most ideal. However, large vehicles, such as the semi-trucks that the WYDOT pilot installed onboard units on, often have "self-blocking" physical elements that obstruct the vehicle's own DSRC antennas from direct line of sight with other vehicles. This resulted in "shadows" for the Wyoming vehicles that prevented remote vehicles from properly communicating with the trucks. To alleviate this effect, the Wyoming team worked with USDOT's communication experts to perform numerous tests in Wyoming and at the Aberdeen Proving Grounds. The testing concluded that the effect of the DSRC shadows could be best alleviated by mounting the antennas on the side mirrors of the semi-trucks.

*"This is quickly emerging technology. And that's why we're documenting as much information as possible for other states to help them figure out infrastructure [2]."*

*– Vince Garcia, WYDOT*

## Case Study

**CV Pilots' Interoperability Test marks watershed moment for connected vehicle technology [\(2018-00831\)](#).**

To pave the way for a nationwide deployment, a major long-term goal of the CV Pilot Deployment Program is for the connected vehicle devices and equipment to be interoperable, meaning that they would be able to operate as designed anywhere in the country, regardless of where they were built. The cooperative agreements between the USDOT and the CV Pilot Deployment Sites included a requirement for the CV Pilot sites to perform an activity that showed the devices from the three sites being interoperable. To meet this requirement, the USDOT and CV Pilot sites agreed to perform an Interoperability Test that would test: 1) interactions between different sites' OBUs and (2) interactions between selected OBUs and RSUs.

Over a period of several months, the CV Pilot sites collaborated to harmonize the data elements that would make such interactions possible. The CV Pilot sites next



## Case Study (continued)

worked with the USDOT and its support contractor to develop a plan to conduct an Interoperability Test that would take place at Turner-Fairbank Highway Research Center (TFHRC) in McLean, Virginia from June 26-28, 2018.

Planning for the testing event was jointly led by the CV Pilot sites in coordination with TFHRC and USDOT staff. TFHRC and its Saxton Transportation Operations Laboratory (STOL) contractor provided support to the CV Pilot sites as well as the facility and supporting equipment for the testing. This support included installing the same RSU models used by the sites to allow them to replicate their configurations, installing OBUs from the sites in vehicles and providing trained drivers to operate the vehicles during the interoperability test runs. In addition to the USDOT and sites, representatives of the CV Pilots' Independent Evaluation (IE) team were present to observe in support of the broader independent evaluation effort. Six TFHRC-provided vehicles were used for the testing with each vehicle being outfitted with an OBU from one of the CV Pilot site's OBU vendors – Tampa (3), New York City (2) and Wyoming (1). Additionally, the sites each loaded the TFHRC-supplied RSUs with their own software.

***“The data generated from these CV deployment projects will show that A) it works, or B) it doesn't, which is just as important [3].”***

***– Bob Frey, THEA***

The systems' capabilities were demonstrated in staged scenarios on TFHRC's closed road course. In total, 102 interoperability test runs were conducted for four test cases – FCW, IMA, EEBL and reception of SPaT/MAP messages. Data was downloaded off of the OBUs immediately following each test run, with nearly 5 GB worth of data being generated over the test period. This data will be uploaded to the USDOT's Secure Data Commons (SDC) for further analysis to help identify lessons learned that can be gleaned for future testing. Overall, the three-day testing event was a major success that went above and beyond the event's original testing objectives, with time allotted on the last day for some impromptu tests by the sites. Results of the testing indicated successful transfer of messages between the six vehicles fit with

devices from five different OBU vendors. Out of the five vendors, four utilized DSRC and one used both DSRC and SiriusXM Radio. Additionally, equipment from New York City and Tampa's vendors demonstrated the successful transfer of messages between the site-configured RSUs and the sites' OBUs. The event was lauded by many for being well-planned, well-organized, and well-executed, with some attendees reporting that it was the most successful connected vehicle testing event they had ever participated in.



Group shot of the Interoperability Test participants pictured with the logos of the three CV Pilot sites: New York City (left), Tampa (middle) and Wyoming (right).

## References

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