I-95 TRUCK PARKING DEMONSTRATION SYSTEM
SUMMARY OF KEY LESSONS LEARNED
REVISED – DECEMBER 2018

Introduction/System Overview:

When the I-95 Corridor Coalition initiated its demonstration project, reliable truck parking space monitoring systems had not yet been successfully deployed in outdoor lots anywhere in North America. Technologies then available to detect empty parking spaces in indoor garages had limited applicability to real-time truck parking applications. Other demonstration efforts, including several pilot tests by the Federal Motor Carrier Safety Administration (FMCSA), got underway shortly after start-up of the Coalition's project. While the Coalition's initial objective was to make use of existing off-the-shelf products, adapting those products to the project requirements proved exceedingly challenging. Practical, but essential, issues involving technology – such as getting power to the hardware installed in parking lots and communicating remotely with that hardware – presented challenges beyond what was initially anticipated. Additionally, a range of institutional barriers needed to be overcome to ensure successful system deployment.

I-95 Corridor Coalition's truck parking project focused on implementing a production-level, real-time system that showed: (1) technology can accurately identify available parking spaces in a commercial vehicle rest area or parking lot; (2) parking data can be collected, processed, and compiled in real-time; and (3) the data can be communicated to drivers in a safe, timely, useful, and efficient manner. During the demonstration pilot's initial testing phase, truck parking technologies were successfully deployed at public rest areas in Maryland and Virginia. Ultimately, the project implemented a real-time truck parking system on a corridor of five public rest area sites along I-95 and connector interstate I-64 in Virginia.

In addition to achieving the program objectives noted above, the system satisfied a series of design and development principles specified near the outset of the project. These principles stated that the system needed to be:

- Safe,
- Accurate,
- Timely and reliable,
- Seamless and interoperable,
- Without cost to users,
- Modular,
- Flexible and adaptable, and
- Scalable to different lot sizes and configurations.

Project deployment and demonstration was performed in three primary phases, as follows:

- **Detection Technology Pre-Testing.** A truck parking occupancy detection technology testbed was set up at the Chesapeake House Rest Area in Maryland. Multiple technologies were installed and tested at the site prior to Tier 1 deployment.
- **Tier 1 Deployment.** The Ladysmith Rest Area NB in Virginia and the Maryland Welcome Center NB in Maryland were selected as the Tier 1 sites to represent the multi-state nature of this project and demonstrate a data-dissemination system that was seamless and interoperable. These sites were fully outfitted with the space-by-space in-pavement radar-based detection system, sensor peripherals, and CCTV cameras for monitoring purposes. The Tier 1 field system was also integrated with the truck parking central platform.
- **Tier 2 Deployment.** The following sites were selected jointly by the Virginia Department of Transportation (VDOT) and the Coalition for Tier 2 deployment and integration. The rationale for

selecting these sites was to outfit a cluster of parking lots for truckers traveling northbound on I-95 in Virginia, as well as truckers traversing east and west on I-64 in close proximity to I-95:

- Carson Safety Rest Area, Carson, VA – I-95 NB, MM 37.
- New Kent East Safety Rest Area and Welcome Center, New Kent, VA – I-64 EB, MM 213.
- New Kent West Safety Rest Area, New Kent, VA – I-64 WB, MM 213.
- Ladysmith Safety Rest Area, Caroline County, VA – I-95 NB, MM 107.
- Dale City Safety Rest Area, Dale City, VA – I-95 NB, MM 154.

The deployment phase of this project was completed in March 2018, with the responsibility for continued operation and maintenance of the real-time truck parking system transitioned from the Coalition to the Virginia Department of Transportation (VDOT). VDOT continues to successfully operate and maintain the Virginia sites.

This document highlights key "lessons learned" over the life of this demonstration project by the Coalition, its partners, and its contractor support team, led by Kapsch TrafficCom USA. These insights and observations were gleaned from our real-world, "boots-on-the-ground" activity over the life of this contract. The "lessons" are organized by their dominant area of focus: technical, operational, and institutional.

System Overview

Figure 1 depicts the architecture for the existing Truck 'N Park System. It consists of three major subsystems as follows:

- **Data-Collection –** The truck parking system uses in-ground, ultra-low power wireless radar sensors as the primary component in collecting the raw vehicle occupancy data in designated truck parking areas. One sensor is used for each parking space. The data from these sensors is wirelessly sent to the local access point controller or repeaters. Depending on the layout and size of each parking lot, one or more repeaters are used. The access points and repeaters are mounted on poles in the parking area. A configurable amount of time after a vehicle parks or exits a space, the system updates the space occupancy status change and communicates it to the data integration system via the access points and cellular modems. Cameras are installed at the site to visually verify the sensor data.
- **Data-Integration –** The system's data-integration component is responsible for key data-integration and processing functions. Primary capabilities include retrieving raw occupancy data from each monitored truck parking area, calculating parking availability by area, and forwarding the parking availability data to dissemination outlets. This subsystem includes software and hardware at a central location to provide the following functionality:
    - **Communications** – The communications application communicates data from the field equipment through use of cellular technology. It collects raw parking space count data and sends it to the system's server application.
    - **Database Management/Application Processing** – This server receives and processes the raw parking space availability counts from the communications system. After receiving the raw data, it stores it in a database for a configurable time interval.

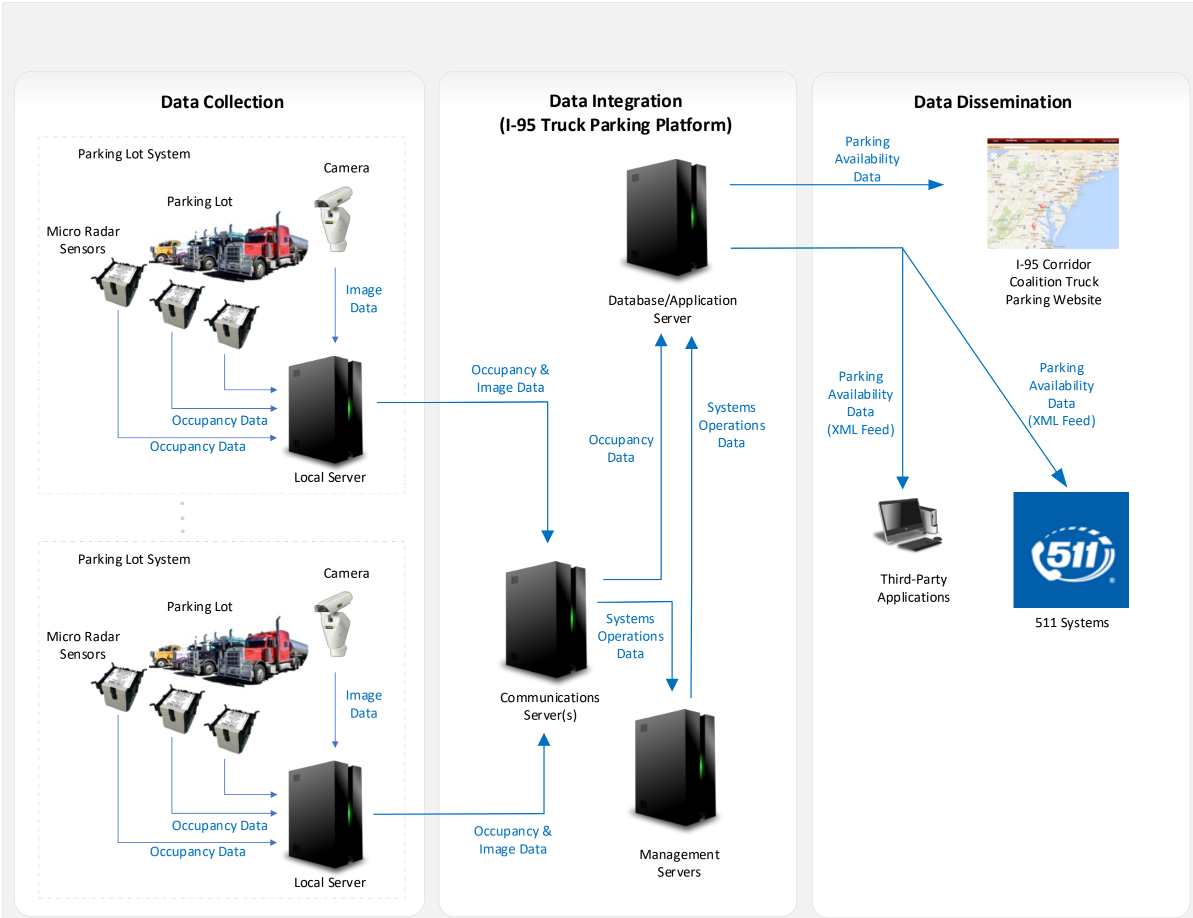

Figure 1. System Overview Diagram

- **External Data Feed –** The external system data feed API provides parking space inventory and available parking space information in a data stream for use by authorized users.
- **Overall Management/Operations** – Functionality exists to support management and administration of the system. These functions include:
  - Monitoring the general health of the system (e.g., to ensure that data flows between system components are operating properly).
  - Notification and reporting of system alarms/failures.
  - Data archiving and reporting/querying capabilities
  - Adjusting system configuration parameters (e.g., to modify frequencies in receiving raw occupancy data and disseminating parking availability data to external systems, or to modify the configuration of detection zones for data collection).
  - Restoring and backing up the system.

- **Data Dissemination –** The truck parking system is capable of providing near real-time truck parking availability information via a range of mechanisms and media in order to ensure that the information is available to as many truckers as possible. The primary methods include:

- **Truck Parking Website** – For pre-trip planning, a dedicated website is available to enable truck operators to view parking availability information by location. Links to local and state transportation agencies traveler information websites is also available.
- **External Data Feed** – A standardized data feed is established to provide near real-time parking availability data to transportation agencies and other information service providers for display directly from their own websites and other dissemination outlets. The guidance documentation for organizations wishing to receive the data is posted on the Truck Parking Website.
- **Interactive Voice Recognition (IVR) –** Automated parking availability information was provided through an IVR system with easy-to-use prompts for identifying desired parking locations. Truckers could also setup an automatic callback to receive on parking space status at the specified lots as they progressed through their routes. Emphasis is placed on using the IVR telephone system with a blue-tooth compatible, hands-free phone for safety reasons. The IVR system was discontinued in the latter part of the project due to limited usage.
- **511 and Portable Dynamic Message Signs –** In the latter part of the project, VDOT integrated the XML data feed from the Coalition's platform to display data on dedicated portable message signs placed upstream of the 5 sites outfitted with truck parking technology and on the *511 Virginia* website.

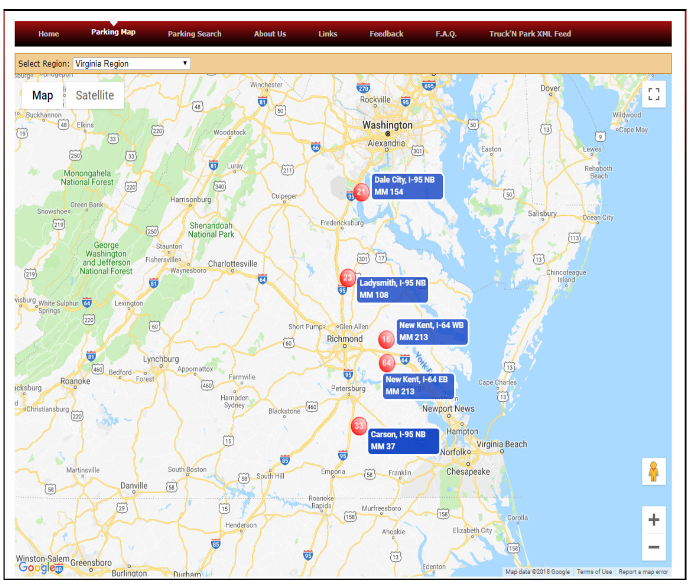

Figure 2. I-95 Coalition's "Truck N' Park" Website (Left) and Portable DMS (Right)

Technical Lessons

General Note: Over the life of this project, a panoply of potentially pertinent truck parking occupancy detection technologies and applications routinely emerged and evolved. While this frequently had the effect of opening new technological vistas and opportunities to the Coalition team, it was also challenging insofar as the development team often felt compelled to chase after moving technology "targets." Ultimately though, given this was a real-world deployment and demonstration project, the optimal technologies and procedures meeting the project requirements at the time decision-making was needed had to be selected, even though technology would continue to evolve. It was impractical to choose technologies that might mature several years hence; what was needed were technologies that would perform satisfactorily at the time of selection. This important fact impacted the choice of the parking space occupancy detection technology. It also shaped decisions on mechanisms for delivering the parking lot occupancy information to truckers.

Key technical lessons learned are identified and examined below:

System modularity is essential. One key tenet of the Coalition's system design was modularity. The data-collection, data-integration, and data-dissemination subsystems were designed to be technology-agnostic and modular. This was done, in part, so that future advancements in data-collection technology would not require major redevelopment of the data-integration and data-dissemination subsystems. It was also done so that practitioners could use elements of the Coalition system alongside components from other systems. For example, VDOT was able to display the parking information on portable dynamic message signs and share it on *511 Virginia* without the Coalition having to make major changes to the data-integration or data-dissemination subsystems.

A stand-alone Truck Parking platform was developed with the intent to provide a standardized data feed to State DOTs for integration with their advanced traffic management systems (ATMS) and traveler information systems. This helped streamline the system development process, allowed for the parking platform requirements to be purely focused on project needs, and minimized the level-of-effort involved in dealing with ATMS integration and data feed requirements in multiple states.

Information on truck parking space availability must be communicated to drivers safely. During the system design phase, the U.S. Department of Transportation launched a national driver distraction education campaign. Consistent with this campaign, the Coalition and its contractor team revisited the data-dissemination components of the project's concept of operations (ConOps) to ensure that the Coalition's distribution of truck parking information would not contribute to driver distraction. Consequently, several adjustments were made to the ConOps – and the associated technologies under development – to optimize driver safety. For example, the Coalition decided it would not develop a mobile website and app for data dissemination. On the other hand, multiple safety features were added to the system, including user-friendly decision-tree menus and voice prompts, menu options with automatic default values, and automatic call-back "abort" on the interactive voice recognition (IVR) system after several rings.

Key elements of the system design were developed using inputs from truckers. The Coalition conducted a user forum with a panel of commercial vehicle drivers to walk through the public website and IVR system. The user session was convened in Louisville with eight driver "captains" from the *America's Road Team Program*, sponsored by the American Trucking Associations (ATA), along with additional representatives from ATA and the Coalition. *America's Road Team* is a national public outreach program led by a small group of professional truck drivers who share superior driving skills and superlative safety fitness records.

The primary aim of the session was to demonstrate and gather Road Team Captain inputs on the two data-dissemination interfaces that were under development to provide truck parking data to truckers – the website and interactive voice recognition system. The second objective was to ensure that over-the-road usage of the system minimized driver distraction and optimized safety. Key topics covered included pre-trip planning, timing of truckers' rest periods and breaks, conveyance of information elements to truckers (directions to lot, lot amenities and attributes, etc.), parking at Truck Weigh and Inspection Stations (TWIS), driver distraction, and driver privacy concerns.

Overall, the Road Team Captains were fully supportive of the Truck Parking project and were comfortable with the demonstrated interfaces. The drivers provided valuable insights to improve the website and IVR interfaces. Insights and inputs gathered from these drivers were extremely useful in enhancing the safety, look, and feel of the system for users.

The Coalition's system required the use of space-by-space monitoring to meet the system accuracy and reliability requirements. Two approaches – space-by-space detection and entry-exit counting – were considered for the project. Accuracy, costs, and overall sustainability were the major considerations for determining the suitable approach to meet the project objectives. The general outcomes from testing and field observations of the approaches are as follows:

- Space-by-Space Counting:
  - This approach is generally more accurate than entry-exit counting.
  - Minimal resets and recalibration are required.
  - Although accurate, the space-by-space approach only provides parking lot availability for the designated spaces in the lot, i.e., trucks parked in undesignated spaces and on the off- and on-ramps of the lot cannot be detected.
  - Geometric changes in the striping and layout of the parking spaces typically necessitates deployment of new sensors if an in-pavement detection technology is used.
- Entry-Exit Counting:
  - The system only provides an estimate of the total number of trucks in the lot, including non-designated spaces such as parking lot shoulders.
  - The system can be prone to cumulative errors and typically requires daily adjustments or "resets."
  - The resets require complete CCTV coverage of the parking area to accurately count the total number of trucks in the lot; this may be expensive to install and labor-intensive to maintain and operate.
  - Manufacturer-supplied machine vision algorithms are normally not fine-tuned for truck parking applications. It can be time-consuming to identify and address the machine vision issues in coordination with camera manufacturers.
  - Tree shadows and other moving objects can interfere with vehicle detection and result in false positives.
  - Wide ramps sometimes mean that trucks inadvertently bypass the detection zones without being counted.
  - Not all vehicles entering the rest area are there to park.
  - Most rest areas have common entry and exit ramps for commercial and non-commercial traffic. Additional software development customized to each lot is therefore needed to classify vehicles and obtain accurate counts in mixed traffic.
  - Every truck entering a parking area may not park in a designated parking space, so the system cannot be used to disseminate parking information on the occupancy of specific spaces to truckers.

Optical imaging technology (at the time of our tests) lacked accuracy and software APIs for truck parking detection. Extensive testing of detection technologies was performed at the Chesapeake House Travel Plaza testbed on I-95 in Maryland prior to the Tier 1 system deployment. Optical imaging was initially tested as the technology of-choice for real-time parking data collection at the sites. During space-by-space and entry-exit testing, it was observed that fog, pole expansion due to changes in air temperature, and pixel separation between trucks significantly impacted the accuracy of the cameras. In addition, the cameras lacked off-the-shelf software back then to support truck parking applications. Similar issues were encountered with the testing of laser sensors.

In-pavement radar showed higher accuracy than magnetometer sensors. After additional research, two in-pavement sensor technologies were identified – magnetometer and radar. Both sensors were deployed and tested extensively at Chesapeake House to identify a technology to meet the project objectives. The observations from the testing were as follows:

- The radar sensors met the accuracy requirements of the detection system. Testing included deployment of both dual-lobe and single-lobe sensors. The sensors were placed in various locations within a space to identify the optimal layout of the equipment. This helped in balancing the relationship between accuracy and cost (e.g., would deploying two sensors or dual-lobe sensors in a single parking space substantially improve accuracy?). The testing did not justify the use of two sensors or dual-lobe sensors in a single space.
- The magnetometer sensors were less accurate than the radar sensors, and relatively more expensive. Also, the sensors tested were procured from a company in Europe which required retrofitting the antennas to work with the required frequencies in the US. The manufacturer-recommended epoxy had to be ordered from Germany causing major cost and logistical ramifications.
- The testing revealed that conditions such as fog and lighting (night/day) did not impact the performance of the in-pavement sensors.
- The testing indicated some degradation of performance under snow and heavy-rain conditions, but this decline was judged to be manageable.

Based on the field testing, the Coalition moved forward with implementing space-by-space, in-pavement radar-based sensor technology for detecting truck parking occupancy at the Tier 1 and Tier 2 sites. A single in-pavement sensor was installed in each space at the selected sites. Additional insights gleaned from the sensor deployment experience include the following:

- The sensors have a small footprint in the pavement and are easy to install.
- The sensors are wireless and battery-powered. This eliminates the need for running communications and power from the cabinet to each sensor.
- The radar technology in the sensor minimizes false positive detections due to the sensor detecting trucks in adjacent spaces.
- The sensor accuracy was retested after Tier 1 deployment at Ladysmith. Conditions such as fog and lighting (night/day) did not impact the performance of the in-pavement sensors. The sensors were 95.2% accurate in clear conditions. The testing did, however, indicate deterioration in sensor performance to 92.1% under heavy-rain conditions.
- The sensors use radar as the primary detection technology. However, due to deterioration of radar performance during snow conditions, an in-built magnetometer is used for detection during snow; here an accuracy of 88.8% was noted.
- The aggregate cost of deploying in-pavement sensors in larger lots, such as private truck stops, could be considerable due to the number of sensors and peripherals required – although the cost of the technology continues to decline.
- CCTV cameras should be deployed in the parking areas to spot-check the sensor data.

The field system can be deployed on existing infrastructure, but reliability will be impacted by the power supply capabilities at the rest areas. The Coalition's field system (including access points, repeaters, cabinets, and CCTV cameras) was designed for installation on existing infrastructure at the rest areas, such as utility poles. This was done to reduce the system footprint in the lot by eliminating the need to construct pole foundations, install new poles, run power supplies, etc. The approach resulted in significant savings in cost and installation time, but limited the locations where the equipment could be positioned. This led to the following challenges, particularly during the Tier 1 deployments:

- Continuous power for a 24/7 operation was an issue because power to the poles was 277V and was turned off during the day from a central circuit inside the rest areas.
- These power supply limitations at the parking lots necessitated the use of uninterruptible power supply (UPS) units that could step down the voltage from 277V to 120V to power the equipment, provide backup power during the day when the lights were switched off, and recharge the batteries at night when the pole power was switched on.
- Off-the-shelf UPS products to support these power supply requirements were not available, so the UPS's had to be custom-manufactured. This impacted the lead times for equipment delivery. It also led to lower reliability of the UPS's, and slower response times for equipment repairs since spare parts were not readily available.
- Several months after the Tier 1 deployments were completed, the contractor team started observing repeated power supply outages at the Maryland Welcome Center site. After extensive discussion with MDSHA and multiple site visits to the rest area to try to correct the electrical problem, the decision was made collectively by the Coalition and MDSHA to decommission the site due to the unreliability of the power supply.

Alternatives for continuous power supply to the field system should be identified in coordination with lot owners/operators, and appropriate solutions implemented before the system is deployed. Building on the experiences of the Tier 1 system operations, the Coalition team worked closely with VDOT to implement 24/7 power supply from the rest area buildings to the truck parking equipment at all Tier 2 locations, except Carson. This resulted in improved power reliability, significant cost-savings to the project, and the ability to use off-the-shelf UPS equipment solely to support short-term power outages.

Additional details on the power supply activities at the Tier 2 sites are enumerated below:

- The Ladysmith NB truck parking lot was re-outfitted with the in-pavement detection system after the rest area was reconstructed by VDOT. During reconstruction, the Coalition worked with VDOT to run continuous 120V power to the base of the poles where the access points, CCTV cameras, and equipment cabinet would be installed.
- There were no existing poles at the Dale City NB lot suitable for powering the detection equipment. Consequently, the Coalition collaborated with VDOT to install one steel pole with foundation and 3 wooden poles at the lot. This pole installation effort required extensive coordination with the VDOT Central Office Traffic Engineering Division, the Northern Operations Region and Materials Division, and VDOT's electrical contractor. VDOT's strict specifications and inspection requirements for the construction of pole foundations and acceptance of work were adhered to.
- At the New Kent West rest area, the continuous power supply to the equipment cabinet was run from a small maintenance shed at the lot. Several months after the system was deployed, the maintenance shed partially collapsed and had to be demolished by VDOT for safety reasons. The Coalition then worked with the VDOT maintenance contractor to resupply continuous power directly from the rest area facility.
- In several instances, due to limited availability of existing poles for installing and supplying power to CCTV cameras, 100% visual coverage of the designated spaces could not be achieved. For example, continuous power supply could only be routed to a single pole at New Kent East because running power to poles in the southern part of the lot would have been cost-prohibitive.

Rest area reconstruction, restriping schedules, and static signage updates influence deployment timeframes and should be coordinated with site owners/operators. Several times during the project effort, the Coalition's deployment schedules were impacted by changes to the rest area configuration as follows:

- The Ladysmith rest area was reconstructed and restriped after system installation was finished and the site was operating. This required extensive coordination with the construction contractor for the temporary removal of all detection equipment at the lot, rendering the system non-functional for several months.
- During pre-installation site visits to the Dale City NB lot, it was observed that the parking spaces were not sufficiently long to fully accommodate most modern-day tractor-trailers currently on the road. This appeared to be hindering efficient use of the available spaces in the lot, meaning that even though there were empty parking spaces, many trucks could not fit in those spaces. Consequently, with the Coalition's guidance, VDOT restriped the lot to accommodate longer trucks and improve the spacing between rows so that the parked trucks did not block access to the available spaces. Because of pavement temperature requirements for the restriping material to set, the restriping activity had to be delayed due to winter weather.
- At Ladysmith, the truck parking area consists of two sub-lots. The truck parking system is designed to provide parking availability for each sub-lot. The Coalition team worked with VDOT to install a static sign at the entrance of the lot to designate the sub-lots as "Lot 1" and "Lot 2", respectively.

Operational Lessons

The Coalition's contractor team furnished operations and maintenance of the system during the Tiers 1 and 2 demonstrations. Key takeaways from the operational experience are enumerated below:

The truck parking central system requires only limited active monitoring. Even though the system is operational 24/7, once system reliability is validated shortly after system installation, it requires active manual monitoring for just a few hours a day to check equipment status and report any anomalies. Automatic alerts are sent by the system if major system components malfunction.

During Tier 1, there were no significant issues with the central platform. Most problems encountered with the field data-collection system related to power supply at the sites, as noted previously. For example, several times the automatic switchover from pole power at night to battery power during the day resulted in voltage fluctuations, causing the modems to "freeze" and the field systems to lose their data connections. Field maintenance had to be dispatched to manually reset power to the modems. This issue was substantially eliminated in Tier 2, with the provision of continuous power supply to the equipment.

Real-time data should be disseminated using multiple dissemination mechanisms that provide a seamless experience for users. The Coalition's model demonstration system used a combination of public website, interactive voice recognition (IVR), and an external XML data feed to disseminate the parking availability information. The currency of data is an important consideration for the real-time dissemination of the truck parking information. Initial discussions with State DOT stakeholders revealed that the data could not be updated on then-existing dynamic message signs (DMS) due to emergency or incident messages taking higher priority over parking data, and state-of-the-practice delays in manually posting the parking information on the signs. In addition, in the initial design phases of this project, it was determined that the Coalition states did not, at that time, have the traffic management systems and staffing "bandwidth" available sufficient to maintain the critical and timely updates needed to post parking availability data on DMS. For these reasons, data dissemination via existing DMS was not part of the initial concept. However, having an XML format for dissemination, left open the possibility for future integration of dedicated DMS as a data-dissemination outlet to truckers.

Access of the IVR system by truckers and use of the related call-back scheduling tool on the public website were extremely limited, and so these system components were decommissioned in the final stages of the project. Because the Tier 2 system was to be transitioned by the Coalition to VDOT, the Coalition decided that extensive outreach alerting drivers to the IVR-related functions would not be performed (since VDOT had already indicated it did not plan to maintain the IVR functions). This may explain, in part, the limited use of the IVR system.

The XML data feed has been a highly successful tool/approach for data-dissemination:

- VDOT is currently ingesting the feed to furnish parking data on *511 Virginia*, and to third-party application developers via VDOT's *Smarter Roads* portal.
- In addition, VDOT is posting real-time parking availability information on portable message signs upstream of the outfitted truck parking sites.
- American Truck Parking has also integrated the feed and furnishing parking information on its website.
- Data feed access instructions and a sample schema are published on the Coalition's Truck Parking website, which is helpful in providing easy access to the information to interested parties.

In the future, it is anticipated that parking data, such as the Coalition's, will be delivered directly to truck in-vehicle displays via mapping applications, or broadcast through connected vehicle roadside units (RSUs).

Cellular communications technology is reliable. Cellular modems were deployed at the lots for backhaul communications in order to eliminate the substantial costs of running wired communication lines to the truck parking system cabinets. The cellular technology was generally reliable. There were recurring monthly charges associated with the data plans for the cellular modems. The CCTV cameras were configured to transmit low-resolution video to minimize cellular data overages and the resulting penalties.

Advance outreach to the regional stakeholders who are tasked with integrating and assuming control of system maintenance is essential to a successful transition. On completion of the Tier 2 system deployment, the Coalition began the process of transitioning the system to VDOT. Several challenges had to be overcome to achieve a successful transition.

The initial concept was to integrate the sensor data feed directly from the application programming interface (API) to the VDOT ATMS. Unfortunately, more immediate priorities related to the ATMS development delayed VDOT's plans for truck parking system integration. Additionally, though VDOT intended to take over the field maintenance responsibilities under its Statewide Maintenance contract, there were limitations on adding the field equipment to the contract.

Ultimately, VDOT finally decided on an alternative approach by agreeing to take over the financial responsibilities for the operations and maintenance (O&M) of the field equipment and the Coalition's truck parking platform over the near-term. The transition required the compilation of site drawings, equipment specifications, detailed inventory of all field equipment, etc. Training for field maintenance personnel was also required.

Institutional Lessons

Several important institutional lessons from the Coalition's experience with the truck parking demonstration system are summarized below:

Systems engineering documents are important. This project followed the Federal Highway Administration's (FHWA's) "Systems Engineering Process." Towards this end, in the early years of the project, concept of operations, requirements, and design documentation was developed. Several review cycles were conducted with FHWA to refine and finalize the documents since this was one of the first truck parking grants in the nation and was to serve as a model for subsequent grant awards. The documentation and review process required significant level-of-effort and contributed to delay in some of the development activities. However, it resulted in a comprehensive documentation of the system concept, requirements, and design which can be used a guidance for future projects.

It is important for the technology to work early-on to seek buy-in from state agencies. The Coalition accepted FHWA's grant funding for this project on behalf of its member states. Eight of our states signed on as partners to the grant application. Of these, five states thoughtfully considered implementing parking space detection technologies at commercial vehicle rest areas, and two states ultimately participated in the technology deployments. Our states all gave generously in time and resources to address the truck parking problem.

During the initial phase of the project, the Coalition reached out to all member states to identify potential sites for truck parking system deployment. The Delaware Valley Regional Planning Commission (DVRPC), Maryland State Highway Administration (MDSHA), and New York State DOT (NYSDOT) each responded with multiple potential sites. NYSDOT has a limited number of small truck rest areas on I-95, so they identified locations on I-84.

The largest public rest area site in Delaware on I-95 (Biden Welcome Center) was being reconstructed and the available locations identified by DVRPC were not suitable for Tier 1 deployment. After the Welcome Center was reconstructed, the Coalition began discussions with DelDOT to deploy the Tier 1 system. DelDOT requested that the Coalition contractor work with HMS Host (the rest area concessionaire) on an agreement to deploy the parking system at the site. After over a year of negotiations on the draft agreement, it was decided not to pursue deployment at the site due to major contractual risks for both contractors.

The Coalition's contractor faced technical issues and delays because the originally proposed off-the-shelf optical imaging technology, once it was field-tested, did not meet the project requirements. Since this was one of the first projects of its kind in the country, there was incomplete understanding of the implementation challenges. The contractor conducted months of testing involving installation of multiple detection technologies, including sensors, a temporary trailer housing power and communications equipment, coordination with vendors, etc., at Chesapeake House, Maryland to select technologies that met the requirements. These efforts, taken together, had a significant impact on the project scope, level-of-effort, and schedule and ultimately meant that the truck parking system was deployed at fewer sites than initially planned.

Seeking buy-in from states also became challenging. The topic of truck parking was not on the "critical path" for many of our states – in part, because several of these states were awaiting the outcomes of the Coalition demonstration project before formulating their own approaches to truck parking. Since the Tier 1 system installation was delayed and there was no production-level system that the states could commit to, several member states who had signed-on as partners could not follow-through on their support for this project. Some member states independently sought out truck parking solutions, but these state-level investigations did not always line up with, or connect to, the Coalition-led activities. One of the key outcomes from this process was that having a technical solution that works and implementing it quickly is critical to gaining buy-in from the states.

In addition, the grant funding for this effort accrued to the Coalition directly. The challenge was that investment in outcomes and assumption of risks were generally not shouldered by the individual states, since the Coalition was managing the effort and taking on the primary risks. For the most part, individual states did not have to account for project funding, since that responsibility resided primarily with the Coalition and its state administrator, MDSHA. In retrospect, it may have been desirable to structure this project differently so that funding was shared directly with some of our member states.

This dearth of urgency and investment also tended to impact the commitments states were able to make to the truck parking demonstration, and the speed at which activities progressed. One exception to this generalized pattern was the Commonwealth of Virginia, which embraced the Coalition's model approach to truck parking and ultimately moved the project onto its own critical path of state priority projects.

Establishing clear and streamlined institutional parameters will help to minimize impediments and anticipate challenges. The Coalition's truck parking system was designed to be minimally intrusive. It generally involved placing a small detector puck just below the pavement surface in each parking space. The remainder of the equipment – cameras, communications hardware, uninterruptible power supplies, and cabinets – were nearly always installed on existing utility poles and other infrastructure already in the parking lots. Electrical power was pulled from rest area facilities to the parking system.

Arrangements had to be made to be with states on multiple decisions and topics, including the following: (1) the general decision to move forward with the truck parking program, (2) which parking areas to outfit with the system, (3) review and concurrence on layout of equipment at the lot, (4) plans to power the system, and (5) authorization to access the site for system installation and periodic maintenance. Sight lines needed to be maintained for camera views of the parking lot and cellular communications.

Multiple entities within a state DOT were typically involved in the pre-deployment activities and working through the issues was often time-consuming and complex. The decision-makers choosing to move forward with the truck parking technology were not necessarily the organizational stakeholders who managed the rest areas. Management of rest areas on toll roads generally involved different organizations and stakeholders than did those on non-tolled facilities. The public rest areas in some states were operated by third-party concessionaires, and this added an additional layer of complexity. Furthermore, responsibility for rest area maintenance was typically contracted out.

Decision-making deliberations, arriving at agreements and memorandums of understanding (MOUs), securing permissions, and coordinating activities and schedules proved time-consuming and accounted for significant delay in the project. Staff turnover at agencies also posed challenges when liaisons/points-of-contact (POC's) at agencies changed; when new state POCs were assigned to the effort, time was needed to bring those persons up-to-speed on the project and needs.

During future comparable projects, it is imperative that, at the outset, we identify and implement the strategies, mechanisms, and procedures to streamline the decision-making and coordination processes.

There are costs to install and continue to operate truck parking systems and agencies must be prepared to address this, whether operating directly or through third-party arrangements. A key lesson learned early on by the Coalition was that it was not inexpensive to deploy, operate, and maintain a truck parking information system, particularly within a project that was one of the first ventures into real-time truck parking system implementation. To achieve suitable system accuracy and reliability, and to be able to accommodate a range of parking lot configurations, we concluded that space-by-space monitoring is the preferred approach (at least within the constraints of current technology). Fortunately, since we began our work, the cost of the technologies we used dropped markedly. Additionally, as our activities evolved, we were able to achieve economies-of-scale that brought down total deployment costs. Were we to proceed with additional future deployments, we anticipate that further economies-of-scale would be achievable.

Nevertheless, even with these improvements in technologies and efficiencies in deployment, outfitting commercial vehicle parking lots and maintaining system components will almost certainly continue being a costly proposition.

The Coalition, in consultation with its partners, has searched for business models that might offset the costs of deploying or operating parking technology systems for truckers. During this project, we were not able to identify viable business models that would offset operational costs. As the Coalition system was focused on public agency sites, there was not an ability to "commercialize" the system. "Pay-to-park" reservations systems were precluded given commercialization restrictions and data from various research and survey efforts (i.e., ATRI surveys) did not substantiate significant willingness and/or financial levels of payments by truckers that would support cost offsets, even if such practices were permissible. In addition, there was not the ability to assess data value for financial offset. Clearly, truck parking data can have significant value for agencies. However, it will require significant effort to perform a value-of-data analysis and prepare guidelines on ownership, data-sharing agreements, sales to third-parties, royalties, etc. This data issue is a topic that should be explored in the event agencies engage in implementation of real-time truck parking systems, either directly or through third-parties. Acceptable models would, presumably, need to safeguard the value and integrity of data generated by the system and protect our states from unwarranted liability claims or lost revenue.

Though, at present, technology costs are constraining, this may be less the case in the near future. For instance, sophisticated prediction algorithms working off combinations of data (e.g., partial lot conditions and crowd-sourcing) may help drive down technology costs.

Mechanisms that encourage private truck-stop participation in coordinated parking-dissemination systems are desirable. Early on, the Coalition hypothesized that, to have a positive impact on the truck parking problem, one needs to outfit a "cluster" of parking lots with the parking technology. It wouldn't be enough to communicate to drivers that a given parking lot was full; rather, one would want to be able to advise the drivers as to the locations of alternative lots with available supplies of parking spaces. Realization of this cluster concept was substantially achieved in Virginia when we outfitted the public rest areas on I-95 North, from Carson in the south to Dale City in the north; and on I-64 East and West, not far from where I-64 intersects with I-95. The key limitation of this cluster, however, is that there are sizable travel distances between most of the rest areas.

The optimal solution, of course, would be to enable private truck stops to be part of the cluster. After all, nationwide, approximately 90 percent of the available commercial vehicle parking spaces near the interstate system are in private truck stops. If private lots can be assimilated into the cluster, one can begin to offer truckers realistic, practical parking alternatives when some lots are full. Indeed, being able to accomplish this seems a necessary step on the path to effectively managing the truck parking problem.

The issue is that, with only a handful of exceptions, truck stop operators have been reluctant to join with the public sector in furnishing information on parking space availability. Though some operator chains are beginning to provide occupancy information to customers, they are tending to do so independently, distinct from the public sector. Private operators have competitive interests to manage and protect. They may have a disinterest in communicating to customers the fact that their lots are at capacity; they may prefer not to be part of a process that could steer traffic away from their lots.

A logical evolution in the efficacy of truck parking technology systems will need to find ways to couple public and private parking activity. The public sector must better understand the motivations and needs of the private truck stop community. Then the two communities can, ideally, find ways to work together to bridge the gap.

Sharing concepts and deployment experiences among stakeholders considering or implementing real-time truck parking systems is important. Across the nation, there have now been a variety of truck parking technology initiatives and demonstrations. Many have been funded by FHWA, several by FMCSA, and others funded locally or by academia. Initially, during much of the life of the Coalition project, these truck parking projects have tended to progress in "stovepipe" fashion, with relatively little cross-pollination and in-depth exchange about experiences and challenges between projects.

Throughout the tenure of its truck parking project, the Coalition has been steadfast in its call for greater dialogue on experiences with truck parking system implementation. We must find ways for deeper discussion, better clarity, and openness and forthrightness. Practitioners need to be able to build on the successes of their predecessors, rather than reinventing the wheel. Activities such as the National Coalition on Truck Parking and the Coalition's Truck Parking Workshop offer forums for addressing this. Exchanges on best practices, products, and approaches – such as those being collected and catalogued by the National Coalition on Truck Parking – will be helpful to states considering truck parking strategies. At the same time, conducting workshops with public-sector agencies and talking in-depth about approaches, challenges, and strategies directly tied to the "nuts and bolts" of *implementing* a system, will help to advance interest internally and create champions.

Conclusions:

At the concept stage, the I-95 Corridor Coalition established three goals for this project:

- Continuously monitor the availability of commercial vehicle parking spaces across the coverage area,
- Process and compile parking space availability data in real-time, and
- Furnish truckers with accurate, up-to-date parking space availability information efficiently and safely.

This project successfully met these goals. The Coalition's truck parking system provides real-time parking space availability information to truckers on I-95 and I-64 in Virginia. This is a production- level system that is modular and expandable.

The system remains active after a successful transition to VDOT. The system's XML data feed has been integrated with VDOT's 511 system, and data are being disseminated to truckers via the *511 Virginia* website, smart phone applications, and on portable DMS signs located upstream of the outfitted parking lots.

Experiences and lessons learned from this project are expected to be beneficial to other states and jurisdictions pursuing the implementation of systems to provide parking availability information to truckers, thereby improving safety on the nation's roadways.