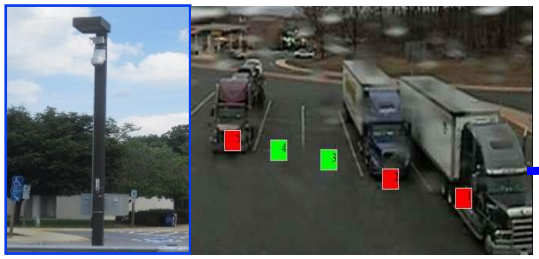


I-95 Corridor Coalition

TRUCK PARKING PROJECT
DELIVERABLE 4.1 - EVALUATION

December 2018

EXECUTIVE SUMMARY

This evaluation report details the results of the truck parking demonstration project. The project spanned multiple years, beginning with project scoping and workplan development, identification of user functional requirements and system requirements, and investigation of technologies along with options. A Concept of Operations was developed, followed by the development of the system's architecture, requirements, and design. A Phase I Pilot Deployment was conducted and tested to assess initial design concepts and to fine-tune the system for a Phase II deployment, which included system, technology, and communications implementation at 5 sites. Phase II deployment was completed, including acceptance testing, and the Phase II system sites went operational in 2017. The system was operated for several months, including monitoring and data collection, with baseline parking occupancy statistics collection during the period of November 15, 2017 through January 31, 2018; post-implementation data collection was conducted for the Phase 2 pilot demonstration during the period of February 14 through April 30, 2018. Pre-deployment of the truck parking system vs. post-deployment showed an average increase of 5% in truck parking space utilization. Sensor accuracy ranged between 95-99%, with some slight deterioration during heavy rain or snow. System uptime, exclusive of power outages, was 99.9%. The parking system website remained online throughout the period, and showed steady visitor traffic to the website, with the length of user visits increasing as the test period progressed. Truckers' needs were identified, including being without cost to these users as per the original project requirements. The demonstration project period concluded on March 31, 2018, and then the system, having been installed at 5 Virginia sites, was turned over to the Virginia DOT for continued operation, demonstrating system viability, transferability, modularity, scalability, and adaptability. System performance monitoring by the Coalition continued for a month after the transition to VDOT until April 30, 2018. Overall, the project proved to be beneficial to state departments of transportation, truckers/users/stakeholders, and project operators, developers and designers.

The project also identified further work which should be explored:

- determine whether and where cross-state communications are needed for long-distance truckers, particularly for cross-border travel.
- elucidate why truckers are stopping and where they are stopping.
- Identify best communications media/equipment with the truckers, such as placement of VMS/DMS parking availability alerts.

This report is organized as follows:

1. Baseline Overview;
2. Results Part 1 – sensor accuracy, system uptime and reliability, and communications with truckers – IVR and website;
3. Results Part 2 – a comparison of before and after parking space occupancy by time of day, and by day of week/time of day for each Phase 2 pilot deployment site;
4. System transferability, modularity, scalability, and adaptability; and
5. Conclusions.

1.0 BASELINE OVERVIEW

Based on stakeholder input, the truck parking technology system was developed on the following principles; the system had to be:

- Safe;
- Accurate;

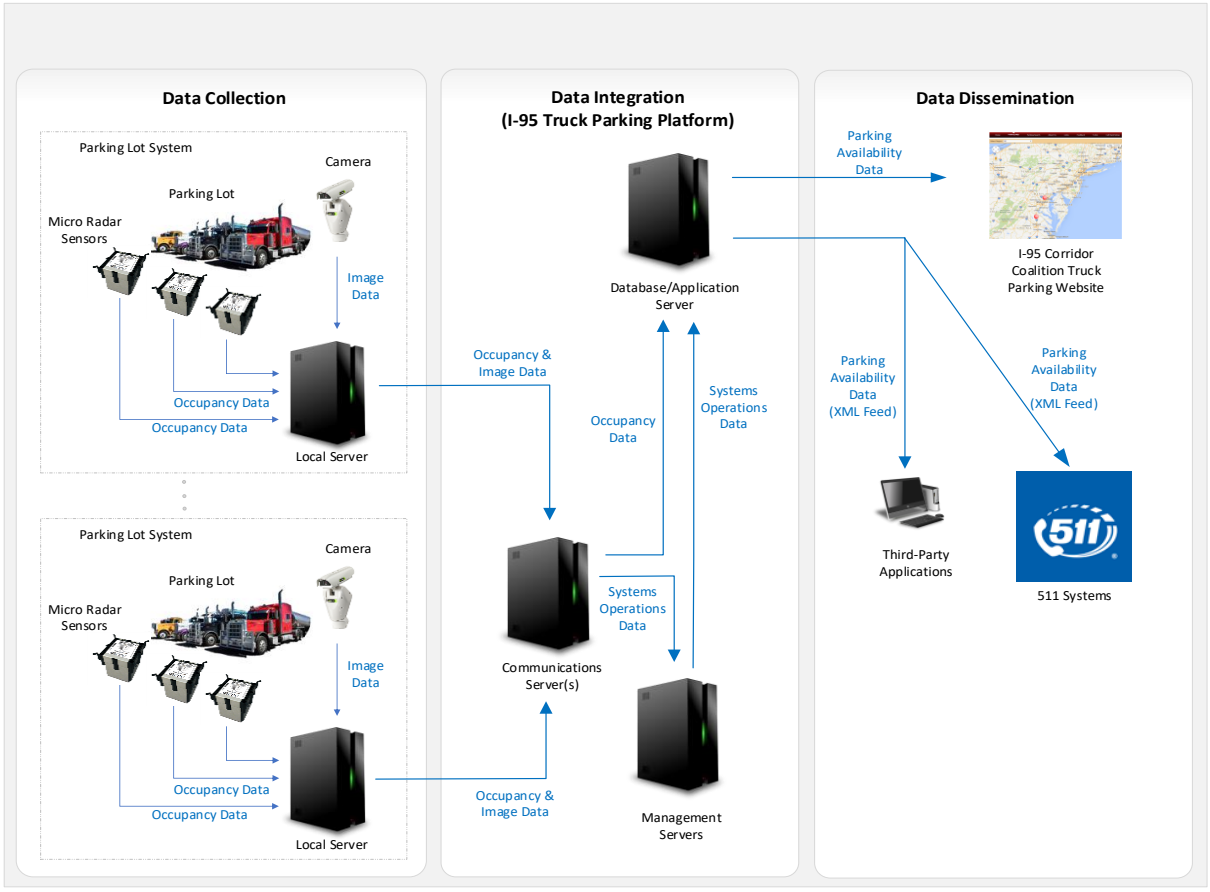
- Timely and reliable;
- Seamless and interoperable;
- Without cost to users;
- Modular;
- Flexible and adaptable; and
- Scalable to different lot sizes and configurations.

The overall goals for the proposed system were to:

- monitor continuously 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.

Based on these goals and principles, the I-95 Corridor Coalition's modular Real-Time Truck Parking Availability System was composed of three major subsystems, depicted in the image below:

- Data Collection Subsystem – Collected raw vehicle occupancy data in designated truck parking areas.
- Data Integration Subsystem – Integrated and processed vehicle occupancy data collected from all instrumented truck parking areas to calculate parking availability by area.
- Data Dissemination/Traveler Information Subsystem – Disseminated real-time parking availability information to truck operators through a range of mechanisms and media, including a Truck Parking website.



Project deployment and demonstration were 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.
- **Phase 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.
- **Phase 2 Deployment.** The following sites were selected jointly by the Virginia Department of Transportation (VDOT) and the Coalition for Tier 2 deployment and integration, and eventual transitioning to VDOT. 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 Areas 1 and 2, Caroline County, VA – I-95 NB, MM 107.
    - Dale City Safety Rest Area, Dale City, VA – I-95 NB, MM 154.

Under the jurisprudence of FHWA, and prior to "going Live" during demonstration project phase 2, the I-95 Coalition conducted a System Acceptance Test for each of the three developed and integrated system components to verify that system functionality adhered to the system goals and resulting system requirements. Test results demonstrated that system functionality and system requirements met specifications. After acceptance, the system was deployed at the phase 2 demonstration sites, with data monitoring and collection proceeding through the demonstration period. Thereafter, the system was transitioned to VDOT for ongoing operation and maintenance.

2.0 Results Part 1 – Sensor Accuracy, System Uptime, and Communications with Truckers

Results for the deployed sites included review of Sensor Accuracy and System Uptime, in support of project goal 1 to monitor continuously the availability of commercial vehicle parking spaces across the coverage area.

2.0.1 Sensor Accuracy

Sensor accuracy was tested under various weather conditions during the project's early phases, and the following table shows the results of the in-pavement sensor technology testing at Chesapeake House testbed:

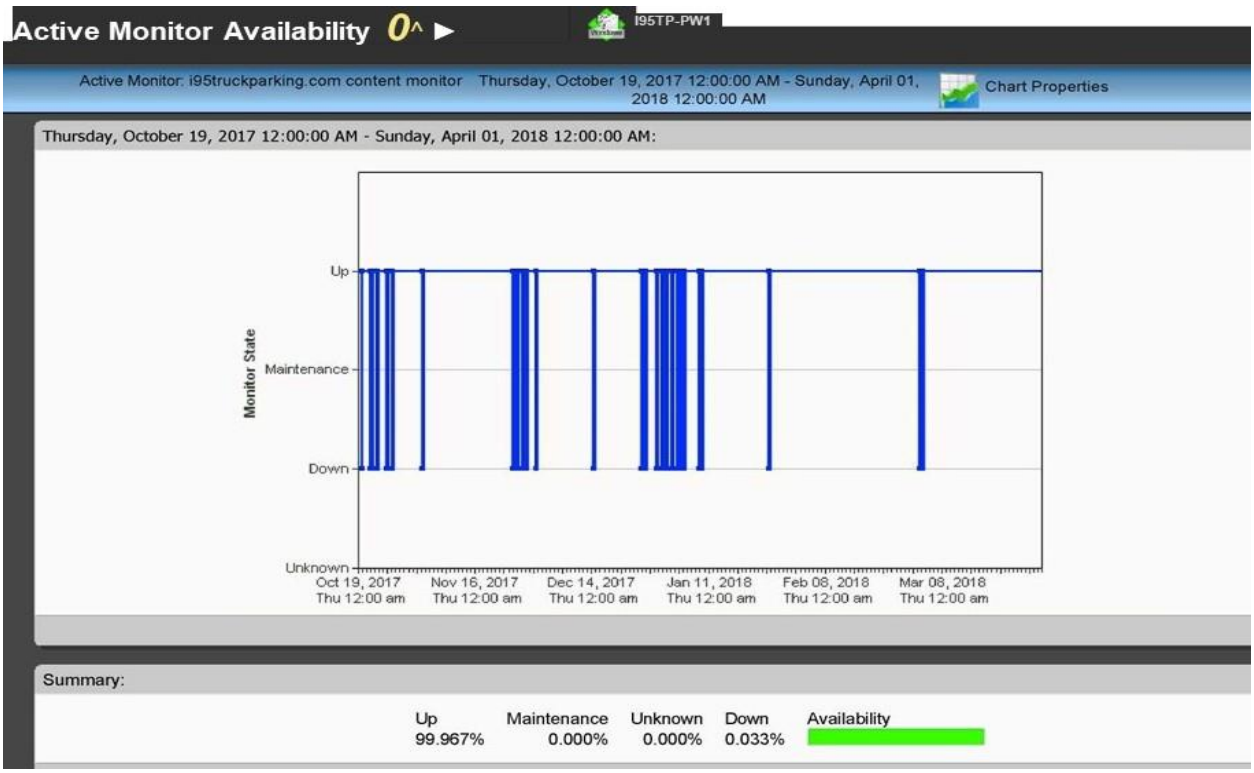
Parking Space #	CLEAR		RAIN		SNOW	
	September 2012	January 2013	September 2012	January 2013	September 2012	January 2013
1	92%	95%	89%	95%	-	95%
2	100%	96%	89%	94%	-	88%
3	95%	95%	100%	90%	-	92%
4	96%	94%	91%	80%	-	83%
5	96%	93%	97%	91%	-	94%
Average	**96%**	**95%**	**93%**	**90%**	**-**	**90%**

It was found that detection accuracy reduced during rain and snow conditions, sometimes being triggered by precipitation. There were numerous false alarms during rain and snow, for the sensors were being triggered by the precipitation. The sensors were most accurate during clear conditions. The maximum range of a single radar sensor is 8-10 feet, so the sensors cannot detect short vehicles parked in the extreme back of the space. For the Phase 2 pilot deployment, sensor accuracy was tested after initial deployment at the Ladysmith and Carson sites. Conditions such as fog and lighting (night/day) did not impact the performance of the in-pavement sensors. The sensors were 95% accurate at the Ladysmith site in clear weather conditions. At the Carson site, sensor accuracy was tested and showed a 99.8% accuracy rate under clear weather conditions:

Accuracy Summaries (April 2018)			
Location	**Database Total**	**Ground-Truth Total**	**Accuracy Rate**
Ladysmith (7:00PM – 10:00PM)	734	773	95.0%
Carson (6:00AM – 9:00AM)	402	403	99.8%

2.0.2 System Uptime and Reliability

Overall uptime and ongoing reliability regarding Active Monitor Availability for the period of October 19, 2017 through April 1, 2018 was 99.967% as shown below, directly taken from the system's Active Monitor Availability report:



The field system uptime is summarized in the table below. The New Kent West and Dale City lots were integrated in late-October. The New Kent West lot was down in February - March 2018 because the maintenance shed from which the power was supplied to the truck parking cabinet collapsed, and VDOT had to shut down power in the maintenance shed for safety reasons. There was a power issue at Carson in January 2018 that was causing the modem to freeze intermittently. The ATT SIM cards in the cellular modems were replaced with Verizon SIM cards at all sites to meet VDOT requirements; the communication system was down while the SIM cards were replaced, and the modems reconfigured to work with the new SIM cards. Power supply to the cabinets at some sites was shut down during UPS replacement in March before system transition to VDOT. Despite all of the above, overall field system uptime exceeded an average of 96% for the period.

Field System Uptime (October 2017 – April 2018)	
Site	**Uptime**
Carson	96%
New Kent East	99%
Ladysmith	98%

Field System Uptime (November 2017 – April 2018)	
Site	**Uptime**
Dale City	99%
New Kent West	90%

2.0.3 Communications with Truckers – IVR and Website

The IVR telephone system served as a data dissemination method for the Truck Parking Location System during the initial Phase I pilot demonstration. It provided parking availability information through a series of easily understood questions and answers based on live speech and text-to speech. An automatic call-back system updated truck operators on parking space status at the specified parking lots as commercial vehicle drivers progress through their trips. However, access to the IVR system by truckers and use of the related call-back scheduling tool on the public website were limited, so these system components were decommissioned in the final stages of the project. Because the Phase 2 system was to be transitioned by the I-95 Corridor Coalition to VDOT, it was 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.

The system website used for communications with truckers was monitored throughout the demonstration period. Presented below are website statistics, by month, for the period of February through April 2018. "Unique Visitors" refers to a person who visits a site at least once within the reporting period. "Number of Visits" is the total number of visits to the site within the reporting period. "Pages" is the total number of pages viewed:

Website Statistics (February 14 - April 30, 2018)			
Month	Unique visitors	Number of visits	Pages
Feb-18 (half month)	1,059	1,202	680,900
Mar-18	1,856	1,991	1,833,073
Apr-18	1,986	2,028	1,836,715

The number of unique visitors increased during the demonstration months; the number of visits and the number of pages viewed also increased during the demonstration months, indicating that truckers found the website to be valuable.

3.0 Results - Parking Space Occupancy

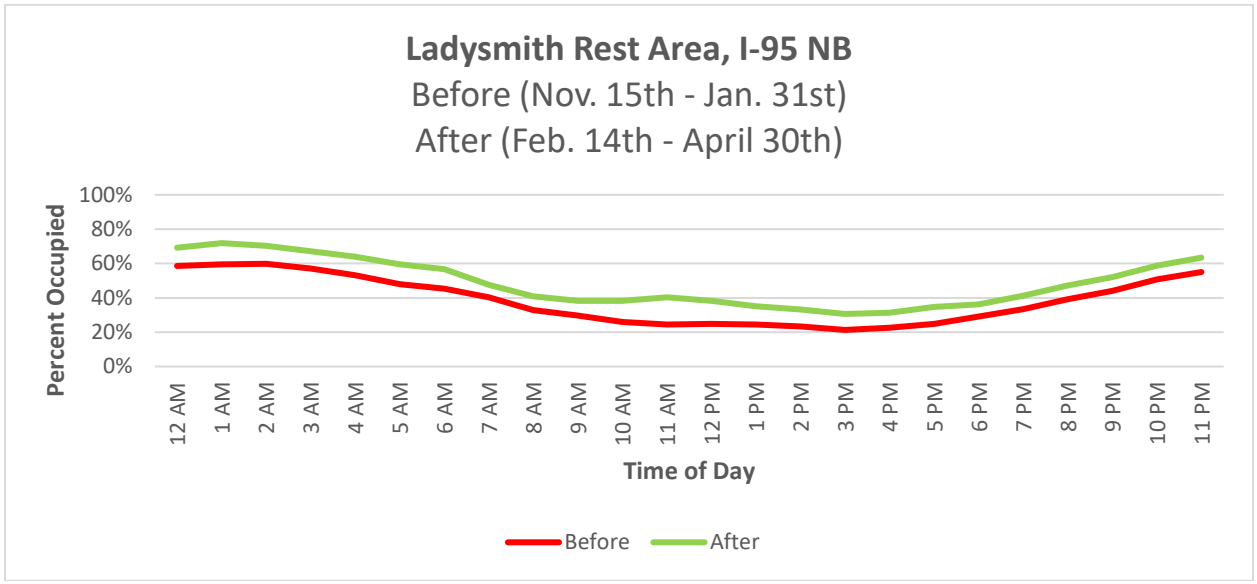
The Truck Parking Availability System, in support of project goals 2 and 3, processed and compiled parking space availability data in real-time; and then furnished truckers with accurate, up-to-date parking space availability information efficiently and safely.

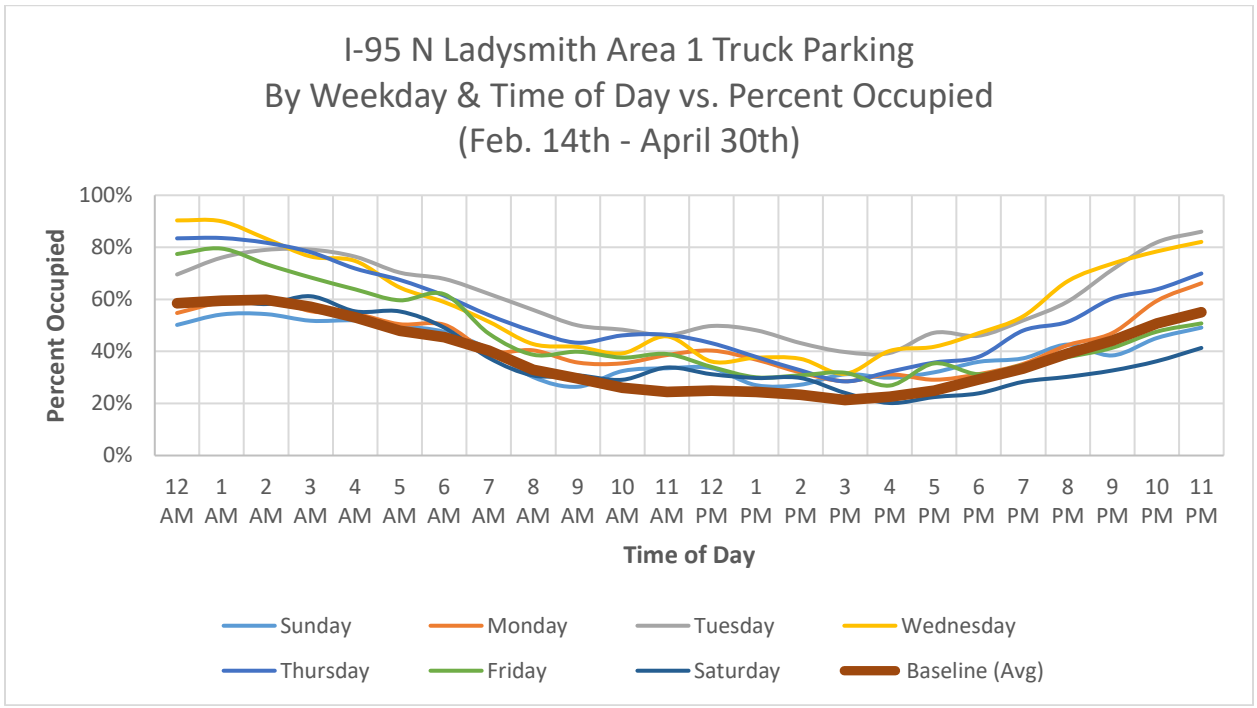
To assess space occupancy before and after system deployment, the November 15, 2017 – January 31, 2018 pre-DMS utilization baseline statistics are compared with parking space occupancy by time of day for the period of February 14, 2018 – April 30, 2018 for each site; thereafter parking space occupancy by time of day and day of the week is presented for each demonstration site. Overall statistics showed a 5% increase in parking space occupancy during the Phase 2 test period.

3.1 Ladysmith Area 1 Space Occupancy

Average parking space occupancy for this lot increased by 10% during the Phase 2 test period. Peak times were as expected – during late night/early morning hours, as shown below.

Hour	Before (Nov. 15, 2017 – Jan. 31, 2018)	After (Feb. 14 – April 30, 2018)
12 AM	59%	69%
1 AM	60%	72%
2 AM	60%	70%
3 AM	57%	67%
4 AM	53%	64%
5 AM	48%	60%
6 AM	45%	57%
7 AM	40%	48%
8 AM	33%	41%
9 AM	30%	38%
10 AM	26%	38%
11 AM	24%	40%
12 PM	25%	38%
1 PM	24%	35%
2 PM	23%	33%
3 PM	21%	31%
4 PM	23%	31%
5 PM	25%	35%
6 PM	29%	36%
7 PM	33%	41%
8 PM	39%	47%
9 PM	44%	52%
10 PM	51%	59%
11 PM	55%	64%

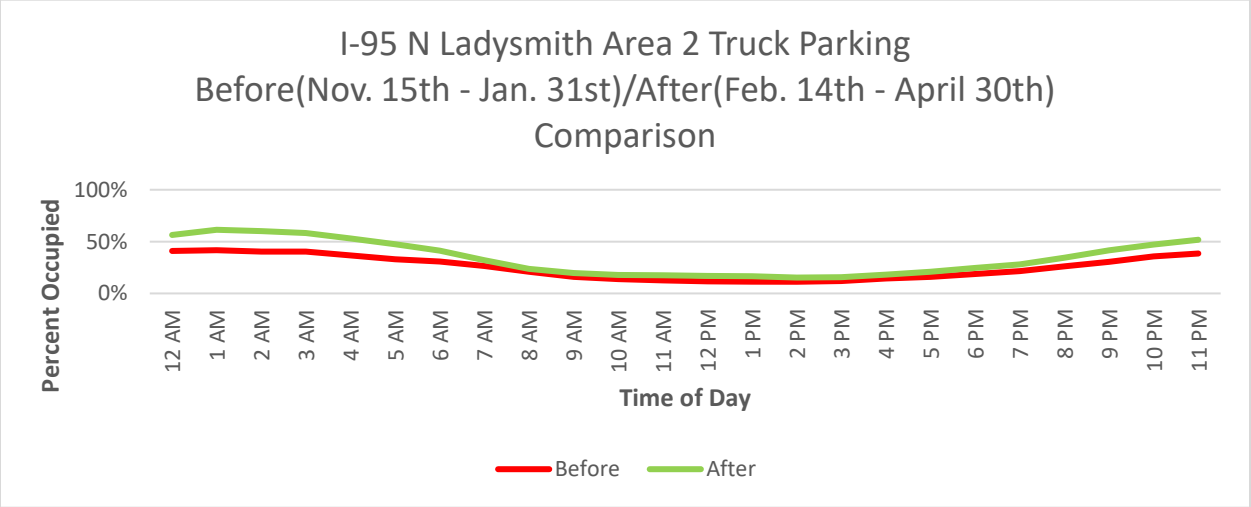

Ladysmith Rest Area, I-95 NB
Before (Nov. 15th - Jan. 31st)
After (Feb. 14th - April 30th)
Percent Occupied
100%
80%
60%
40%
20%
0%
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
Time of Day
Before
After

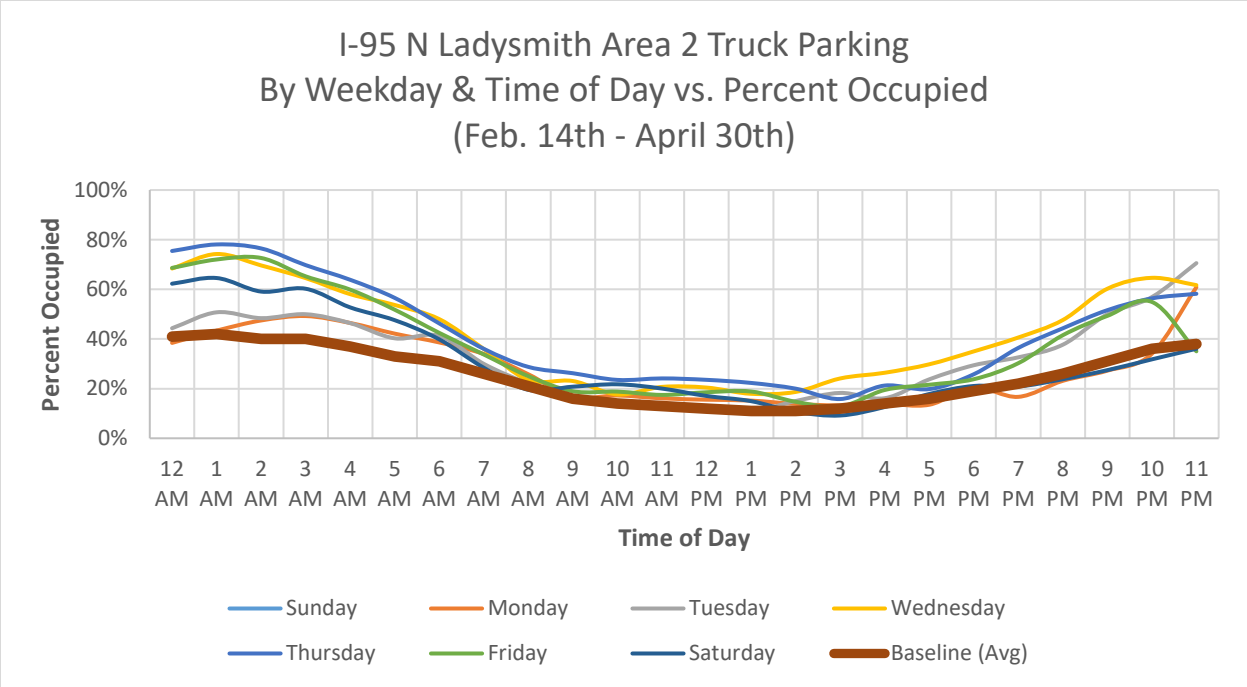

I-95 N Ladysmith Area 1 Truck Parking
By Weekday & Time of Day vs. Percent Occupied
(Feb. 14th - April 30th)
Percent Occupied
100%
80%
60%
40%
20%
0%
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
Time of Day
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Baseline (Avg)

3.2 Ladysmith Area 2 Parking Space Occupancy

Average parking space occupancy for this lot increased by 9% during the Phase 2 test period. Peak times were as expected – during late night/early morning hours, as shown below.

Hour	Before (Nov. 15, 2017 – Jan. 31, 2018)	After (Feb. 14 – April 30, 2018)
12 AM	41%	57%
1 AM	42%	61%
2 AM	40%	60%
3 AM	40%	58%
4 AM	37%	53%
5 AM	33%	48%
6 AM	31%	41%
7 AM	26%	32%
8 AM	21%	24%
9 AM	16%	20%
10 AM	14%	18%
11 AM	13%	17%
12 PM	12%	17%
1 PM	11%	17%
2 PM	11%	15%
3 PM	12%	16%
4 PM	14%	18%
5 PM	16%	21%
6 PM	19%	25%
7 PM	22%	28%
8 PM	26%	34%
9 PM	31%	42%
10 PM	36%	47%
11 PM	38%	52%



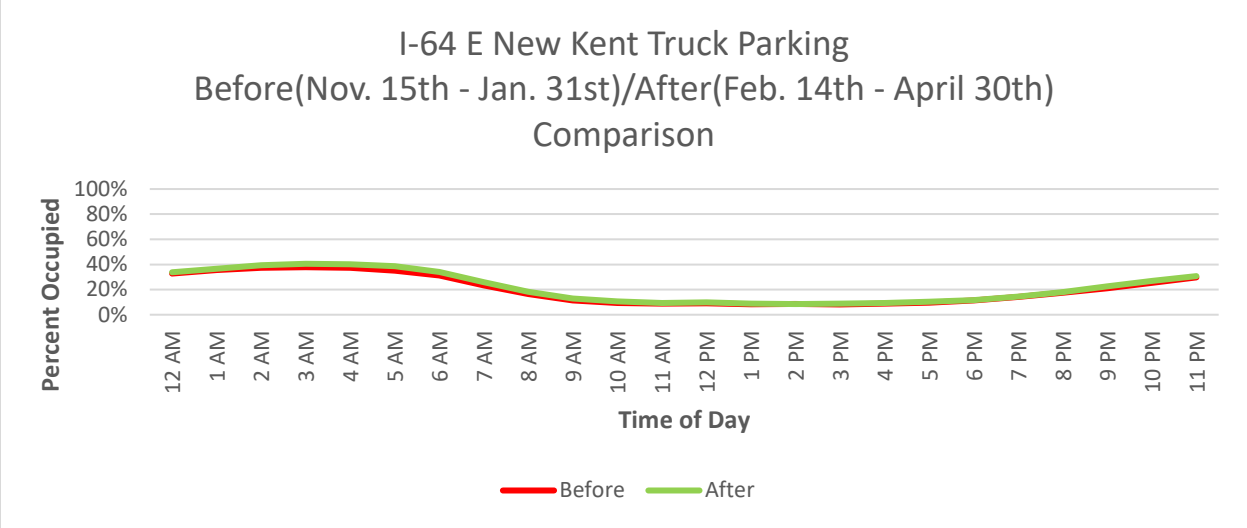


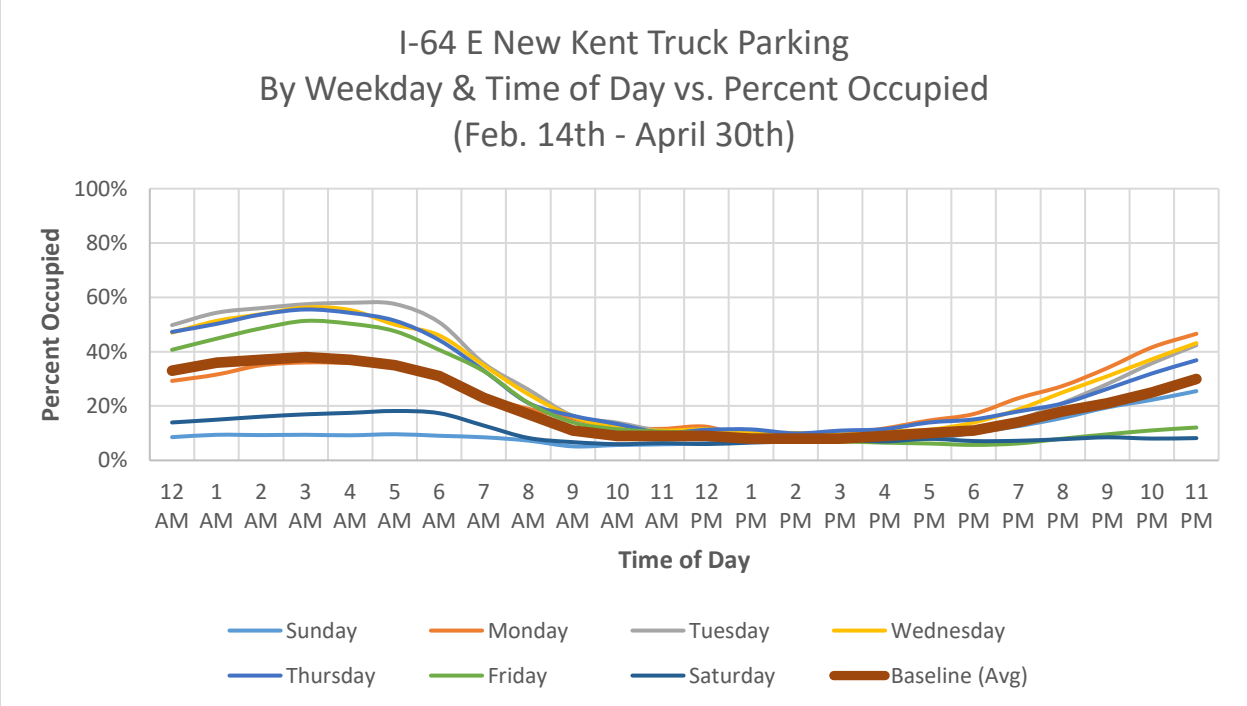
3.3 New Kent East Parking Space Occupancy

Average parking space occupancy for this lot increased by 4% during the Phase 2 test period. Peak times were as expected – during late night/early morning hours, as shown below.

Hour	Before (Nov. 15, 2017 – Jan. 31, 2018)	After (Feb. 14 – April 30, 2018)
12 AM	33%	34%
1 AM	36%	37%
2 AM	37%	39%
3 AM	38%	41%
4 AM	37%	40%
5 AM	35%	39%
6 AM	31%	34%
7 AM	23%	26%
8 AM	17%	18%
9 AM	11%	13%
10 AM	9%	11%
11 AM	9%	9%
12 PM	9%	10%
1 PM	8%	9%
2 PM	8%	8%
3 PM	8%	9%
4 PM	9%	9%
5 PM	10%	10%
6 PM	11%	12%
7 PM	14%	14%

Hour	Before (Nov. 15, 2017 – Jan. 31, 2018)	After (Feb. 14 – April 30, 2018)
8 PM	18%	18%
9 PM	21%	23%
10 PM	25%	27%
11 PM	30%	31%

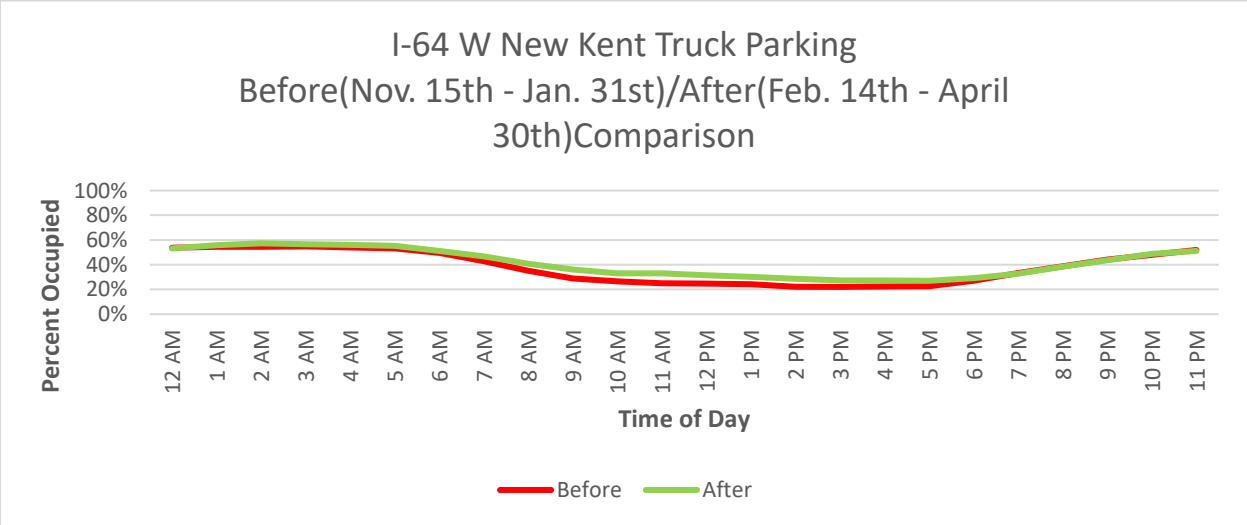


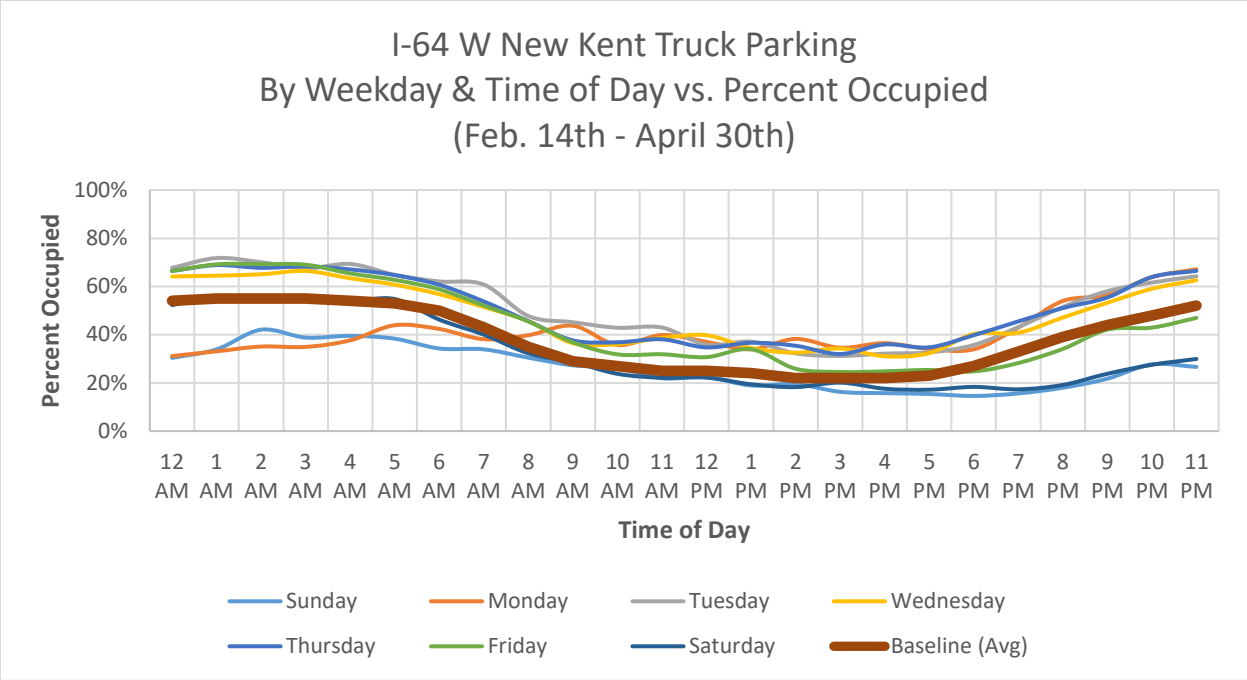


3.4 New Kent West Parking Space Occupancy

Average parking space occupancy for this lot increased by 3% during the Phase 2 test period. Peak times were as expected – during late night/early morning hours, as shown below.

Hour	Before (Nov. 15, 2017 – Jan. 31, 2018)	After (Feb. 14 – April 30, 2018)
12 AM	54%	53%
1 AM	55%	56%
2 AM	55%	57%
3 AM	55%	57%
4 AM	54%	56%
5 AM	53%	55%
6 AM	50%	51%
7 AM	43%	47%
8 AM	35%	41%
9 AM	29%	36%
10 AM	27%	33%
11 AM	25%	33%
12 PM	25%	31%
1 PM	24%	30%
2 PM	22%	29%
3 PM	22%	27%
4 PM	22%	27%
5 PM	23%	27%
6 PM	27%	29%
7 PM	33%	33%
8 PM	39%	39%
9 PM	44%	44%
10 PM	48%	49%
11 PM	52%	51%



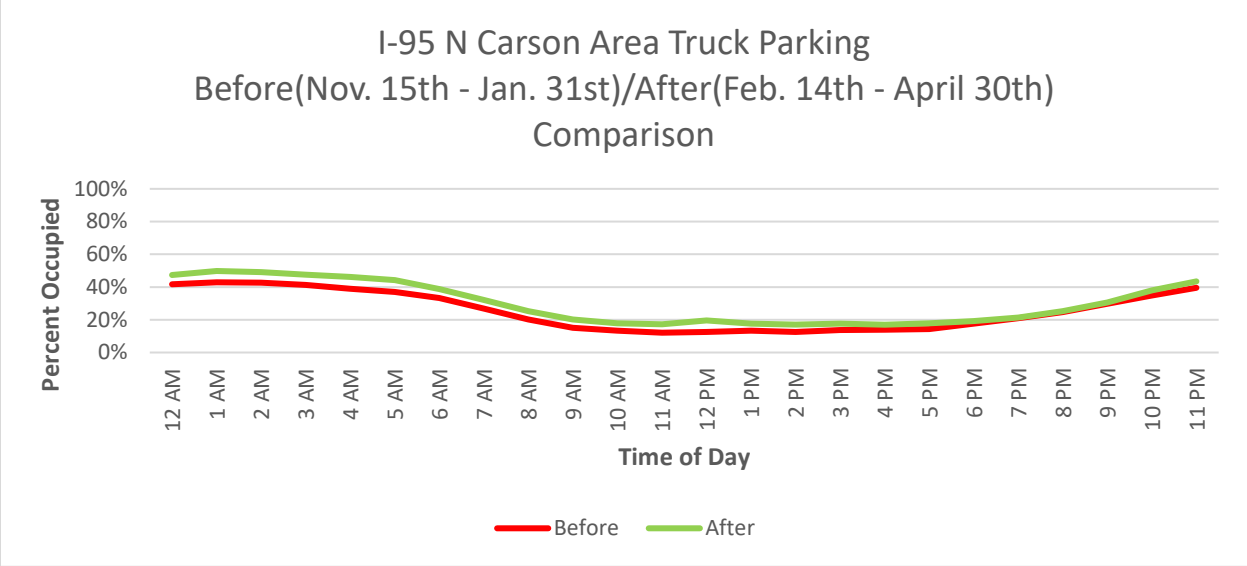


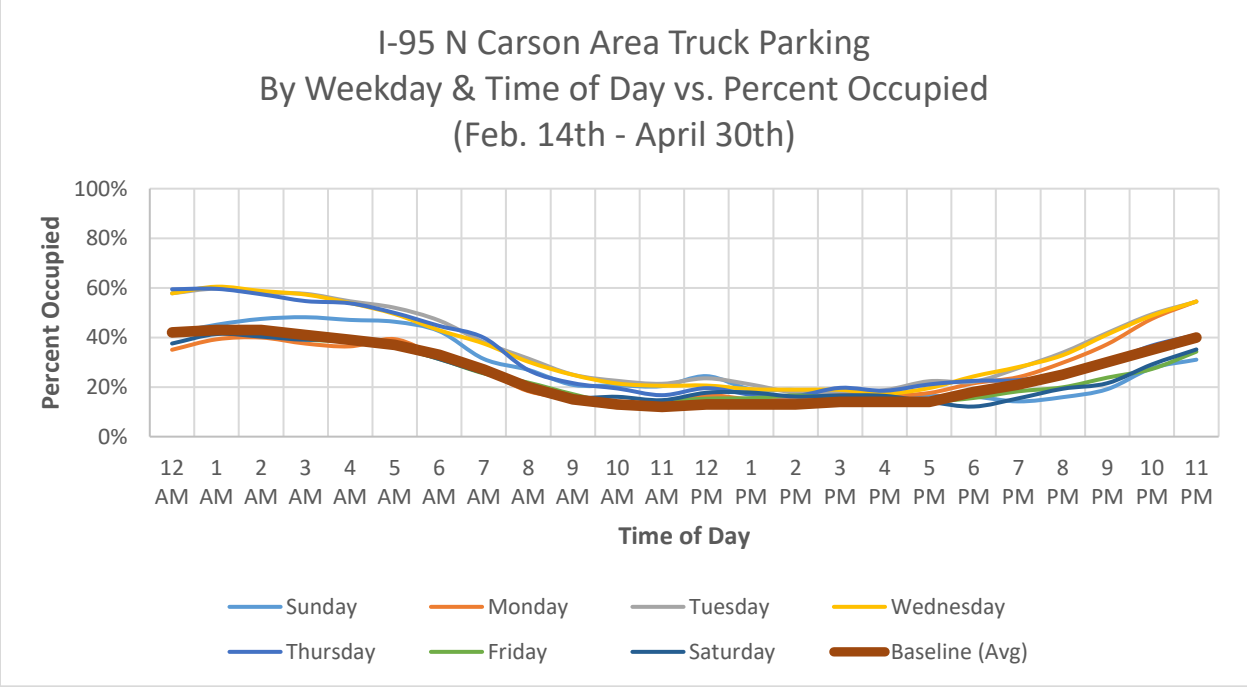
3.5 Carson Parking Space Occupancy

Average parking space occupancy for this lot increased by 1% during the Phase 2 test period. Peak times were as expected – during late night/early morning hours, as shown below.

Hour	Before (Nov. 15, 2017 – Jan. 31, 2018)	After (Feb. 14 – April 30, 2018)
12 AM	42%	47%
1 AM	43%	50%
2 AM	43%	49%
3 AM	41%	48%
4 AM	39%	46%
5 AM	37%	44%
6 AM	33%	39%
7 AM	27%	32%
8 AM	20%	25%
9 AM	15%	20%
10 AM	13%	18%
11 AM	12%	17%
12 PM	13%	20%
1 PM	13%	18%
2 PM	13%	17%
3 PM	14%	18%
4 PM	14%	17%
5 PM	14%	18%
6 PM	18%	19%
7 PM	21%	21%

Hour	Before (Nov. 15, 2017 – Jan. 31, 2018)	After (Feb. 14 – April 30, 2018)
8 PM	25%	25%
9 PM	30%	31%
10 PM	35%	38%
11 PM	40%	44%

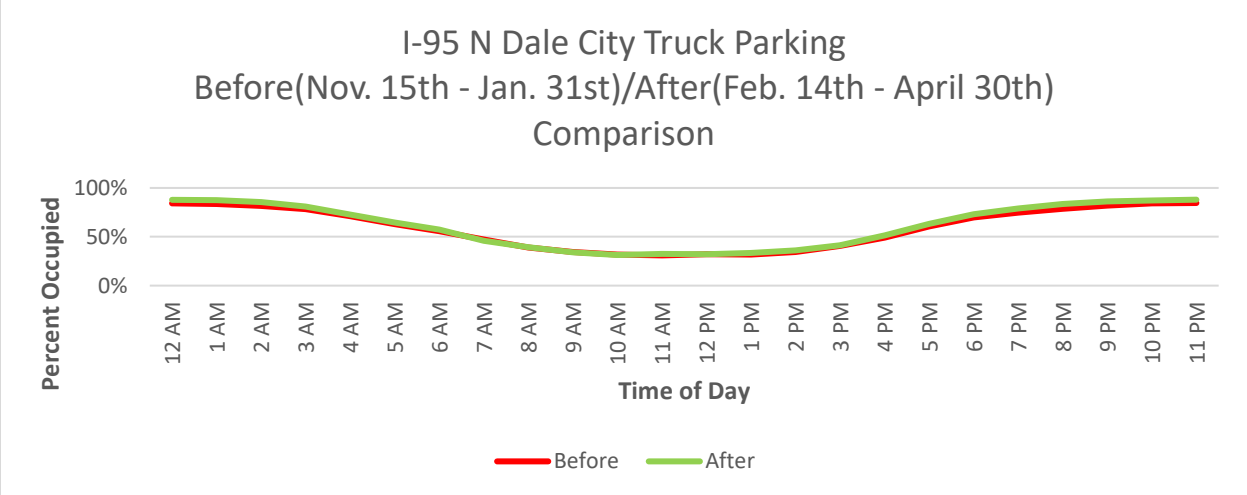


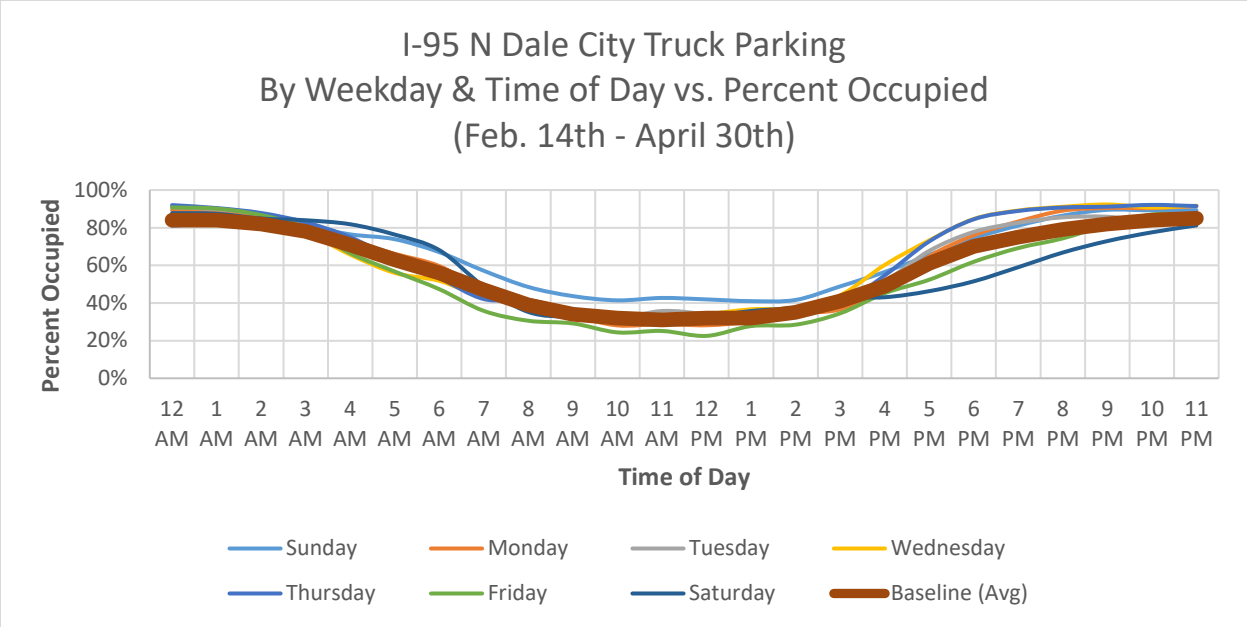


3.6 Dale City Space Occupancy

Average parking space occupancy for this lot increased by 2% during the Phase 2 test period. Peak times were as expected – during late night/early morning hours, as shown below.

Hour	Before (Nov. 15, 2017 – Jan. 31, 2018)	After (Feb. 14 – April 30, 2018)
12 AM	84%	88%
1 AM	84%	87%
2 AM	82%	86%
3 AM	78%	81%
4 AM	71%	73%
5 AM	63%	65%
6 AM	56%	57%
7 AM	47%	46%
8 AM	39%	39%
9 AM	34%	34%
10 AM	32%	31%
11 AM	31%	32%
12 PM	32%	32%
1 PM	32%	33%
2 PM	35%	36%
3 PM	41%	41%
4 PM	49%	51%
5 PM	61%	63%
6 PM	70%	73%
7 PM	75%	79%
8 PM	79%	84%
9 PM	82%	86%
10 PM	84%	87%
11 PM	85%	88%





4.0 Transferability, Modularity, Scalability, and Adaptability

The I-95 Coalition truck parking system is a stand-alone system. It does not require interface with other agency or statewide systems to be able to provide parking lot availability information to truckers. However, states and other stakeholders have the option of providing direct links to the parking availability information via systems such as state 511 or from customer kiosks at welcome centers and rest areas using the XML data feed. This feed can also be used by third-party application developers.

The demonstration project period concluded April 30, 2018, and the system installed at 5 Virginia sites was turned over to Virginia DOT for continued operation. VDOT decided to integrate the XML data feed from the existing hosting environment to VDOT's data dissemination system, and VDOT agreed to take over the financial responsibilities for the operations and maintenance of the field equipment and the Coalition's truck parking platform over the near-term. The XML data feed from the Coalition Platform provides the truck parking availability data to VDOT's 511 system and the Smarter Roads Portal. The XML data feed access information was made available on the I-95 Truck Parking website. VDOT's intent is to incrementally work towards integrating the data feed with the VDOT's ATMS. In summary, this transition to VDOT demonstrated that original project goals of system transferability, modularity, scalability, and adaptability were successfully met.

5.0 Conclusions

The project successfully achieved the demonstration of all project goals. System viability was demonstrated, operational concepts were proven, and the original project goals of transferability, modularity, scalability, and adaptability were met. Overall, the project was beneficial to state departments of transportation, truckers/users/stakeholders, and project operations, developers and designers. The demonstration project showed:

- the proof of concept was viable;
- sensor accuracy ranged between 95-99% on an average, with some deterioration during heavy rain or snow;
- overall uptime and ongoing reliability regarding Active Monitor Availability was consistently higher than 99.9%; field system uptime exceeded an average of 96% for the period;

- the parking system website consistently remained online throughout the period, and showed increased number of visits to the site over time, increasing in number of unique visitors and time spent on the website as the test period continued;
- it is important to have a modular aspect of the system, particularly since technology is evolving rapidly. System portability is important to enable the best chance at future usability so the system can be moved to different platforms as the hardware passes its useful life or grows obsolete;
- the capability for states to integrate the parking system into their existing systems, without the need for a third party vendor, affords the states greater flexibility in being able to implement, operate and maintain the system;
- truckers' needs were identified, and were met, without cost to these users; and
- the phase 2 demonstration, which ran for 75 days after equipment installation and testing, showed a 5% improvement in parking space utilization.

The project also identified further work which should be explored:

- determine whether and where cross-state communications are needed for long-distance truckers, particularly for cross-border travel.
- elucidate why truckers are stopping and where they are stopping.
- identify best communications media/equipment with the truckers, including placement of VMS/DMS parking availability alerts. Spacing of advance DMS/VMS parking availability alerts needs to be explored as to whether they should be placed farther in advance of the parking site to enable truckers time to make decisions whether to stop or not stop.