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Commercial Truck Parking Detection Technology Evaluation for Columbia County Rest Areas

Contract #: BDV31-977-56

University of Florida
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SI (MODERN METRIC) CONVERSION FACTORS

SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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16. Abstract

Rest areas along Florida's interstate routes are heavily utilized by commercial trucks for overnight parking. Many of the rest areas regularly experience 100% utilization of the commercial truck parking spaces during the evening and early morning hours.

The objective of this project was to evaluate three different vehicle detection technologies (SENSIT, Sensys, and CivicSmart) as applied to commercial truck parking areas of interstate rest areas. This evaluation addresses several aspects: (1) the accuracy of the vehicle detection in parking spaces, (2) cost of the technology (not included in this report for confidentiality reasons), (3) installation, setup, and maintenance of technology, (4) sensor output integration with SunGuide® software, and (5) sensor durability (to the extent this was possible over the relatively short duration of this project).

The research team recorded video of the rest areas as the ground-truth data and compared the video data with the parking sensor data. Two accuracy tests (event accuracy and occupancy accuracy) were conducted to evaluate each sensor's ability to correctly reflect the status of each parking space. Overall, it was found that all three technologies performed well, with accuracy rates of 95% or better for both tests.

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EXECUTIVE SUMMARY

Rest areas along Florida's interstate routes are heavily utilized by commercial trucks for overnight parking. Being able to communicate commercial truck parking space availability to drivers in advance of arriving at a rest area would reduce unnecessary stops at full rest areas as well as driver anxiety. In order to do this, it is critical to implement a vehicle detection technology to correctly reflect the parking status of the rest area. The objective of this project was to evaluate available in-pavement different vehicle detection technologies to apply commercial truck parking areas of interstate rest areas.

The vehicle parking detection technologies evaluated in this project were SENSIT, Sensys, and CivicSmart. The technologies employed by each vendor are given in the following table.

Vehicle detection technologies

Vendor	SENSIT	Sensys	CivicSmart
Technologies	Magnetic and Infrared	Microwave Radar	Microwave Radar
Operating frequency	902-928 MHz	2400-2483.5 MHz	2.4 GHz (2405-2480 MHz)

The vehicle parking technology was tested at two rest areas within FDOT District 2. The sites are located in FDOT rest area facilities 20161 (I-75 northbound) and 20162 (I-75 southbound) in Columbia County at milepost 413 of I-75 (GPS coordinates: 29.978335, -82.57862).

IPsens installed the Nedap SENSIT detectors in 10 spaces on the southern end of the northbound rest area. CivicSmart installed their sensors in 10 spaces on the northern end of the northbound rest area. Sensys installed their sensors in 10 spaces on the southern end of the southbound rest area.

Video data were collected by the research team to use as the ground-truth data. Each of the detector technology vendors provided access to the data collected by their sensors to the research team. The detector data were compared to the video data in two different tests to determine their accuracy for classifying parking ingress/egress events as well as continuous parking occupancy status. Overall, it was found that all three technologies performed well, with accuracy rates of

95% or better for both tests.

While the project was of relatively short duration, no visual damage of the various detectors was observed during this time. One vendor encountered a failure of one sensor, but this appears to have been due to a faulty sensor rather than physical damage. The sensor was replaced in field by CivicSmart maintenance personnel.

Each of the technology vendors can work with FDOT to integrate their parking sensor data into the SunGuide® software system. The main report should be consulted for further details. Pricing information was provided in a supplemental document for confidentiality reasons. Additionally, due to the number of variables involved and rapidly evolving industry, pricing is very time sensitive. Thus, the vendors should be consulted for precise pricing information for any given application.

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Chapter 1: Introduction

Background Statement

Rest areas along Florida's interstate routes are heavily utilized by commercial trucks for overnight parking. Many of the rest areas regularly experience over-capacity utilization of the commercial truck parking spaces during the evening and early morning hours [1]. Currently, information on the number of available commercial truck parking spaces at Florida rest areas is not available remotely. Thus, aside from obtaining this information through direct communication with someone already on site, a truck driver's only sure way of determining if parking is available at a rest area is to stop at the rest area. Being able to communicate commercial truck parking space availability to drivers in advance of arriving at a rest area would reduce unnecessary stops at full rest areas as well as driver anxiety.

Project Objective and Tasks

The objective of this project is to evaluate available vehicle detection technologies as applied to commercial truck parking areas of interstate rest areas in the state of Florida. This evaluation addresses several aspects: (1) the accuracy of the vehicle detection in parking spaces, (2) cost of the technology, (3) installation, setup, and maintenance of technology, (4) sensor output integration with SunGuide® software, and (5) sensor durability (to the extent this was possible over the relatively short duration of this project).

The specific tasks performed as part of this project are as follows.

1. Identify vehicle detection technologies for use in project — In this task, the research team reviewed the literature and vehicle sensor technology vendor web sites to identify potential vehicle parking detection technologies available for this application.
2. Site visit for ground-truth data collection equipment installation — The vehicle parking technologies were tested at two rest areas within FDOT District 2, located in FDOT rest area facilities 20161 (I-75 northbound) and 20162 (I-75 southbound) in Columbia County at milepost 413 of I-75 (GPS coordinates: 29.978335, -82.57862). Video equipment was installed at the rest areas to record video as the ground-truth data.

3. Collect ground-truth data — After the installation of the video equipment, the data collection commenced. Since the start dates of the vendors were different, the amount of data collected for each vendor was different, but at least one month of video data for each vendor was collected. The amount of data used for accuracy tests was a function of several factors: the truck parking demand, the accuracy rate of the parking detection equipment, and the desired statistical confidence range of the measured accuracy rate. For accuracy tests, the research team obtained the raw data collected from the vehicle sensors and compared with the ground-truth data.
4. Parking data analysis — The following were conducted in this task:
    - reduced the ground-truth data
    - analyzed the ground-truth data
    - compared the ground-truth results to the data obtained from the parking detection technology, and evaluated the accuracy of the vehicle detection technology with respect to parking space utilization
    - gathered information on other aspects of each parking detection technology from participating vendors; for example: installation, SunGuide® integration, cost, durability/maintenance, etc.

Chapter 2: Vehicle Detection Technologies

There are several vendors that sell a product, or products, that are designed solely for the purpose of vehicle parking detection or a multi-purpose detector that they claim can be applied to parking situations. After reviewing the literature and vehicle sensor technology vendor web sites, five vendors were identified that had previous experience in this area or were moving into this area. These five vendors were contacted and given the opportunity to participate in this project. Two of the vendors decided that they were not ready for a test deployment. The three vendors/products that did participate in the project are:

1. NEDAP/IPsens/SENSIT[1] (http://www.nedapidentification.com/products/sensit/)
2. Sensys (http://www.sensysnetworks.com/products/microradar)
3. CivicSmart (http://www.civicsmart.com/)

The vehicle detection technologies above feature wireless in-pavement sensors, which detect the presence of a vehicle as it parks within a boundary around them. The specific technologies used in each sensor are given in Table 1.

Table 1. Vehicle detection technologies

Vendors	SENSIT	Sensys	CivicSmart
Technologies	Magnetic and Infrared	Microwave Radar	Microwave Radar
Operating frequency	902-928 MHz	2400-2483.5 MHz	2.4 GHz (2405-2480 MHz)

The following descriptions of each of the technologies is largely copied or paraphrased from the manufacturer literature, the references for which are contained at the end of the report.

1 Also used in study “Commercial Motor Vehicle Parking Trends at Rest Areas and Weigh Stations”, FDOT report BDK80 977-14, December 2012.

SENSIT

The manufacturer of SENSIT products is Nedap Identification Systems of the Netherlands. In this project, the vehicle detection technology system was provided, integrated and installed by IPsens, LLC (http://ipsens.net/).

According to IPsens personnel, IPsens has been involved in enterprise software development and systems implementation for 41 years and continues to serve in this capacity with large enterprise customers such as NYCPD and NYCDOT. The Nedap SENSIT sensor is currently installed in several countries around the world and has a demonstrated continuous operations record of 5+ years with no sensor replacements required due to battery depletion. The SENSIT system is also installed in several other Truck Parking Installations around the world.

The following description of SENSIT vehicle detection system components were based on the product sheets obtained from the company's website [2].

Nedap's wireless vehicle detection sensors, which are mounted in the pavement of individual parking spots, detect vehicle presence and send that information to a central server. The SENSIT IR is a vehicle detection sensor featuring dual detection technology. The sensors feature earth magnetic field and infrared detection. According to the vendor, the combined detection effectively detects vehicles using a sophisticated algorithm to ensure detection is invulnerable to snow, dirt, and leaves. According to the vendor, the sensors are designed to be vandalism resistant.

The actual status (occupancy) of the sensor is transmitted to the Relay Node, which is part of the wireless mesh network. The Relay Node 2G is a wireless communication unit for on-street applications and is used to relay the messages to a Data Collector. The Relay Node 2G is a fully wireless unit, ensuring easy installation onto nearby posts/poles. According to the vendor, once installed, no maintenance is required for years.

The Data Collector IP65 GPRS is the interface between the vehicle detection sensors, the Relay Node and the IPsens software. The Data Collector IP65 GPRS collects actual status data from the individual sensors via the Relay Node through the wireless mesh network. Offering a variety of communication options, the Data Collector IP65 GPRS automatically inserts all the collected data in the database. Integration with parking guidance, traffic guidance, and enforcement systems can be realized on a server level. The Data Collector IP65 GPRS allows users to operate, maintain, or configure the equipment in the wireless mesh network using bidirectional communication with the systems components. The Data Collector features a back-up battery to ensure the wireless mesh network will remain operational even in case of power failure. Additionally, the Data Collector can be connected to the power source of a light pole or solar power panel. Detailed product specifications are included in Appendix A.

Figure 1. SENSIT vehicle detection technology components

Note: From left to right is SENSIT IR, Relay Node 2G and Data Collector IP65 GPRS.
(Source: http://www.nedapidentification.com/products/sensit/)

Sensys

The MicroRadar sensor from Sensys Networks is an ultra-low power, in-pavement, patented radar sensor, compatible with the entire Sensys Networks' product suite. MicroRadar can detect the onset of parking events and the clearance of cars/trucks from spaces. MicroRadar installs seamlessly as a supplement to existing wireless detection systems, lowering costs by leveraging existing infrastructure and communications. The following description of the Sensys vehicle detection system components were based on the product sheets obtained from the company's website [3].

Sensys Networks VSN240-MP-2 MicroRadar sensor incorporates an extremely low power, wide-band, fixed-position radar with a Sensys NanoPower (SNP) Protocol radio. This compact in-pavement sensor works on the same principle as any other radar. High frequency radio frequency (RF) pulses are transmitted, reflected off a target object, and measured by a time-gated return RF mixer. The MP-2 version incorporates a higher sensitivity radar design and a modified case with tabs to aid installation flush with the road surface—allowing the installation to avoid issues with snowplows and ADA compliance/pedestrian tripping hazards. The MP-2 has specific stability tracking algorithms optimized for parking.

The Sensys Networks Access Point Controller Card (APCC) is a second-generation controller card that maintains low power consumption, supports multiple radios, and allows for additional communication and processing power. The APCC, which is compatible with all of the Sensys Networks VDS240 Wireless Vehicle Detection System products, receives and processes data from the sensors. The APCC then relays the sensor detection data to a roadside traffic controller or remote server traffic management system. Detailed product specifications are included in Appendix B.

Figure 2. Sensys vehicle detection technology components

Note: From left to right is Sensys MicroRadar and Access Point Controller Card (APCC).
(Source: http://www.sensysnetworks.com/products/flexradar#parkingdetection)

CivicSmart

CivicSmart is a technology services and engineering company that specializes in the development and delivery of innovative parking and transportation offerings. CivicSmart is an innovator of "Smart City" parking products, technologies, and services, including vehicle detection sensors, smart parking meters, wireless handheld enforcement devices, and comprehensive data management systems. CivicSmart delivers these Smart City solutions through their wholly owned subsidiary, Duncan Parking Technologies, Inc., which has provided innovative parking equipment, services, and systems to municipalities around the world for nearly 80 years. Today, 2,000 jurisdictions manage their parking programs with the help of a million of their parking devices. These clients include Miami-Dade County, FL; Jacksonville, FL; New Orleans, LA; Atlanta, GA; Chicago, IL; Detroit, MI; North Sydney, Australia; and Harare, Zimbabwe. The following description of CivicSmart vehicle detection system components were based on the information obtained from the company's website [4], as well as product sheets provided by CivicSmart personnel.

For Florida's truck parking occupancy program, CivicSmart proposed the use of in-pavement vehicle detection sensors. The patented vehicle detection sensors use microwave radar-based technology to detect a vehicle entering or leaving a space. According to CivicSmart, the accuracy of the sensors is immune to environmental conditions, passing or adjacent vehicles, and electromagnetic interference. The sensors feature directional radar, which means that they can be installed anywhere near a parking space. Additionally, the sensors use radio waves to transmit data, which means that they are not affected by conditions that plague other sensor technologies (ambient light, color, weather, night/low light, etc.).

The sensors communicate through solar-powered gateways that transmit sensor data to a backend management system for action and analysis. Diagnostic data is sent to CivicSmart so it can monitor the health and "heartbeat" of each node in the State's truck parking system. In-pavement sensors will completely self-configure and communicate directly via a gateway to the server system (either directly to SunGuide® or to their Parking Enterprise Management System). These gateways will be located within a few hundred feet of the sensor, and are typically installed on light poles, parking signs, or traffic signal poles.

The solar-powered gateways feature proprietary low latency, noise-tolerant communications technology, which receives sensor data and can send it to the traffic management center either wirelessly or via a fiber connection. Detailed product specifications are included in Appendix C.

Figure 3. CivicSmart vehicle detection technology components

Note: From left to right is in-pavement sensor and solar-powered gateway.
(Source: http://www.civicsmart.com/)

The main points of contact for each of the vendors are listed in Table 2.

Table 2. Contact information of vendors

Vendor	Name	Email	Phone
IPsens	Gorm Tuxen	gorm.tuxen@ipsens.net	(888) 705-1196
Sensys	Sheldon Pafford	Sheldon.pafford@temple-inc.com	(386) 615-4866
CivicSmart	Bradley Magee	BMagee@civicsmart.com	(480) 510-1557

Chapter 3: Test Site

The vehicle parking technology was tested at two rest areas within FDOT District 2. The sites are located in FDOT rest area facilities 20161 (I-75 northbound) and 20162 (I-75 southbound) in Columbia County at milepost 413 of I-75 (GPS coordinates: 29.978335, -82.57862). An aerial view of this site is shown in Figures 4-6. The Columbia county site has two truck parking areas, as listed in Table 3.

Figure 4. Location and aerial view of Columbia County rest area

Table 3. Columbia County rest area information

Facility Name	Rest area northbound	Rest area southbound
Interstate Number	I-75	
Milepost	MP 413	
FDOT Facility Number	20161	20162
Prior Exit Number	Exit 404	Exit 414
# of Truck Parking Spaces	49	49

Figure 5. Southbound rest area

Figure 6. Northbound rest area

The commercial truck parking space in the rest area has the following approximate dimensions:

- length = 82 feet,
- width = 15 feet, and
- angle = 30 degrees.

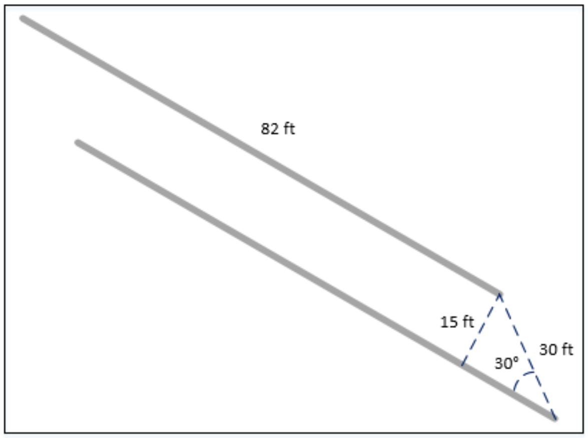


Figure 7. Parking space specifications

Chapter 4: Installation of Technologies

SENSIT

The sensors are placed in a 3-inch-deep core-drilled hole in the pavement. The sensor is designed for use of non-toxic standard mortar mix to hold it in place. The research team observed that the installation was easy, and the water-based mortar makes for easy clean-up after installation.

The process of installing the SENSIT sensor into the road includes the following steps:

1. Find and mark the desired sensor location.
2. Core a hole 3 inches (7.6 cm) deep into the pavement.

Figure 8. Core a hole into the pavement

3. Vacuum or brush the hole clear of dust and debris.

Figure 9. Vacuum the hole

4. Place sensor until the ring sits flush against the pavement and apply the non-toxic standard mortar mix to hold it in place.

Figure 10. Place sensor to the hole

Relay Node 2G should be preferably mounted at about 3-6 meters [10-20 ft] from the floor/ground (e.g., onto a light pole) to allow for line-of-sight with the sensors. The relay node shall visually see the sensors at an angle. The relay nodes are mounted on four light poles in the rest area to receive signal from the sensors.

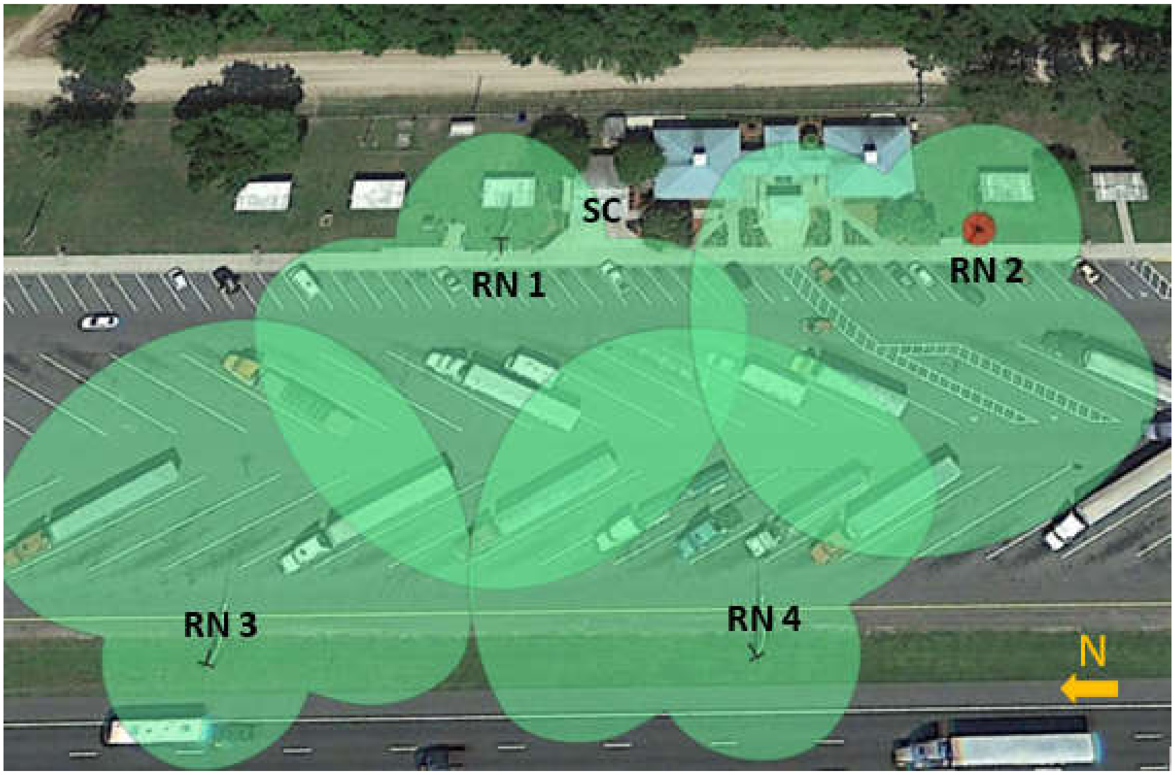


Figure 11. Installed relay nodes

Note: 'SC' is site controller, 'RN' is relay node.
(Source: provided by IPsens personnel)

The Site Controller is mounted on the wall of a building of the rest area. The Site Controller is the main interface point connecting all sensors in its service area with the Cloud Host Server through a cellular modem to the internet or alternative hardline TCP/IP, fiber connection to Host Server. The Site Controller incorporates the Data Collector IP65 GPRS, which is the end data termination point for the local sensor network. If the Site Controller is configured for direct TCP/IP connection, cellular modem can be offered as a backup connectivity option.

The Site Collector is equipped with UPS power supply, which offers additional redundancy to the system's ability to store information on the Sensors in case of loss of connectivity to the site. Site Controller also includes surge protection and power supply to convert from 120V AC to 5V DC to power all internal components.

Figure 12. Installed site controller

Sensys

Again, the research team observed that the installation process for the Sensys detectors was simple. The process of installing the MicroRadar sensor into the road included the following steps:

1. Find and mark the center of the desired sensor location.

Figure 13. Find and mark the sensor location

2. Core a hole approximately 4 inches (10.2 cm) in diameter, and 3 inches (7.6 cm) deep into the pavement. Check depth as you drill, remove debris periodically.

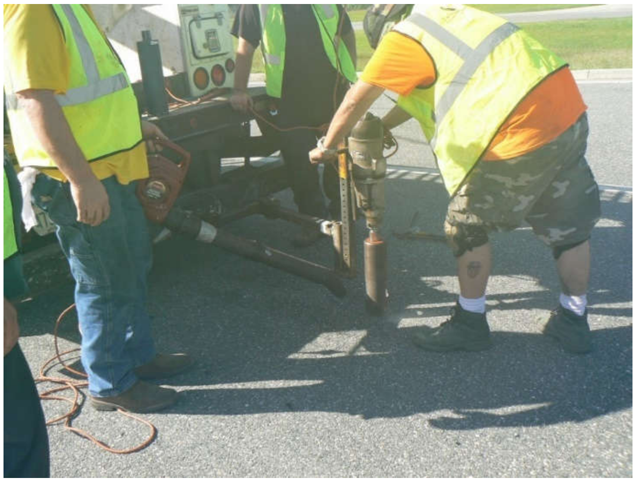


Figure 14. Core a hole into the pavement

3. Vacuum or brush the hole clear of dust and debris. Ensure that the hole is dry as moisture may impede the curing of the epoxy. If moisture is observed, use the heat-gun or torch to dry the inside of the hole completely.
4. Apply epoxy to the bottom of the hole to half of the sensor height.
5. Place sensor until the ring sits flush against the pavement.

Figure 15. Place sensor in the hole

6. Fill hole with epoxy until level to road surface.

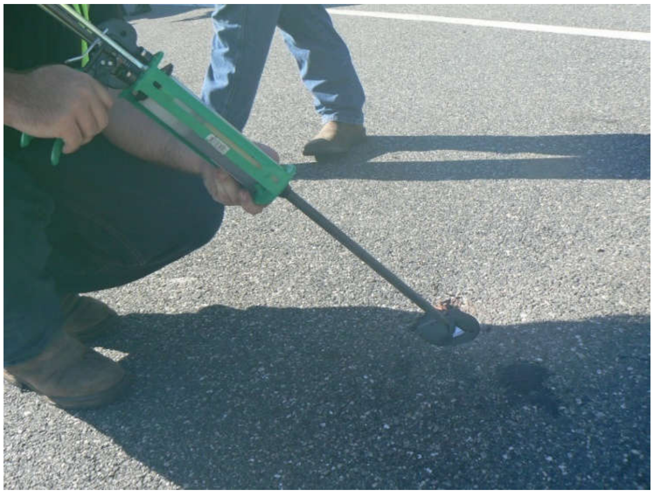


Figure 16. Fill hole with epoxy

CivicSmart

Again, the research team observed that the installation process for the CivicSmart detectors was simple. The in-pavement sensor installation requires the following tools:

1. core drill bit (diamond-embedded recommended)
2. drill motor or coring stand with cooling source (e.g., water)
3. wet vacuum (water trap recommended)
4. marking paint or chalk
5. digging/chipping tool
6. tape measure
7. sensor node assemblies.

The detector installation includes the following steps:

1. Ensure the pavement is solid and stable for each sensor that is to be installed. Mark the drilling point for each parking space, and place drilling equipment over mark. Using a 140-mm core drill bit, drill to a depth of 80 mm into the concrete or asphalt surface. Remove plug.

Figure 17. Mark the drilling point and drill a hole

2. Align the orientation of the sensor on the node (as shown above) to the corresponding type of parking space.
3. Place the sensor node into the hole. Confirm that the top of the sensor enclosure is 6 mm above the ground surface. Then apply epoxy glue around the sensor node.

Figure 18. Put sensor into the hole

The gateway installation requires the following tools:

- ladder (tie down cinch, if needed)
- hammer drill
- hose clamps: Qty. 3 (size dependent on mounting pole diameter)
- Allen bolts: Qty. 2 (M5 x 40 mm)
- Allen wrench and gateway assembly.

The gateway installation includes the following steps:

1. Choose a hose clamp respective of the mounting pole diameter. Slide the hose clamp into the slots provided in the solar mount bracket.
2. Tighten the adjustable hose clamp. For the top bracket only, use a 0.5 to 7 N-m torque capacity and 7-mm socket nut driver.
3. Mark the height from the top pole mount clamp edge to adjust the angle required using a measuring tape and marker. Separation between clamps for different elevation angles are as follows:
   - 25° – 850 mm
   - 50° – 575 mm
   - 75° – 175 mm
4. Using a 7-mm socket nut drive, tighten the hose clamp bolt on the bottom pole mount bracket.
5. Slide the hose clamp into the slots of the gateway mounting brackets.
6. Affix the gateway assembly onto the gateway mounting brackets using an M5x25 mm Allen bolt and tighten using 4-mm Allen key. Affix the gateway mount below the solar mount bracket to the pole.

Installation Time

For this project, all three vendors installed the sensors and other relevant equipment that covered the 10 parking spaces within 2-3 days. After the installation of the parking sensors and related equipment, each vendor spent 1-2 weeks tuning and calibrating their system. It should also be noted that while all the detectors were installed in asphalt pavement at this site, all of the vendors noted that their detectors are also easily installed in concrete pavement.

Chapter 5: Data Collection

Vendor Parking Spaces Assignment

Each of the three vendors was assigned to a 10-space section on either the northbound side or southbound side of the rest area. To avoid possible interference among the signals of the different vendors, vendors with similar operating frequencies were not located on the same side. The parking space assignment plan for the vendors is shown in the Table 4.

Table 4. Vendors allocation plan

Vendor	**SENSIT**	**Sensys**	**CivicSmart**
Frequency	902 – 928 MHz	2400 – 2483.5 MHz	2405 – 2480 MHz
Placement	Northbound	Southbound	Northbound
Sensors per space	3	3	2

The parking space assignment for the vendors is illustrated in Figures 19 and 20. CivicSmart was the second vendor that installed their sensors at the northbound rest area, so there were constraints about their equipment locations in order to avoid possible interference with the SENSIT equipment that had already been installed. However, it is not known whether this had any impact on the performance of the CivicSmart system.

Figure 19. Southbound rest area vendor parking space distribution (Sensys)

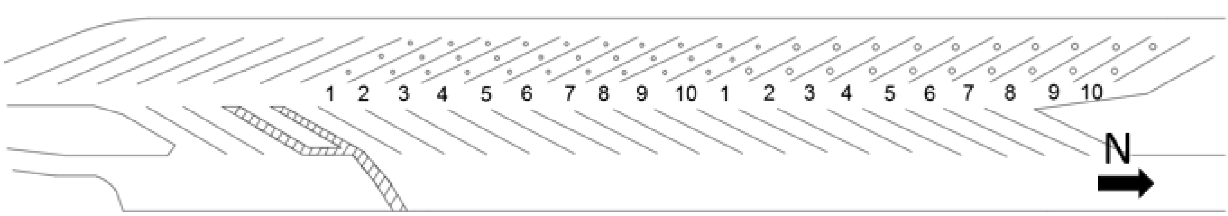


Figure 20. Northbound rest area vendor parking space distribution (left: SENSIT, right: CivicSmart)

Video Installation

The project used video cameras to record the truck parking area as the ground-truth data—two cameras for the northbound rest area and one camera for the southbound rest area. The cameras were mounted to the top of light poles in the rest area. Figure 21 illustrates the video camera installation set up and approximate fields-of-view for the two northbound side camera installations. Figure 22 shows a picture of one of the camera installations—camera mounted to the top of the light pole (35 ft), which is connected with video and power transmission cables running through PVC conduit, which connect to a battery and digital video recorder (DVR) inside a Pelican case that is chained to the light pole. Figure 23 shows the fields-of-view from the three cameras.

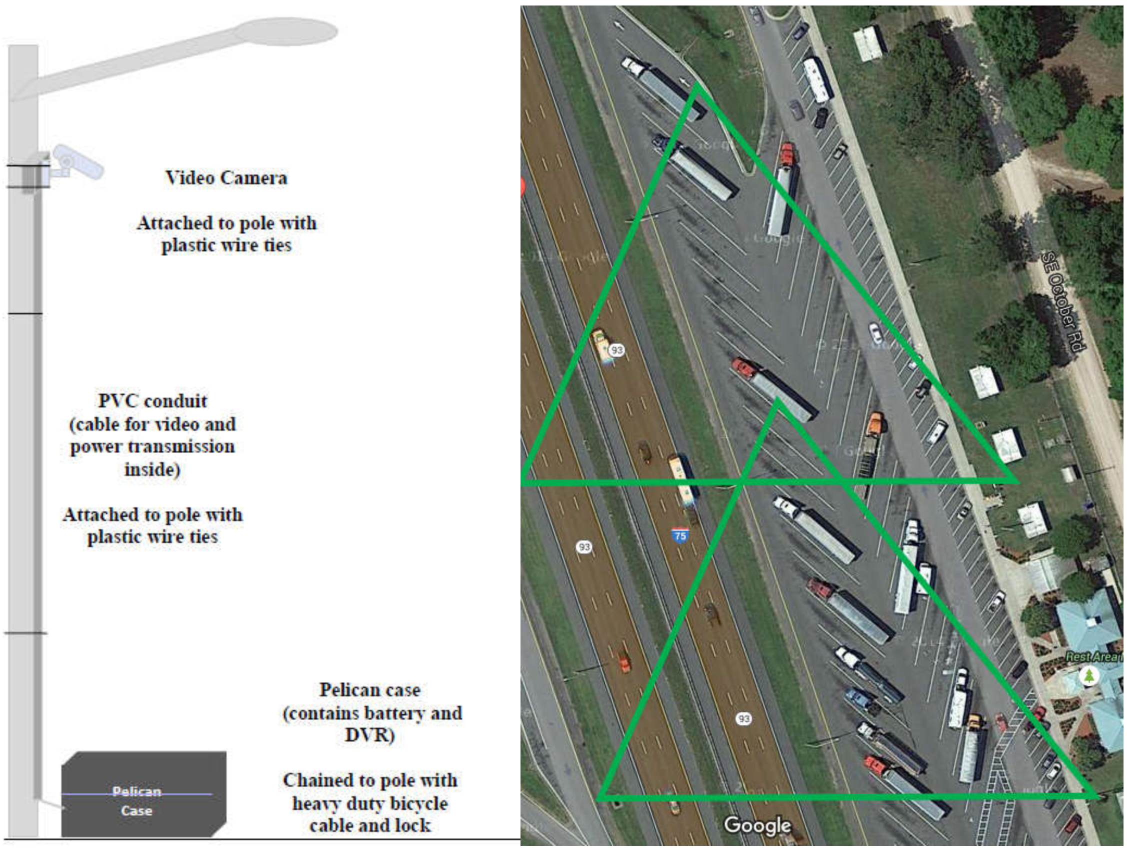


Figure 21. Camera installation schematic and camera range

Figure 22. Installed camera, PVC conduit, and Pelican case

Figure 23. Camera view (From top to bottom: SENSIT, Sensys, and CivicSmart)

Collect Video Ground-Truth Data

Once the video equipment was installed, and the vendors were finishing with calibrating their sensors, the data collection commenced. Video was recorded at the parking rest area for several weeks:

- SENSIT and CivicSmart: 8/10/2016 - 10/05/2016
- Sensys: 8/24/2016 - 10/05/2016

Chapter 6: Tests and Evaluation of the Parking Detection Technologies

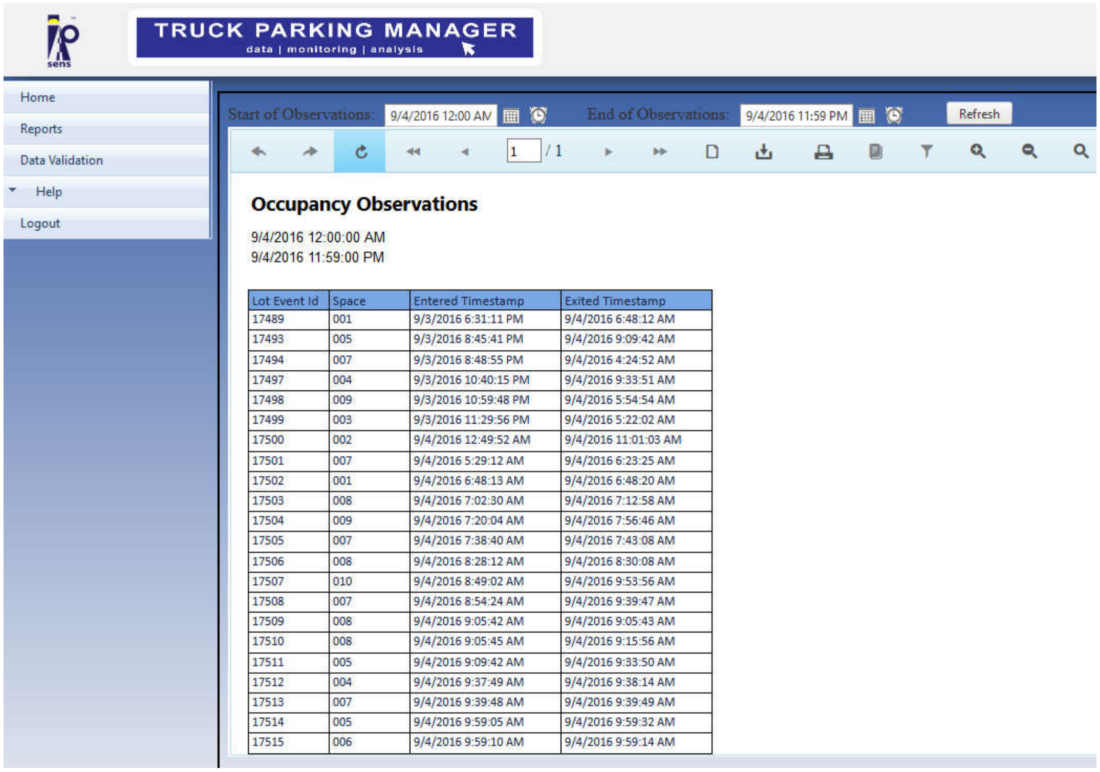
Video Data Reduction

The ingress and egress movements of each vehicle were recorded manually. The manually recorded data included the following information for each entering/exiting truck:

1. parking space number
2. time entered space
3. time exited space
4. vehicle type (such as truck with no trailer, truck with vehicle trailer, truck with flatbed trailer, truck with closed trailer, truck with double closed trailer, truck with tanker trailer, single unit truck, RV, other: personal car, etc.).

The research team developed a data analysis software tool to process and analyze the data. The manually recorded video data are saved into CSV-formatted files to be loaded into the software tool for further analysis.

The research team obtained the raw data collected by the vehicle sensors and compared them with the ground-truth data for the accuracy tests. The raw data of SENSIT sensors were collected from the company's backend system, the Truck Parking Manager, as shown in Figure 24. The raw data of Sensys sensors were collected from the company's backend system, the Sensys Networks Archive Proxy and Statistics (SNAPS) system, as shown in Figure 25. The raw data of CivicSmart were provided by their personnel in CSV-formatted files, as shown in Figure 26. The CSV-formatted files of the raw data from the sensors can be loaded into the data analysis software tool developed by the research team for accuracy tests. A brief introduction of the software tool is included in Appendix E.

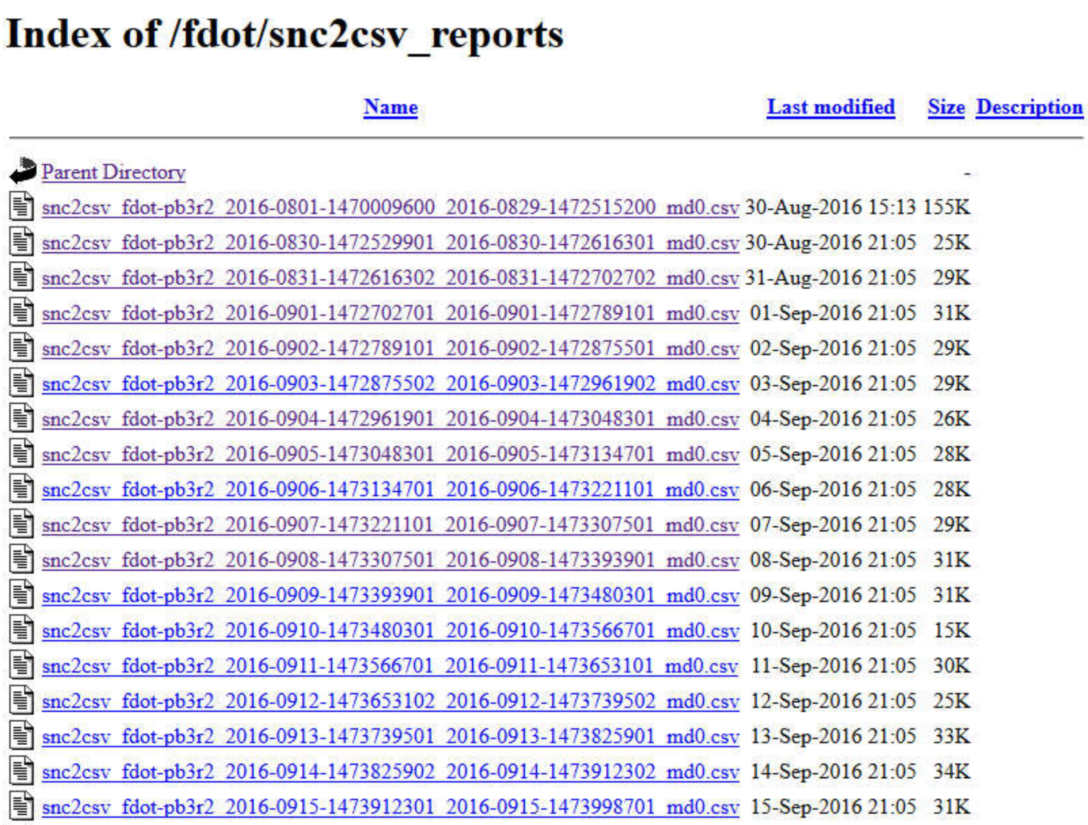


Occupancy Observations

9/4/2016 12:00:00 AM
9/4/2016 11:59:00 PM

Lot Event Id	Space	Entered Timestamp	Exited Timestamp
17489	001	9/3/2016 6:31:11 PM	9/4/2016 6:48:12 AM
17493	005	9/3/2016 8:45:41 PM	9/4/2016 9:09:42 AM
17494	007	9/3/2016 8:48:55 PM	9/4/2016 4:24:52 AM
17497	004	9/3/2016 10:40:15 PM	9/4/2016 9:33:51 AM
17498	009	9/3/2016 10:59:48 PM	9/4/2016 5:54:54 AM
17499	003	9/3/2016 11:29:56 PM	9/4/2016 5:22:02 AM
17500	002	9/4/2016 12:49:52 AM	9/4/2016 11:01:03 AM
17501	007	9/4/2016 5:29:12 AM	9/4/2016 6:23:25 AM
17502	001	9/4/2016 6:48:13 AM	9/4/2016 6:48:20 AM
17503	008	9/4/2016 7:02:30 AM	9/4/2016 7:12:58 AM
17504	009	9/4/2016 7:20:04 AM	9/4/2016 7:56:46 AM
17505	007	9/4/2016 7:38:40 AM	9/4/2016 7:43:08 AM
17506	008	9/4/2016 8:28:12 AM	9/4/2016 8:30:08 AM
17507	010	9/4/2016 8:49:02 AM	9/4/2016 9:53:56 AM
17508	007	9/4/2016 8:54:24 AM	9/4/2016 9:39:47 AM
17509	008	9/4/2016 9:05:42 AM	9/4/2016 9:05:43 AM
17510	008	9/4/2016 9:05:45 AM	9/4/2016 9:15:56 AM
17511	005	9/4/2016 9:09:42 AM	9/4/2016 9:33:50 AM
17512	004	9/4/2016 9:37:49 AM	9/4/2016 9:38:14 AM
17513	007	9/4/2016 9:39:48 AM	9/4/2016 9:39:49 AM
17514	005	9/4/2016 9:59:05 AM	9/4/2016 9:59:32 AM
17515	006	9/4/2016 9:59:10 AM	9/4/2016 9:59:14 AM

Figure 24. Raw data of SENSIT sensors



Index of /fdot/snc2csv_reports

Name	Last modified	Size	Description
Parent Directory		-	
snc2csv_fdot-pb3r2_2016-0801-1470009600_2016-0829-1472515200_md0.csv	30-Aug-2016 15:13	155K	
snc2csv_fdot-pb3r2_2016-0830-1472529901_2016-0830-1472616301_md0.csv	30-Aug-2016 21:05	25K	
snc2csv_fdot-pb3r2_2016-0831-1472616302_2016-0831-1472702702_md0.csv	31-Aug-2016 21:05	29K	
snc2csv_fdot-pb3r2_2016-0901-1472702701_2016-0901-1472789101_md0.csv	01-Sep-2016 21:05	31K	
snc2csv_fdot-pb3r2_2016-0902-1472789101_2016-0902-1472875501_md0.csv	02-Sep-2016 21:05	29K	
snc2csv_fdot-pb3r2_2016-0903-1472875502_2016-0903-1472961902_md0.csv	03-Sep-2016 21:05	29K	
snc2csv_fdot-pb3r2_2016-0904-1472961901_2016-0904-1473048301_md0.csv	04-Sep-2016 21:05	26K	
snc2csv_fdot-pb3r2_2016-0905-1473048301_2016-0905-1473134701_md0.csv	05-Sep-2016 21:05	28K	
snc2csv_fdot-pb3r2_2016-0906-1473134701_2016-0906-1473221101_md0.csv	06-Sep-2016 21:05	28K	
snc2csv_fdot-pb3r2_2016-0907-1473221101_2016-0907-1473307501_md0.csv	07-Sep-2016 21:05	29K	
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snc2csv_fdot-pb3r2_2016-0909-1473393901_2016-0909-1473480301_md0.csv	09-Sep-2016 21:05	31K	
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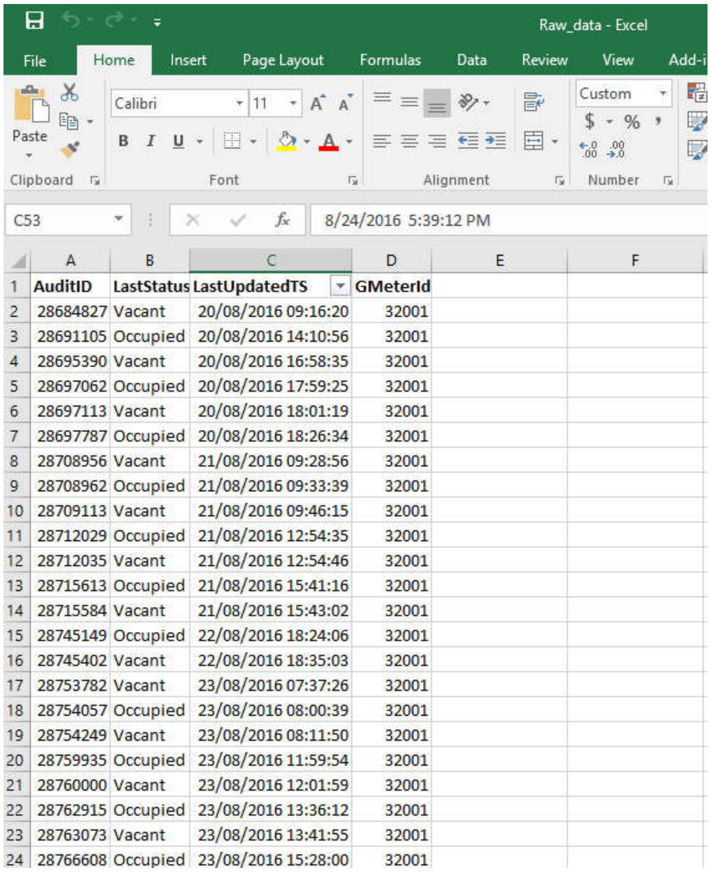
snc2csv_fdot-pb3r2_2016-0911-1473566701_2016-0911-1473653101_md0.csv	11-Sep-2016 21:05	30K	
snc2csv_fdot-pb3r2_2016-0912-1473653102_2016-0912-1473739502_md0.csv	12-Sep-2016 21:05	25K	
snc2csv_fdot-pb3r2_2016-0913-1473739501_2016-0913-1473825901_md0.csv	13-Sep-2016 21:05	33K	
snc2csv_fdot-pb3r2_2016-0914-1473825902_2016-0914-1473912302_md0.csv	14-Sep-2016 21:05	34K	
snc2csv_fdot-pb3r2_2016-0915-1473912301_2016-0915-1473998701_md0.csv	15-Sep-2016 21:05	31K	

Figure 25. Raw data of Sensys sensors



	AuditID	LastStatus	LastUpdatedTS	GMeterId
2	28684827	Vacant	20/08/2016 09:16:20	32001
3	28691105	Occupied	20/08/2016 14:10:56	32001
4	28695390	Vacant	20/08/2016 16:58:35	32001
5	28697062	Occupied	20/08/2016 17:59:25	32001
6	28697113	Vacant	20/08/2016 18:01:19	32001
7	28697787	Occupied	20/08/2016 18:26:34	32001
8	28708956	Vacant	21/08/2016 09:28:56	32001
9	28708962	Occupied	21/08/2016 09:33:39	32001
10	28709113	Vacant	21/08/2016 09:46:15	32001
11	28712029	Occupied	21/08/2016 12:54:35	32001
12	28712035	Vacant	21/08/2016 12:54:46	32001
13	28715613	Occupied	21/08/2016 15:41:16	32001
14	28715584	Vacant	21/08/2016 15:43:02	32001
15	28745149	Occupied	22/08/2016 18:24:06	32001
16	28745402	Vacant	22/08/2016 18:35:03	32001
17	28753782	Vacant	23/08/2016 07:37:26	32001
18	28754057	Occupied	23/08/2016 08:00:39	32001
19	28754249	Vacant	23/08/2016 08:11:50	32001
20	28759935	Occupied	23/08/2016 11:59:54	32001
21	28760000	Vacant	23/08/2016 12:01:59	32001
22	28762915	Occupied	23/08/2016 13:36:12	32001
23	28763073	Vacant	23/08/2016 13:41:55	32001
24	28766608	Occupied	23/08/2016 15:28:00	32001

Figure 26. Raw data of CivicSmart sensors

Although the parking detection technologies should be insensitive to lighting conditions, Table 5 provides the number of daylight and nighttime hours used in the data analysis for each vendor.

Table 5. Number of daytime and nighttime data for each vendor

	SENSIT	Sensys	CivicSmart
Daytime (h)	70	84	96
Nighttime (h)	64	84	16

The overall weather condition during the data collection period was warm and humid, with frequent rains. The research team conducted a brief analysis of the ground-truth data regarding the day of week parking space occupation, parking hours, and parking vehicle types, detailed figures and statistics are provided in Appendix G.

Accuracy Tests

Two accuracy tests were applied for evaluation of the parking detection technologies in this preliminary analysis: turnover accuracy and occupancy accuracy. The turnover accuracy test evaluates the sensor's ability to identify parking events (parking ingress or egress) correctly. The occupancy accuracy test evaluates the percentage of time in which the sensors report the status of the parking spaces (vacant or occupied) correctly. Table 6 provides the accuracy test results of the three technologies. More detailed results of the accuracy test are included in Appendix D.

Table 6. Accuracy tests results

Technology	Number of parking events	Turnover accuracy (%)	Turnover ratio (parking events/h)	Number of hours	Occupancy accuracy (%)
SENSIT	1073	95.25	8.01	134	97.36
Sensys	776	97.94	4.62	168	99.15
CivicSmart	488	96.11	4.45	112	97.20

In this project, each parking space has two or three sensors (depending on the vendor). For all vendors, the method used to identify an occupied parking space is that at least one of the detectors needs to be in the 'on' status (vehicle over or near the detector). Conversely, if all the sensors in the space are in the 'off' position, the parking space is considered to not be occupied. Then, the parking space status obtained from the sensor is compared to the ground-truth data for accuracy tests. In this case, the accuracy includes turnover/occupancy by any type of vehicle.

The turnover ratio (average number of parking events per hour) is also shown for each vendor, as an informational item to give an indication of the amount of parking activity in each vendor's set of assigned spaces. This measure should not be interpreted as necessarily being correlated with the accuracy of the respective systems. Given that truck drivers typically park in the closest available space to the entrance of the rest area, these turnover ratio values match our expectations. That is, since the SENSIT detectors were closer to the entrance of the rest area than the Sensys and CivicSmart detectors, we would expect a higher turnover ratio for the SENSIT spaces.

Table 7 shows the 95% confidence interval of the turnover accuracy for each detection technology. The confidence interval is calculated based on the number of events (n) and the turnover accuracy (p), assuming a binomial distribution, as shown in Equation 1.

$$\textbf{Confidence Interval} = \hat{p} \pm z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}, \alpha = 5\% \quad \textbf{(1)}$$

Where:

α is the statistical significance level
n is the number of parking events for a specific vendor
p is the turnover accuracy for a specific vendor

Table 7. Turnover accuracy confidence interval

	SENSIT	Sensys	CivicSmart
Number of parking Events (n)	1073	776	488
Turnover Accuracy (p)	95.25%	97.94%	96.11%
95% Conf. Interval	94%-97%	97%-99%	94%-98%

With respect to the difference in the number of events between the vendors, the following should be noted:

- The confidence interval values would not change for Sensys if it had the same number of parking events as SENSIT, and assuming the p value remained unchanged.
- The confidence interval for CivicSmart would change to 95%-97% if it had the same number of parking events as SENSIT, and the p value remained unchanged. Because of the issues described earlier, the sample size for CivicSmart was smaller than the sample size for the other vendors.

Despite the different number of parking events across vendors, the relatively narrow range of the 95^{th} percentile confidence interval values for each vendor shows that the accuracy results are fairly stable.

Observations

This section describes the issues, if applicable, that were observed in the data analysis process that may explain particular results.

SENSIT

- One issue is that the sensors sometimes generate more events than the ground-truth data. For example, the video showed that a truck had been parked continuously in a space for 2 hours, but the sensors might report several 'on'/'off' events during that same period. However, the time intervals corresponding to these events might be between only 10-40 seconds. In this case, the SENSIT algorithm for reporting parking events is properly accounting for these short duration changes in sensor status, as the sensors normally have certain lag time to change status, so that the occupancy status would not be affected. Further testing may identify situations where the parking status is incorrectly reported because of longer duration incorrect readings of the sensor(s).

Sensys

- During one analysis period (9/3/16) of the Sensys detector data, there was a period (16:20 – 17:10) of very heavy rain. Nearly all of the incorrect readings of the Sensys detectors happened during this heavy-rain period. During non-rain periods, the accuracy of the Sensys detectors was very high. However, this was a one-time observation, no similar observations were found by the research team among other observations under raining conditions. The accuracy results under raining conditions, for all vendors, can be found in Table 17 in Appendix D.
- According to information provided by Sensys personnel: Some preliminary results indicate that small amounts of ice and sheeting water will not degrade performance, although the manufacturer is cautious to make this claim for all icing and sheeting/standing water conditions as testing has been limited.

CivicSmart

- The CivicSmart sensors also have the same issue of multiple events of several seconds duration described above, but the parking occupancy status should not be affected if the interval of events is small, as the sensors normally have a certain lag time before they change status.

- CivicSmart inadvertently activated the sleep mode of their sensors, which means that events from 8 PM to 6 AM were not detected. In this case, the accuracy analysis for CivicSmart only focused on the time period of 6 AM to 8 PM.
- According to CivicSmart personnel, there was a server outage in the staging server on their data center, which may have caused latency in the data.
- CivicSmart lost readings from one sensor for three weeks (8/19 – 9/7). They fixed it on 9/12.
- During 9/16 and 9/17, CivicSmart personnel went to the site for calibration of their sensors and ended up having problems with their sensor IDs. A CivicSmart representative said the data from 9/16 – 10/03 could not be used because of the issue, and correct data from the sensors was provided after 10/03.
- The CivicSmart sensor data and the ground-truth data (video) used to have a 2-minute offset (i.e., time-stamp difference). However, on September 1st, between 6 AM to 8 PM, the offset changed to 6 minutes. From September 1st, the offset between CivicSmart sensor data and ground-truth data has remained 6 minutes. This issue was raised with CivicSmart representatives, and they said it is because their domain controller was off by six minutes for two weeks in September.
- Again, another issue is that the sensors sometimes generate more events than the ground-truth data; for example, the video might show a truck that had been parked continuously in a space for 2 hours, but the sensors might report several events during that same time period. However, the time intervals corresponding to these events might be between only 10-40 seconds. Further testing may identify situations where the parking status is incorrectly reported because of longer duration incorrect readings of the sensor(s).

Appendix F contains additional information from the vendors about the inaccurate parking detection events.

Integration with SunGuide® System

The following information has largely been provided by the vendors and has not been independently verified by the research team, as a full integration and testing exercise was beyond the scope of the project.

SENSIT

IPsens can use its Truck Parking Manager Application to integrate with the SunGuide system, as illustrated in Figure 27, but again, was not tested by the research team. The Truck Parking Manager (TPM) application is the central data system for the IPsens solution. According to the vendor, for the system components capacity, each data collector can support up to 15 relay nodes max and 500 SENSIT nodes max (ground sensors) per Data Collector. Theoretically the maximum number of sensors in one network is about 65,000 but in general the above scale is applied for optimal system performance. This cloud hosted, or centrally served and controlled, application connects all information from every sensor at every site to support the following key operations:

1. Import, analyze, and compile all raw data from the field-deployed sensor systems.
2. Function as the central management interface for all operational data collected through field-deployed devices such as sensors. Compiles final data output for every space through an algorithm monitoring the combined status of all sensors in a space.
3. Advanced Maintenance Monitoring conducts automated analysis of the status and of individual systems components while also running algorithms to alert of unusual behavior of the systems as a whole. Tracks pending maintenance alert status and work orders while compiling a historical record of system operability and issues reported.
4. Consolidated data monitoring of all operational data from every monitored parking availability site.
5. Parking availability centric reporting capabilities, with a multitude of pre-designed and custom reporting options.
6. Open IP data exchange through a secure REST web service for further data integration into other 3rd party enterprise type systems.

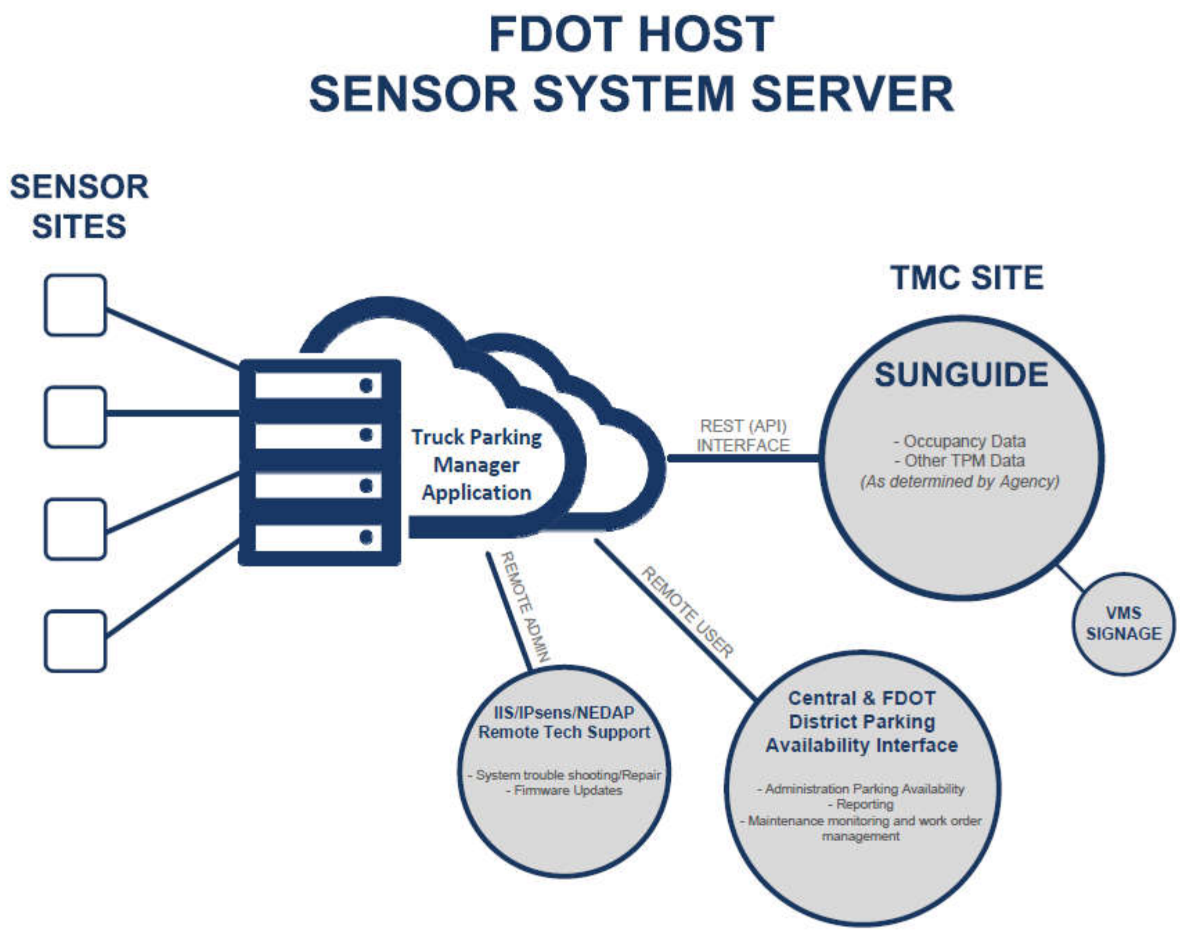


Figure 27. IPsens integration with SunGuide®

(Source: provided by IPsens personnel)

Additional information provided by SENSIT was included in a supplemental document.

Sensys

In conjunction with the Sensys Networks Access Points (AP) and Parking Session servers the system can manage thousands of deployed sensors, archive data and monitor the health of the system. According to the vendor, the SNAPS (Sensys Networks Archive Proxy and Statistics) software can handle up to 200 Access Points (AP), and each access point can handle hundreds of MicroRadar units. Sensys suggests that each remote parking site could utilize a single AP, allowing up to 200 sites with a single server license. SNAPS can be cloud or network based.

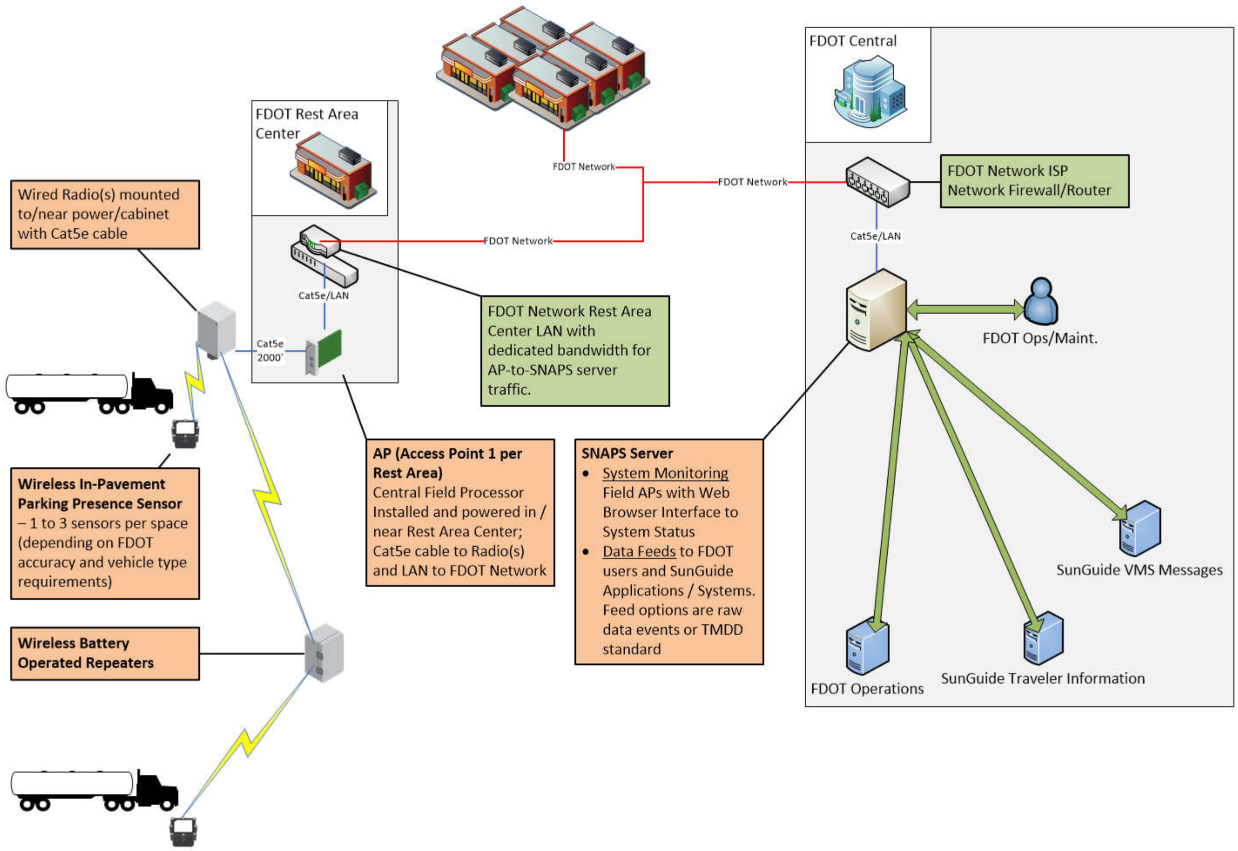
There are two SNAPS-based Parking APIs for server-to-server data interchange of Parking data. A REST API (XML feed) that uses simple web based calls. And a Traffic Management Data

Dictionary (TMDD) implementation that uses TMDD over SOAP. Both offer the same functionality. Both are fully documented in the SNAPS 2.16 Setup and Operating Guide Appendices (available on Sensys Networks' website).

Sensys has several large-scale deployments utilizing the SNAPS server architecture and data exchanged via XML interfaces, such as the Parkopedia and Parkme websites and smart phone applications.

The Institute of Transportation Engineers (ITE) Traffic Management Data Dictionary (TMDD) is an open standard set that anyone can use, and is recommended for use by agencies if they want to develop their central system to be open standard for vendor's data. Sensys Networks is working with the ITE TMDD Steering Committee, which is including parking occupancy and inventory data in its released standards.

Sensys Networks offers products with data feeds supporting the latest TMDD Standard for the Center to Center Communications (currently Version 03.03a), including "Parking Information" datasets that define lot/space inventory and space status/occupancy schema. Sensys Networks server software products implement the Owner Center side of the C2C interface.



Another option exists for interfacing between SunGuide® and directly from the Sensys system in the field, called Event Proxy. Event Proxy is a real-time system that would run on each AP and delivery a “push” or “pull” timestamped for each unique sensor ID event. However, use of the direct field-to-FDOT SunGuide® server architecture (without use of SNAPS) would not allow for field equipment diagnostics/monitoring and buffered data transmit logic if communication is lost and restored. It could, however, be deployed on an AP in unison with a SNAPS server on the same network as FDOT SunGuide®.

CivicSmart

The PEMS system comes with a set of default RESTful Web service APIs to facilitate system integrations and interoperability between PEMS and DOT’s SunGuide® software systems. The API is designed to “PUSH” or “PULL” sensor data (or events) in real time for space occupancy information. The sensors/gateways post the sensor data (occupied and unoccupied) to an external server over HTTP/S from the PEMS servers. Sensor transactions will be posted to various systems or will be available to be pulled in real time – typically within a few seconds, no more than 30 seconds after the transaction time. According to the vendor, one gateway can handle 21 to 25 sensors, and the PEMS system has no specific limitation on the number of sensors to handle.

The services include "Get Space Inventory", "PULL Sensor Data", and "PUSH Sensor Data". The API specification document is included as part of our interface control document in the Appendices. The web services will use HTTP or HTTPS protocol to communicate. HTTPS protocol provides for end-point security and encryption/integrity of data during transmission. An SSL (Secure Sockets Layer) certificate helps validate end points and ensure the systems are communicating with each other. Additional Data transmission security is provided via Token bases authentication and IP Filtering. Any required interfaces will be configured as part of the PEMS systems installation.

The CivicSmart sensor system is designed to be flexible to adapt to a variety of solution architectures. The parking detector data can be sent directly to customer systems from the gateways. The system is capable of supporting custom APIs for this integration if required by the customer. CivicSmart's gateways can also be embedded in other products (such as message signs, parking meters, etc.). CivicSmart can also provide a light weight field device manager which will be a front end component that can be hosted within SunGuide systems. The below examples describe some of the ways the systems are currently deployed and illustrate the flexibility of the system:

1. In a city-wide deployment of sensors, the sensor data is being collected by CivicSmart gateways. CivicSmart gateways are integrated directly to the customer's backend and are transmitted via customer's own private APN. CivicSmart has access to diagnostic data and other information required for maintenance functions.

2. In a city-wide deployment of sensors, CivicSmart gateways are integrated into customer owned field equipment and the data is transmitted via a private network that is managed by the customer.

According to CivicSmart, they understand and support FDOT's need to be independent of vendor-owned backend and networks and they feel that they would have no problem meeting those requirements.

Durability/Maintenance

During the course of numerous site visits to exchange batteries and download video data, some brief observations were made of the parking sensors (where convenient). No visual damage was observed of the various detectors. While CivicSmart encountered a failure of one sensor, this appears to have been due to a faulty sensor rather than physical damage. The sensor was replaced in the field by CivicSmart maintenance personnel. It should be kept in mind, however, that the duration of this project was relatively short and observations of the detector conditions should be made by FDOT personnel in another several months.

The rest of the material in this section was provided by the vendors.

SENSIT

IPsens has developed its Advanced Maintenance Monitoring Application and services based on decades of experience in providing parking management applications and connecting various field data devices, such as hand held terminals and parking meters, to a centralized database.

This IPsens Application is comprised of the following key modules:

1. Diagnostics Engine

   The diagnostics engine has been developed to identify systems and component failures. In the case of parking sensors, this is based in part on the connected device's ability to communicate certain diagnostic codes such as battery status, battery failure, sensing status, battery consumption, loss of communication with system, etc.

   Secondly algorithms have been and will continue to be developed based on observed historical system performance and component behavior, to help anticipate and provide early notification of impending system problems.

2. Alert Notification

   Based on the continuous diagnostics monitoring of the system automated first level troubleshooting alerts are generated based on a pre-established priority hierarchy of the diagnosed problem.

   The diagnosed problems are sorted by severity based on its immediate impact on systems' data accuracy. For example, a lost communication failure to an entire parking site will be prioritized higher than the outage of a single attached device, such as an individual parking sensor. Based on the level and type of priority of the issue the system will generate an electronic message (email, sms) to the individual/entity designated as the first level maintenance provider.

3. Work Order Issuance

   Starting with the first notification of a problem, the system generates a first level troubleshooting work order to the designated service provider. First level trouble shooting will be undertaken by the maintenance provider, supported by IPsens technical staff for actual deep level diagnostics and remedial action.

   In the event first level troubleshooting and remote maintenance actions prove unsuccessful, the system provides the maintenance provider with the ability to generate a field maintenance order identifying the expected problem with a call for specific maintenance action to be undertaken.
   Severity status of the problem and requested time for completion in addition to the identification of specific components required on site will be issued as part of the work order.

4. Work Order Processing

   Work orders are issued directly on the Advanced Maintenance Monitoring Application and can be accessed through remote interface using a secure web browser interface. This allows the field maintenance operator the ability to use an internet enabled mobile device to access the work order and notate completion status and/or a call for further action required; in the field or in the back office.

5. Work Order History

   The system automatically tracks the status of all work orders issued by the system. A historical record is automatically generated that can provide information such as failure types by type of equipment, communication, site, space, frequency etc. It also tracks individual and compiled times for problem resolution by several different levels of detail. This feature provides a transparent record to the operator of the performance of equipment, system, and maintenance services.

6. Real Time Outage Map

   The Maintenance Monitoring Application provides a GIS based map of every deployed field device in every location. When a device and or location report a problem it will automatically be posted as a graphic presentation on a real time map in the application. The posted outage/problem identifier will be continued to be posted on the map until a work order has been closed out and the problem has been resolved.

7. Secure Support Interface Layer

   The Maintenance Monitoring Application runs as a secured module within the parking availability application. As such, the maintenance provider of the system can be completely isolated from all access to operational systems data, should the end user wish to do so.

8. Optional, 3rd Party API

   An optional 3rd party API can be provided allowing certain data contained in the Maintenance Monitoring Application to be shared with other data management systems that comply with an open data systems protocol.

9. Maintenance Monitoring Services

IPsens provides several services as part of their Maintenance Monitoring Application offering. These services are key to the systems maintenance-monitoring concept as it allows them to address and monitor problems at a very high level, which can ordinarily not be trained for with an operator of "IOT" devices as it is a constantly changing environment.

Their service offering includes the following components:
Application Maintenance and Updates. The operation of the system requires manned monitoring to generate and analyze the required historical performance; They undertake the task of monitoring systems behavior and identifying the patterns or events that form the basis for development of new or updated automated monitoring algorithms; They undertake all first level troubleshooting and remote repair actions. These can include things from a simple reset and device recalibration; to much more complicated actions such as remotely deploying new firmware upgrades to all devices.

Hardware Support Services. They work closely with all the hardware manufacturers to closely monitor performance and troubleshoot any items that reside outside our ability to address them; Services include reviewing and addressing the on-going performance of the manufactures devices; Additional services address the updating and issuance of new firmware, developed to address particular problems observed and/or the release of new firmware to address issues such as prolonging battery life of connected devices or special operator requirements. Having the hardware manufacturer involved, in cases where this is possible, is a definite advantage to the operator as it allows for problem resolution to include the on-going involvement of the engineers who designed the system [5].

Sensys

According to the Sensys personnel: "There is no required preventative maintenance for our products. They are self-calibrating and self-tuning. Expected parking sensor battery life is 8 years. Expected repeater battery life is 7 years. Only recommended maintenance is firmware updates for access points, radios, repeaters, and sensors. The system will record and report status of all batteries and stability (wireless signal strength, line quality, detection status, etc.), and provide maintenance alerts to user account emails if diagnostic values are exceeded."

CivicSmart

Parking Enterprise Management System (PEMS) comes packed with a full suite of real time and historic reporting, allowing the DOT to look at their truck parking program from multiple angles, from the performance of all sensors to the performance of a single sensor. This data may also be displayed on a tablet or handheld device/smartphone for increased efficiency among field staff.

Designated DOT personnel will have access to real-time alarms and status reporting for system monitoring and maintenance. In addition to these alarms being available through PEMS, they can also be sent via email or text to selected personnel, facilitating even faster maintenance and increasing system uptime.

All management reports are available through our web-based PEMS and can be accessed by authorized users from any computer with an internet connection and standard web browser.

Our PEMS system has a robust reporting mechanism that allows clients real-time and historic access to the data needed to effectively manage their program. The data presented in these reports can be segmented in myriad ways, including date and time, sensor location, and sensor activity. Essentially, this provides the DOT with unlimited report and data capabilities [6].

References

[1] Bayraktar, M. E., Zhu, Y., & Arif, F. (2012). *Commercial Motor Vehicle Parking Trends at Rest Areas and Weigh Stations* (Florida Department of Transportation Research Report BDK80-977-14). Florida International University, Miami, Florida.

[2] Nedap Identification Systems. (2016). *SENSIT Products*. Retrieved from http://www.nedapidentification.com/products/sensit/.

[3] Sensys Networks. (2016). *Sensys Products*. Retrieved from http://www.sensysnetworks.com/products.

[4] CivicSmart. (2016). *Wireless Vehicle Detection Sensors*. Retrieved from http://www.civicsmart.com/wireless-vehicle-detection-sensors/.

[5] IPsens, LLC. (2016). *Advanced Maintenance Monitoring Application & Services Pre-release documentation*. IPsens, LLC, Branson, Missouri.

[6] CivicSmart. (2016). *Proposal for University of Florida Truck Parking Sensors*. CivicSmart, Milwaukee, Wisconsin.

Appendix A

Technical Specifications for IPsens Truck Parking Detection Network Components

Table 8. Technical specifications for SENSIT IR

SENSIT IR	9898620
Operating frequency	902-928 MHz
Detection	Magnetic and IR
Detection height	0 … 90 cm [0 … 35.5 in]
Mounting	Into the floor
Mounting Dimensions	Total: 78 mm [3.07 in] and 73 mm [2.87 in] Above the floor: 20 mm [0.79 in] In the floor: 53 mm [2.09 in]
Weight	365 gram [12.87 oz]
Protection	IP67, completely sealed Housing PE
Material	Black Ployethylene
Operational temperature	-40 … +85°C [-40 …+ 185°F]
Storage temperature	-40 … +85°C [-40 …+ 185°F]
Power supply	Built in lithium battery
Expected lifetime	5-10 years

Table 9. Technical specifications for Relay Node 2G

Relay Node 2G	9212892
Operating frequency	902-928 MHz
Mounting	Onto a pole or wall, metal mounting bracket included
Suggested mounting height	3-6 meters [10-20 ft] from the floor onto a lamppost or pole
Pole dimensions	Min. 40 mm [1.57 in]; Max. 150 mm [6 in]
Wall mounting	With bracket using 4 screws
Weight	365 gram [12.87 oz]
Protection	IP65, completely sealed Housing ASA and Alu
Operational temperature	-40 … +85°C [-40 …+ 185°F]
Storage temperature	-40 … +85°C [-40 …+ 185°F]
Communication range	Relay Node 2G – SENSIT max. 35 m [135 ft] omnidirectional, 50 m [164 ft] directional Relay Node 2G – Relay Node 2G max. 100m [328 ft] Data Collector IP65 GPRS – Relay Node 2G max. 10m [33 ft]
Power supply	Replaceable lithium batteries with expected lifetime of 5-7 years

Table 10. Technical specifications for Data Collector IP65 GPRS

Data Collector IP65 GPRS	9966498
Operating frequency	868.2 MHz
Housing dimensions L×W×H	250 × 90 × 250 mm [9.9 × 3.5 × 9.9 in]
Weight	2200 gram [77 oz]
Protection	IP65
Operational temperature	-40 … +65°C [-40 …+ 149°F]
Storage temperature	-40 … +65°C [-40 …+ 149°F]
Communication range	The nearest node should be positioned within 10 m [33 ft] of the Data Collector IP65 GPRS.
Power supply	100-240Vac, 50-60 Hz, 15 VAC

Appendix B

Technical Specifications for Sensys Truck Parking Detection Network Components

Table 11. Technical specifications for MicroRadar

Sensys MicroRadar	VSN240-MP-2
Operating frequency	2400-2483.5 MHz
Detection	Micro radar
Mounting	Into the floor
Dimensions	2.9” × 2.9” × 2.3” [7.4 cm × 7.4 cm × 5.8 cm]
Weight	0.6 pounds / 0.3 kg
Protection	IP67 ingress protection
Operational temperature	-40 … +85°C [-40 …+ 176°F]
Power supply	Non-replaceable primary Li-SOCI23.6V battery pack 7.2 Ah (normal capacity)
Expected lifetime	8 years

Table 12. Technical specifications for Access Point Controller Card

Access Point Controller Card	
Operating frequency	2400-2483.5 MHz
Mounting	Any roadside location that provides adequate signal coverage to sensors/repeaters 1. No special requirements regarding setback, relative angle of the sun, or mounting stability
Dimensions	Single-slot: 7” × 4.5” × 1.1” (18 cm × 11.4 cm × 3 cm) Double-slot: 7” × 4.5” × 2.3” (18 cm × 11.4 cm × 6 cm) APCC-SPP: 4.7” × 3.5” × 2.4” (12 cm × 9 cm × 6 cm) Isolator: 6.5” × 3” × 1.3” (17 cm × 8 cm × 3 cm)
Weight	Single-slot: 7.9 oz (224 g) Double-slot: 10.5 oz (298 g) APCC-SPP: 14.1 oz (400 g) Isolator: 5.6 oz (159 g)
SPP enclosure rating	NEMA 4X
Operational temperature	Industrial -40 … +80°C
Input voltage	22-26 VDC (24VDC nominal) 9-15 VDC (12 VDC nominal)

Appendix C
Technical Specifications for CivicSmart Truck Parking Detection Network Components

Table 13. Technical specifications for In-pavement Vehicle Detection Sensor

In-pavement Vehicle Detection Sensor	
Operating frequency	2405-2480 MHz
Detection	Microwave radar
Mounting	Into the floor
Dimensions	144 mm × 89 mm
Weight	940 g
Protection	ASTM B117, ISO 9227 Salt Spray ASTM D1735 Humidity Testing IP67 environmental rating GMW 14872 Cyclic Corrosion
Operational temperature	-20 … +80°C
Power supply	3.6 V, 24 Ah Lithium Thionyl Chloride sealed unit
Expected lifetime	8 years

Table 14. Technical specifications for Solar-Powered Gateway

Solar-Powered Gateway	
Operating frequency	2405 - 2480 MHz
Dimensions	Enclosure: 110 mm × 75 mm × 75 mm
Weight	6 kg (including mount)
Protection	RoHS Compatible with FCC Part 15 Compatible with EN 300 440-1 IP54 environmental rating Compatible with ASTM B117, ISO 9227 Salt Spray Compatible with ASTM D1735 Humidity Testing
Operational temperature	-20 °C to 85°C
Power supply	Main power: 8.2 V rechargeable battery pack External power: 12 V, 10 Watt Solar Panel

Appendix D
Detailed Accuracy Test Results

Table 15. Accuracy test results

Technologies	Analysis period	Number of parking events	Turnover accuracy (%)	Number of hours	Occupancy accuracy (%)	General weather condition
IPsens	8/18/16: 8:00-23:59	208	93.27	16	97.89	Dry
	8/19/16: 0:00-23:59	218	97.71	24	97.88	Rain, Thunderstorm
	8/20/16: 0:00-17:00	158	100	24	98.99	Dry
	8/31/16: 0:00-22:00	206	95.15	22	98.27	Rain
	9/05/16: 0:00-23:59	131	93.13	24	96.24	Rain
	9/11/16: 0:00-23:59	152	91.45	24	95.12	Thunderstorm
	Sum	1073	**95.25**	134	**97.36**	
Sensys	9/01/16: 0:00-23:59	114	97.37	24	98.63	Rain, Thunderstorm
	9/03/16: 0:00-23:59	110	93.64	24	98.01	Rain, Thunderstorm
	9/05/16: 0:00-23:59	104	99.04	24	99.20	Rain
	9/06/16: 0:00-23:59	105	100.00	24	99.72	Dry
	9/09/16: 0:00-23:59	109	96.33	24	99.52	Dry
	9/11/16: 0:00-23:59	106	100.00	24	99.49	Thunderstorm
	9/14/16: 0:00-23:59	128	99.22	24	99.49	Rain, Thunderstorm
	Sum	776	**97.94**	168	**99.15**	
CivicSmart	8/20/16: 6:00-20:00	63	98.41	14	99.19	Dry
	8/24/16: 16:00-20:00	23	91.3	4	89.95	Dry
	8/25/16: 6:00-13:00	38	100	7	99.14	Dry
	8/26/16: 16:00-20:00	18	100	4	99.41	Dry
	8/27/16: 6:00-20:00	41	95.12	14	89.99	Dry
	8/28/16: 6:00-15:00	24	100	9	96.97	Dry
	8/31/16: 6:00-15:00	84	97.62	9	98.5	Rain
	9/01/16: 6:00-20:00	57	89.47	14	96.31	Rain, Thunderstorm
	9/04/16: 11:00-20:00	27	85.19	9	99.61	Rain, Thunderstorm
	9/05/16: 6:00-20:00	33	100	14	99.87	Rain
	9/09/16: 6:00-20:00	80	97.5	14	98.91	Dry
	Sum	488	**96.11**	112	**97.20**	

Table 16. Accuracy test results under raining conditions

Technologies	Analysis period	Number of parking events	Turnover accuracy (%)	Number of hours	Occupancy accuracy (%)	General weather condition
IPsens	8/19/16: 0:00-23:59	218	97.71	24	97.88	Rain, Thunderstorm
	8/31/16: 0:00-22:00	206	95.15	22	98.27	Rain
	9/05/16: 0:00-23:59	131	93.13	24	96.24	Rain
	9/11/16: 0:00-23:59	152	91.45	24	95.12	Thunderstorm
	Sum	707	**94.77**	94	**96.85**	
Sensys	9/01/16: 0:00-23:59	114	97.37	24	98.63	Rain, Thunderstorm
	9/03/16: 0:00-23:59	110	93.64	24	98.01	Rain, Thunderstorm
	9/05/16: 0:00-23:59	104	99.04	24	99.20	Rain
	9/11/16: 0:00-23:59	106	100.00	24	99.49	Thunderstorm
	9/14/16: 0:00-23:59	128	99.22	24	99.49	Rain, Thunderstorm
	Sum	562	**97.87**	120	**98.96**	
CivicSmart	8/31/16: 6:00-15:00	84	97.62	9	98.5	Rain
	9/01/16: 6:00-20:00	57	89.47	14	96.31	Rain, Thunderstorm
	9/04/16: 11:00-20:00	27	85.19	9	99.61	Rain, Thunderstorm
	9/05/16: 6:00-20:00	33	100	14	99.87	Rain
	Sum	201	**94.03**	46	**98.47**	

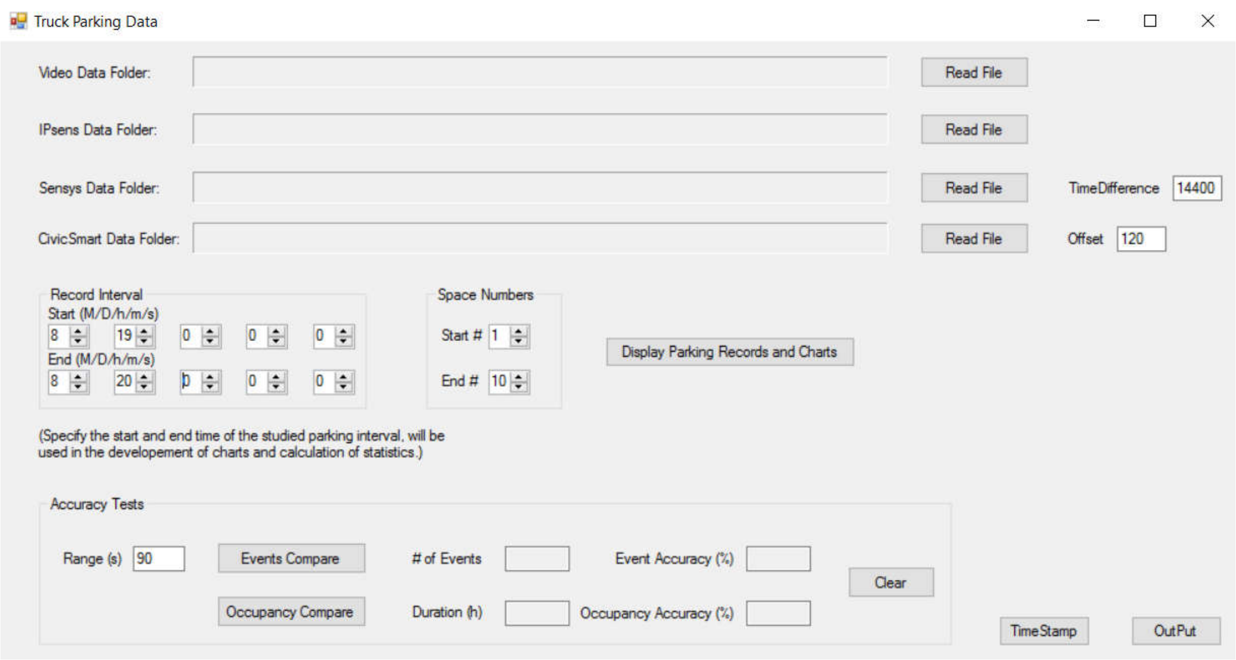
Appendix E

Overview of the Data Analysis Software Tool

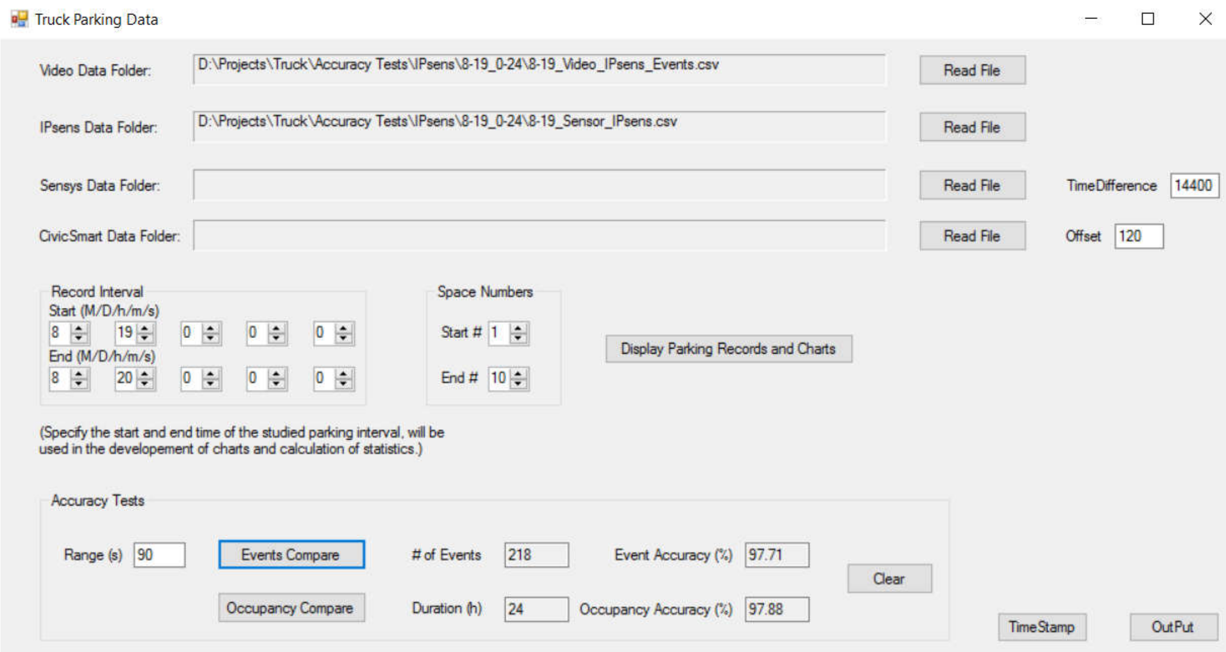
The following is a brief overview of the data analysis software tool developed for this project.

Main screen:

In the main screen, CSV-formatted files of video data and parking sensor data from each vendor can be loaded into the software for analysis. Detailed specifications (record interval, space numbers, the range of accepted error in seconds, etc.) can also be specified accordingly.

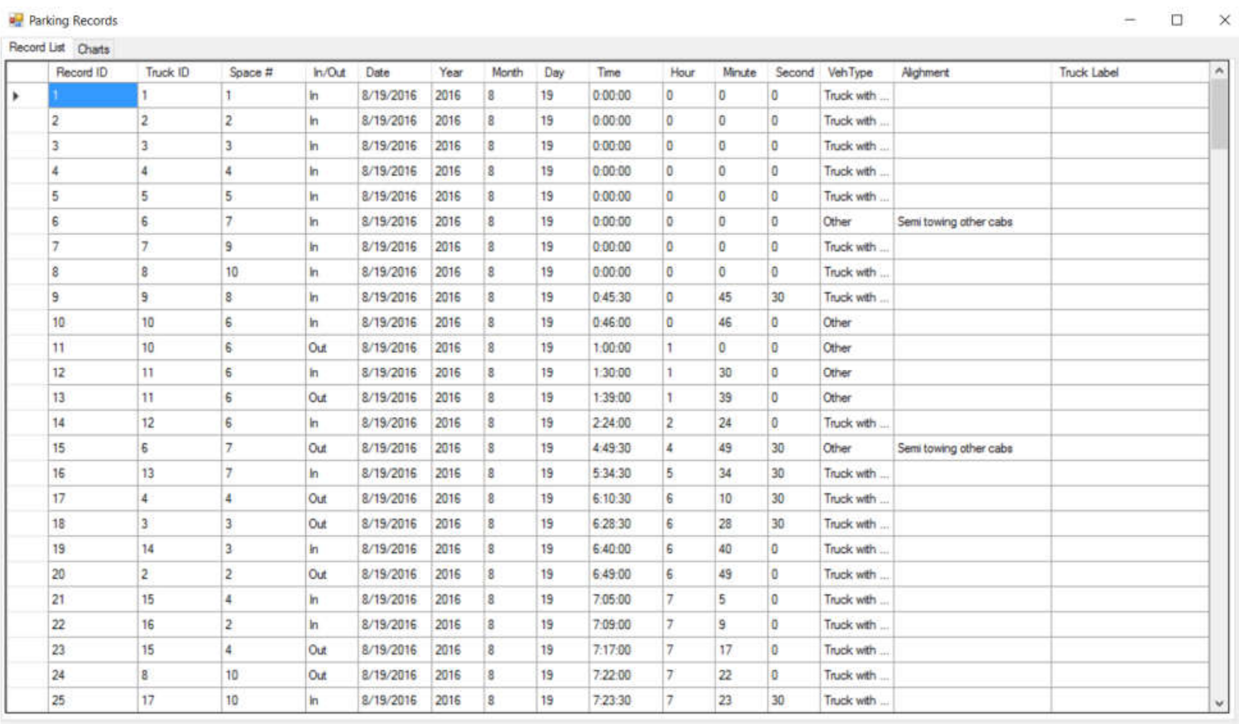


After loading the video data and sensor data files and specified the necessary information, click the "Events Compare" and "Occupancy Compare" buttons in the "Accuracy Tests" section, the number of events in the record, event accuracy (%) and the duration in hours, occupancy accuracy (%) will be calculated and displayed in the screen.



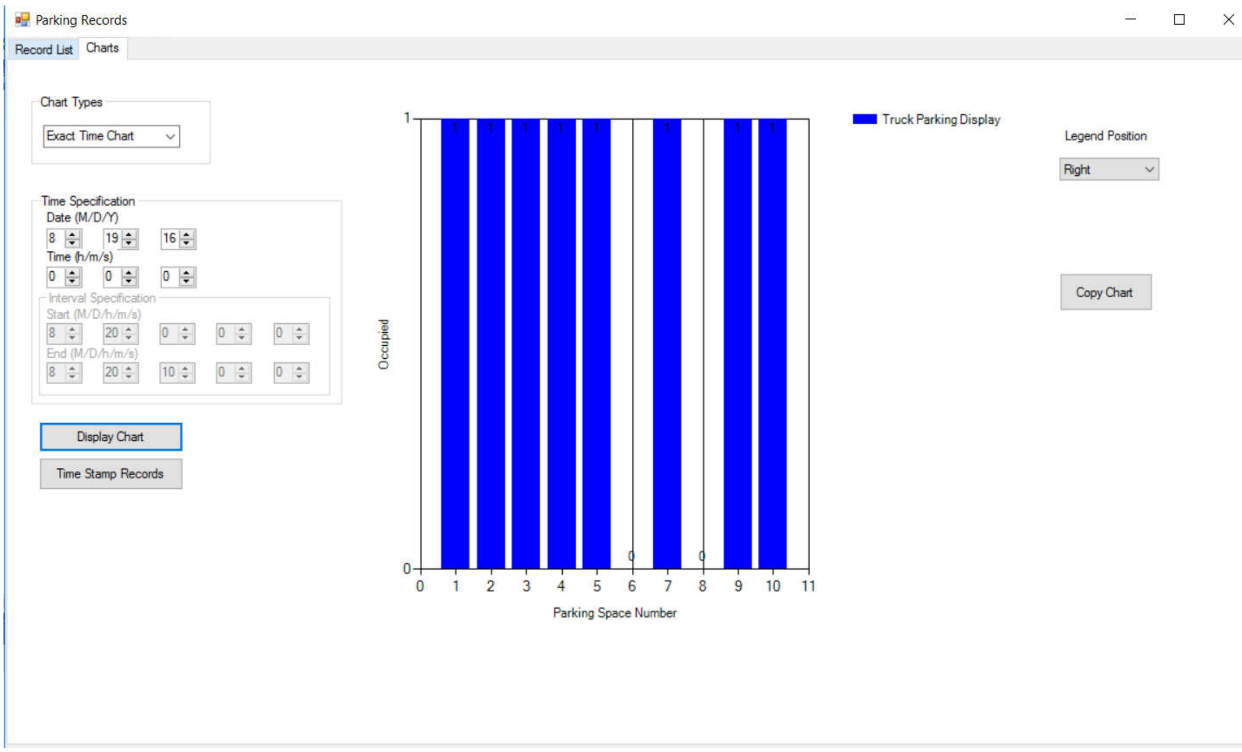
Parking records screen:

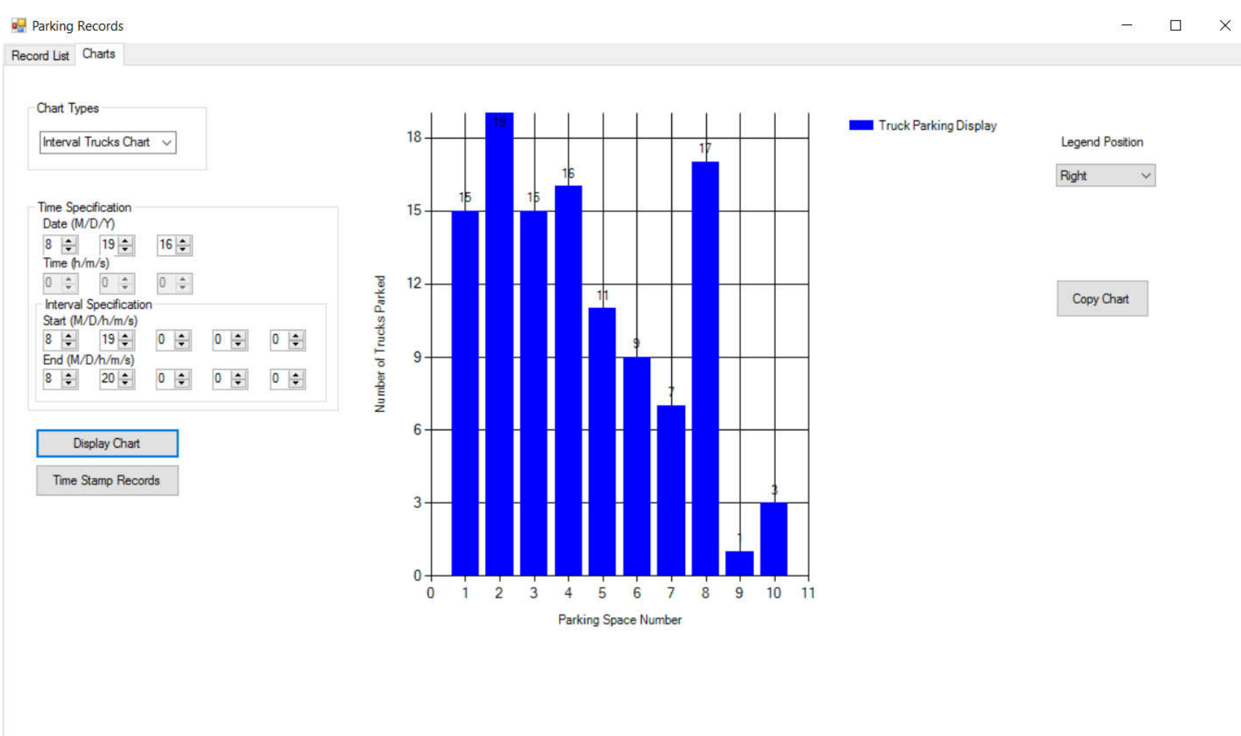
The software can also display the records from the loaded file and various kinds of charts by clicking the "Display Parking Records and Charts" button in the main screen.

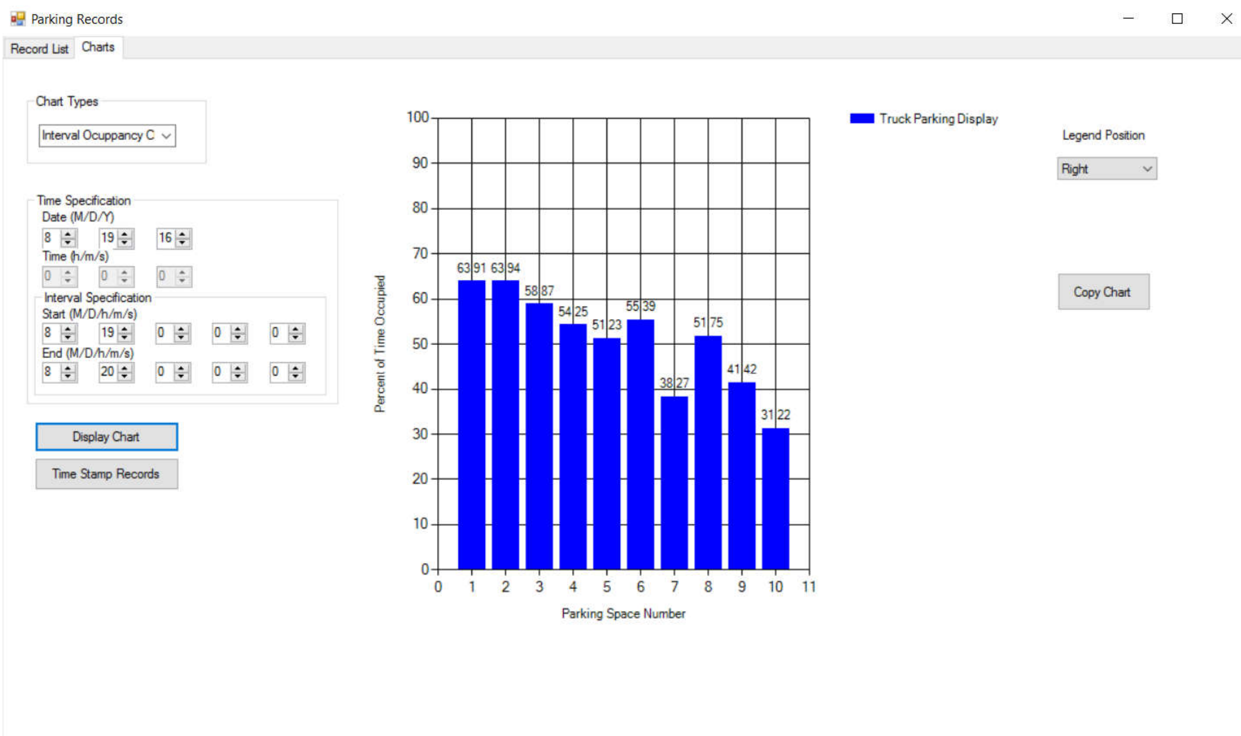


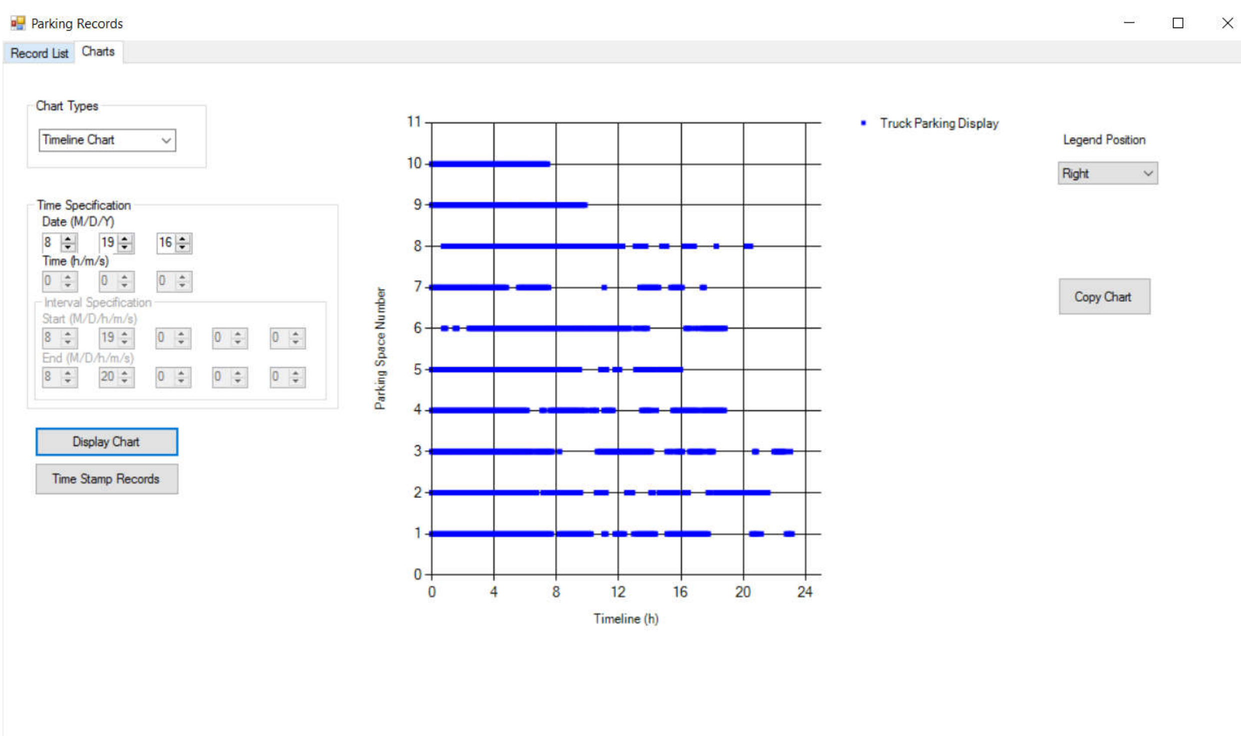
Record ID	Truck ID	Space #	In/Out	Date	Year	Month	Day	Time	Hour	Minute	Second	VehType	Alignment	Truck Label
1	1	1	In	8/19/2016	2016	8	19	0:00:00	0	0	0	Truck with ...		
2	2	2	In	8/19/2016	2016	8	19	0:00:00	0	0	0	Truck with ...		
3	3	3	In	8/19/2016	2016	8	19	0:00:00	0	0	0	Truck with ...		
4	4	4	In	8/19/2016	2016	8	19	0:00:00	0	0	0	Truck with ...		
5	5	5	In	8/19/2016	2016	8	19	0:00:00	0	0	0	Truck with ...		
6	6	7	In	8/19/2016	2016	8	19	0:00:00	0	0	0	Other	Semi towing other cabs	
7	7	9	In	8/19/2016	2016	8	19	0:00:00	0	0	0	Truck with ...		
8	8	10	In	8/19/2016	2016	8	19	0:00:00	0	0	0	Truck with ...		
9	9	8	In	8/19/2016	2016	8	19	0:45:30	0	45	30	Truck with ...		
10	10	6	In	8/19/2016	2016	8	19	0:46:00	0	46	0	Other		
11	10	6	Out	8/19/2016	2016	8	19	1:00:00	1	0	0	Other		
12	11	6	In	8/19/2016	2016	8	19	1:30:00	1	30	0	Other		
13	11	6	Out	8/19/2016	2016	8	19	1:39:00	1	39	0	Other		
14	12	6	In	8/19/2016	2016	8	19	2:24:00	2	24	0	Truck with ...		
15	6	7	Out	8/19/2016	2016	8	19	4:49:30	4	49	30	Other	Semi towing other cabs	
16	13	7	In	8/19/2016	2016	8	19	5:34:30	5	34	30	Truck with ...		
17	4	4	Out	8/19/2016	2016	8	19	6:10:30	6	10	30	Truck with ...		
18	3	3	Out	8/19/2016	2016	8	19	6:28:30	6	28	30	Truck with ...		
19	14	3	In	8/19/2016	2016	8	19	6:40:00	6	40	0	Truck with ...		
20	2	2	Out	8/19/2016	2016	8	19	6:49:00	6	49	0	Truck with ...		
21	15	4	In	8/19/2016	2016	8	19	7:05:00	7	5	0	Truck with ...		
22	16	2	In	8/19/2016	2016	8	19	7:09:00	7	9	0	Truck with ...		
23	15	4	Out	8/19/2016	2016	8	19	7:17:00	7	17	0	Truck with ...		
24	8	10	Out	8/19/2016	2016	8	19	7:22:00	7	22	0	Truck with ...		
25	17	10	In	8/19/2016	2016	8	19	7:23:30	7	23	30	Truck with ...		

Four kinds of charts could be displayed in the software: exact time chart, interval trucks chart, interval occupancy chart, and timeline chart.


Parking Records
Record List
Charts
Chart Types
Exact Time Chart
Time Specification
Date (M/D/Y)
8
19
16
Time (h/m/s)
0
0
0
Interval Specification
Start (M/D/h/m/s)
8
20
0
0
0
End (M/D/h/m/s)
8
20
10
0
0
Display Chart
Time Stamp Records
Occupied
Parking Space Number
Truck Parking Display
Legend Position
Right
Copy Chart


Parking Records
Record List
Charts
Chart Types
Interval Trucks Chart
Time Specification
Date (M/D/Y)
8
19
16
Time (h/m/s)
0
0
0
Interval Specification
Start (M/D/h/m/s)
8
19
0
0
0
End (M/D/h/m/s)
8
20
0
0
0
Display Chart
Time Stamp Records
Number of Trucks Parked
Parking Space Number
Truck Parking Display
Legend Position
Right
Copy Chart


Parking Records
Record List
Charts
Chart Types
Interval Ocuppancy C
Time Specification
Date (M/D/Y)
8
19
16
Time (h/m/s)
Interval Specification
Start (M/D/h/m/s)
End (M/D/h/m/s)
Display Chart
Time Stamp Records
Percent of Time Occupied
Parking Space Number
63.91
63.94
58.87
54.25
51.23
55.39
38.27
51.75
41.42
31.22
Truck Parking Display
Legend Position
Right
Copy Chart


Parking Records
Record List
Charts
Chart Types
Timeline Chart
Time Specification
Date (M/D/Y)
8
19
16
Time (h/m/s)
Interval Specification
Start (M/D/h/m/s)
End (M/D/h/m/s)
Display Chart
Time Stamp Records
Parking Space Number
Timeline (h)
Truck Parking Display
Legend Position
Right
Copy Chart

Appendix F
Vendors' Explanation of Incorrect Test Results

IPsens

After the research team conducted the accuracy tests and shared the results with IPsens, IPsens personnel requested the comparison data and ground-truth data for further examination. According to IPsens personnel, they were able to identify a filter issue that affected their results for 9/5 and 9/11. The following information is provided by the IPsens personnel.

Background:

The sensors can be set to report an event in a number of different modes as follow: Magnetic Only, IR Only, or Automatic. For purposes of this Automatic mode was chosen for all sensors. When in automatic mode the sensor will look primarily at the status of the IR, if the IR gets blocked, while the magnetic sensor sees additional events, a factory set filter will monitor this and reset the sensor to magnetic only sensing based on the threshold setting of the filter. Until the filter settings have been reached the unit will show occupied.

The IPsens sensor array for Truck Parking uses an algorithm which among other things contain the logic for how a space is deemed to be occupied as follow: The algorithm will sort by the automatic occupancy status from the sensor system, which in auto setting is IR first. If one or more sensors in an array shows occupied the space will be deemed occupied by the system for the duration, any changed input from remaining sensors in the space will be ignored for the duration until all occupied inputs have been cleared.

During the test on 9/05/16 this caused the following data anomalies:

In space 4, a small truck enters at 14:09 and departs at 14:29. (Line 86 & 91 in the attached sheet) It parks squarely between the front and middle sensor in the array and does not activate the IR to show occupied. Due to the auto setting on the sensors the event is missed by IR. However, when looking at the input data from the system the event was shown correctly when looking at the magnetic input only. We are currently looking to improve this in the future as a part of the completion of our vehicle classification algorithm, in such a way that the magnetic input would be considered in parallel with the IR input. For now, we consider these events missed.

In space 5, a truck enters at 15:17 and the IPsens algorithm shows the event continuing 11:56 the following day. Upon closer examination we have learned that one of the sensors in the array in space 5 experienced an IR blockage during this occupancy. With the auto sensor filter set in factory default settings this had the unintended consequence of locking the space in an occupied state until an automatic reset took place. This blockage caused the algorithm to ignore the following 7 observed events, which were all correctly identified by other sensors in the array. This can be very easily fixed by remotely changing the filter settings on the individual sensor in the manufacturers firmware settings to a level which takes the redundancy of the additional sensors into account. The filter was set for single sensor discrimination and not an array. We would like to request that these events be changed from missed to correct or be eliminated from the data file as we made an obvious error in correctly configuring the sensor filter settings for an array.

We reviewed the data for 9/11/16 and found issues similar to the ones found in the 9/05/16 files. It is reasonable to assume that taking the actions discussed below for 9/05/16 would yield similar improvements to the on-going data accuracy results going forward.

CivicSmart

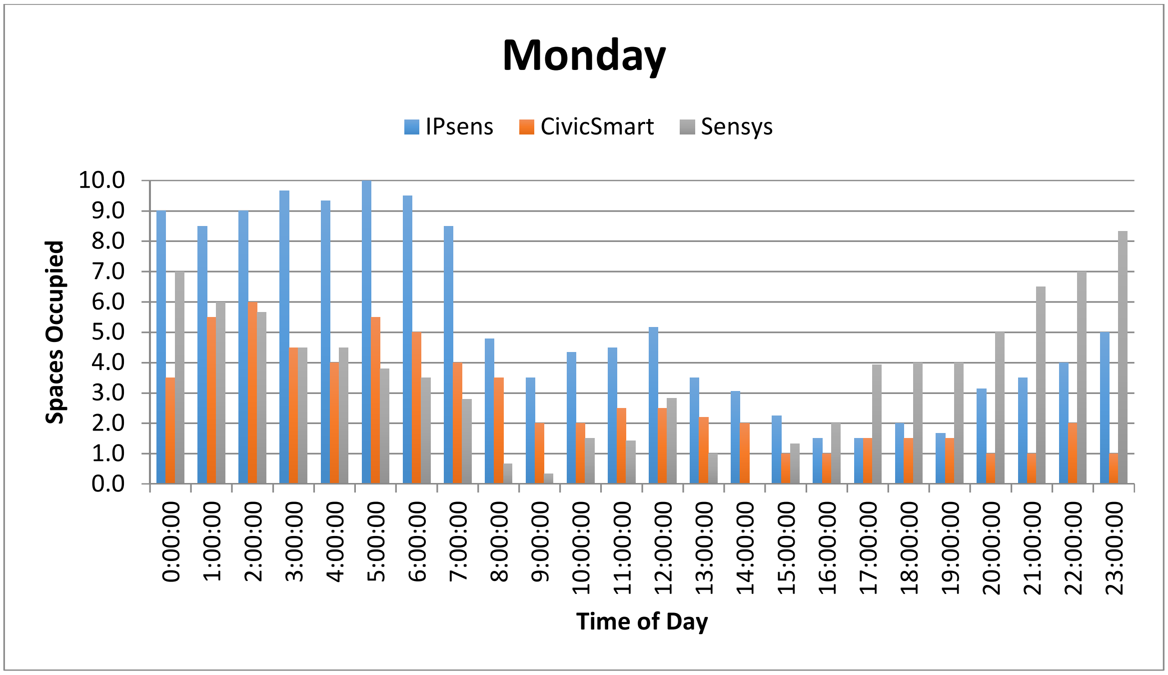
It should be noted that CivicSmart's performance was achieved using only 2 sensors per truck space instead of 3 sensors for the other two solutions. All the misses in CivicSmart's system were due to either 1) data reported by sensor, but ignored for the purposes of this analysis as the event time was off by more than 90 seconds on September 1st due to the sensor domain controller clock offset issue that CivicSmart experienced or 2) short vehicles that pulled up to the head of the space and missed the sensor. CivicSmart has stated that they have since corrected the sensor domain controller time using a network time standard and video analysis shows that moving the sensors by 5 feet within the space will capture short and long vehicles with just 2 CivicSmart sensors.

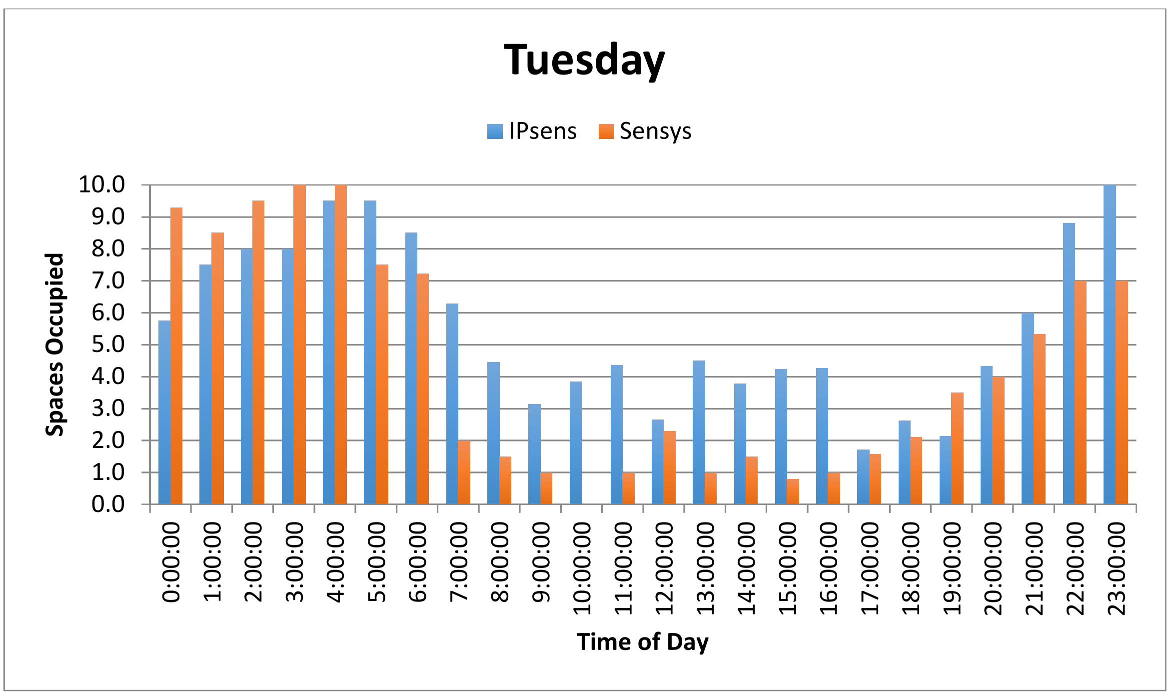
Appendix G

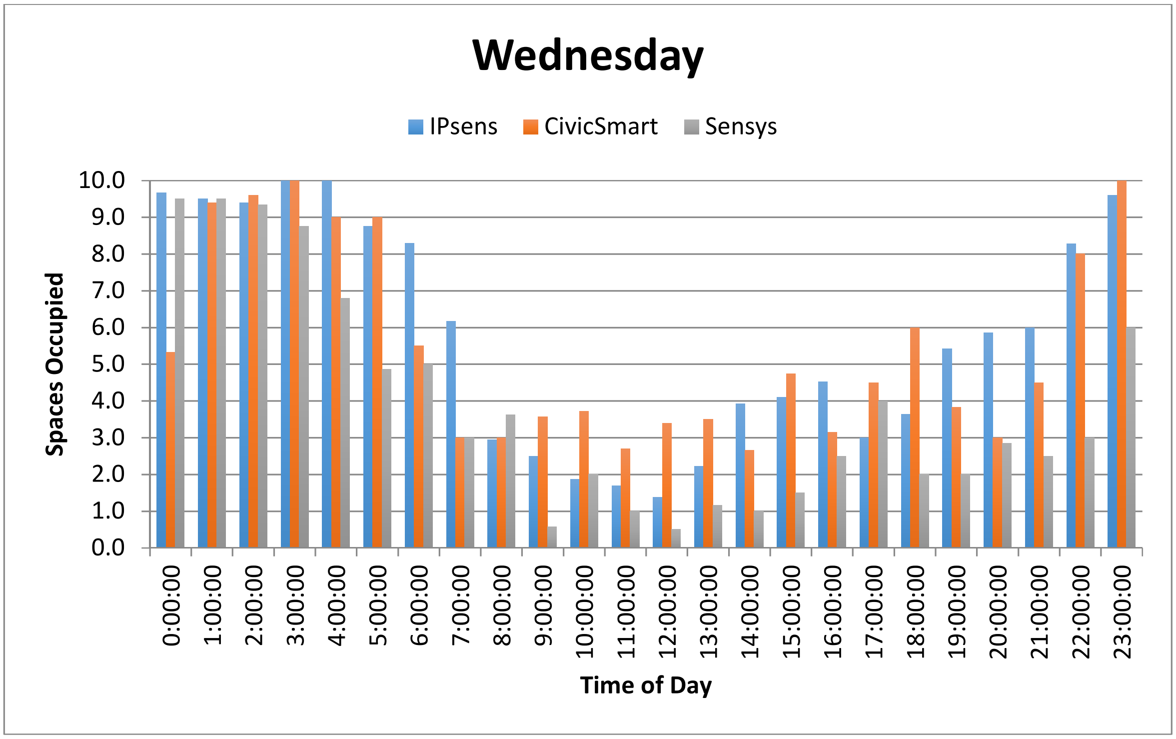
Supplemental Parking Statistics from Video Data Analysis

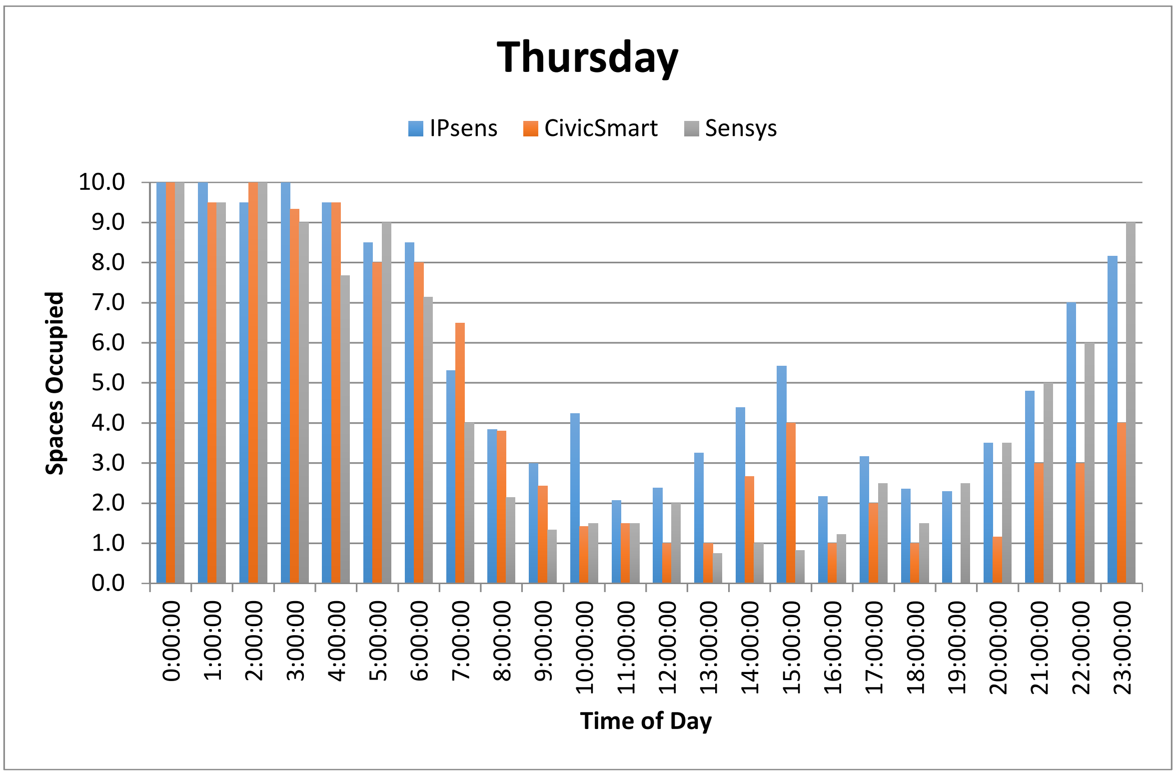
The data in this section were sampled from 8/18/2016 – 9/14/2016.

Time of day parking space utilization, by day of the week:






Wednesday
IPsens
CivicSmart
Sensys
Spaces Occupied
Time of Day
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0:00:00
1:00:00
2:00:00
3:00:00
4:00:00
5:00:00
6:00:00
7:00:00
8:00:00
9:00:00
10:00:00
11:00:00
12:00:00
13:00:00
14:00:00
15:00:00
16:00:00
17:00:00
18:00:00
19:00:00
20:00:00
21:00:00
22:00:00
23:00:00


Thursday
IPsens
CivicSmart
Sensys
Spaces Occupied
Time of Day
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0:00:00
1:00:00
2:00:00
3:00:00
4:00:00
5:00:00
6:00:00
7:00:00
8:00:00
9:00:00
10:00:00
11:00:00
12:00:00
13:00:00
14:00:00
15:00:00
16:00:00
17:00:00
18:00:00
19:00:00
20:00:00
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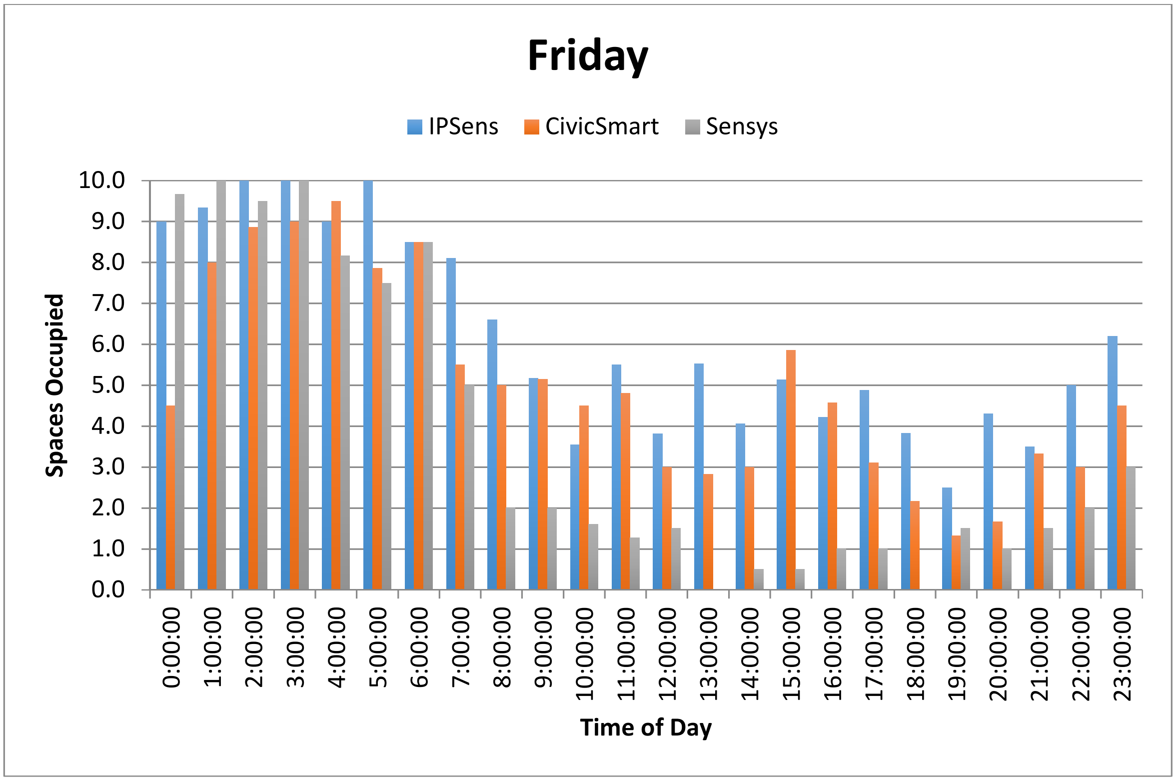
23:00:00


Friday
IPSens
CivicSmart
Sensys
Spaces Occupied
Time of Day
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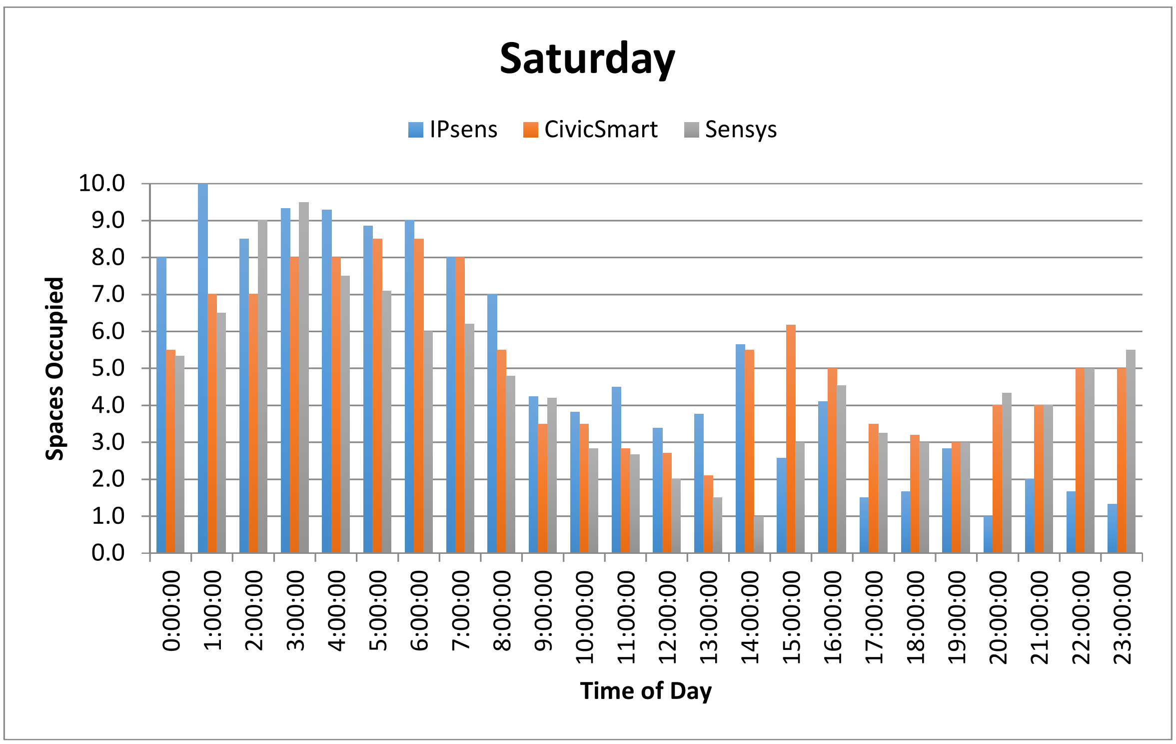
Saturday
IPsens
CivicSmart
Sensys
Spaces Occupied
Time of Day
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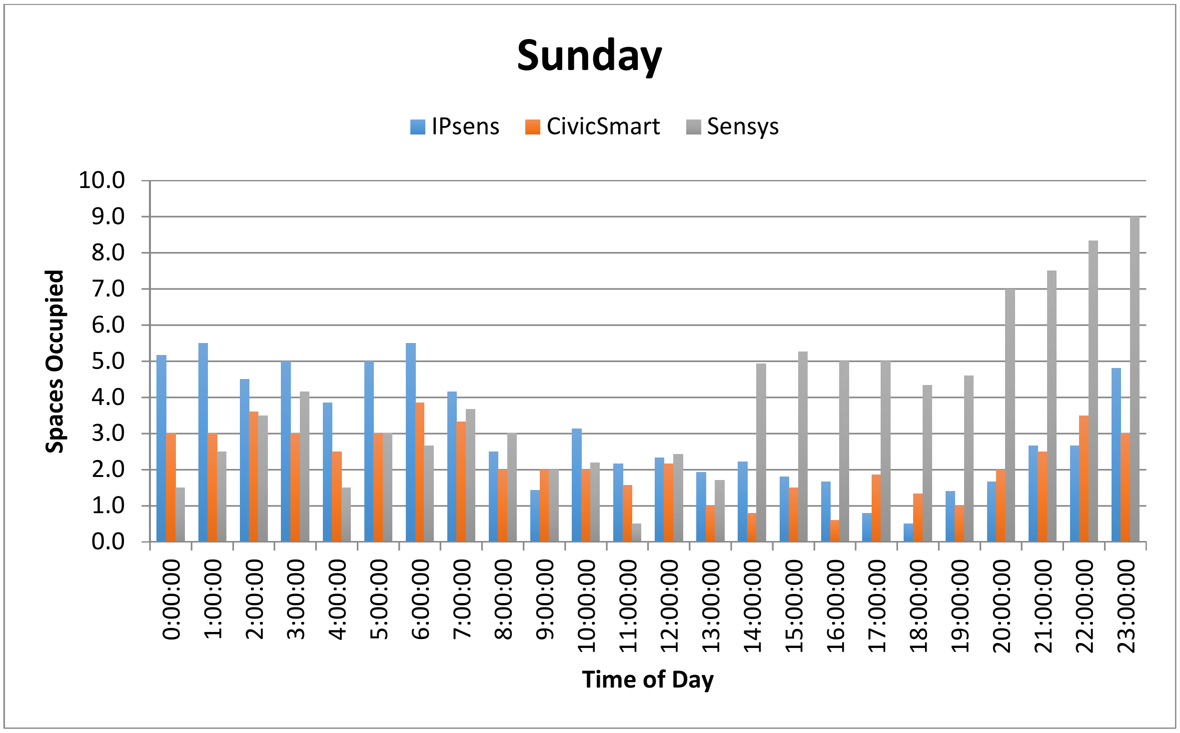
Sunday
IPsens
CivicSmart
Sensys
Spaces Occupied
10.0
9.0
8.0
7.0
6.0
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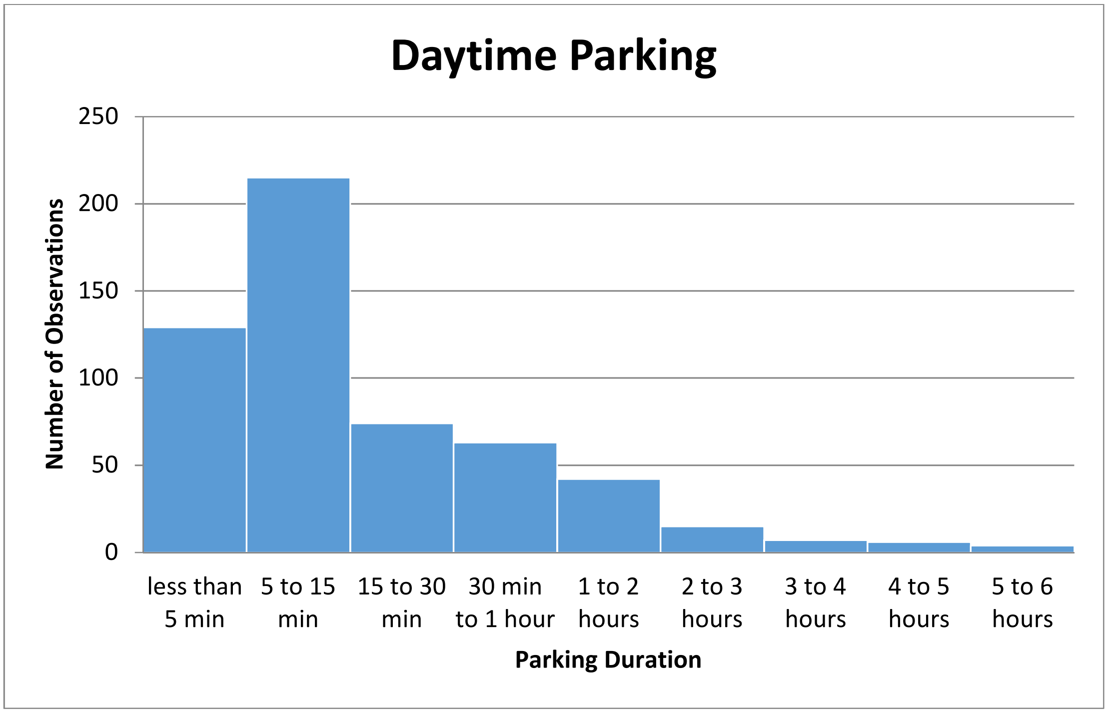
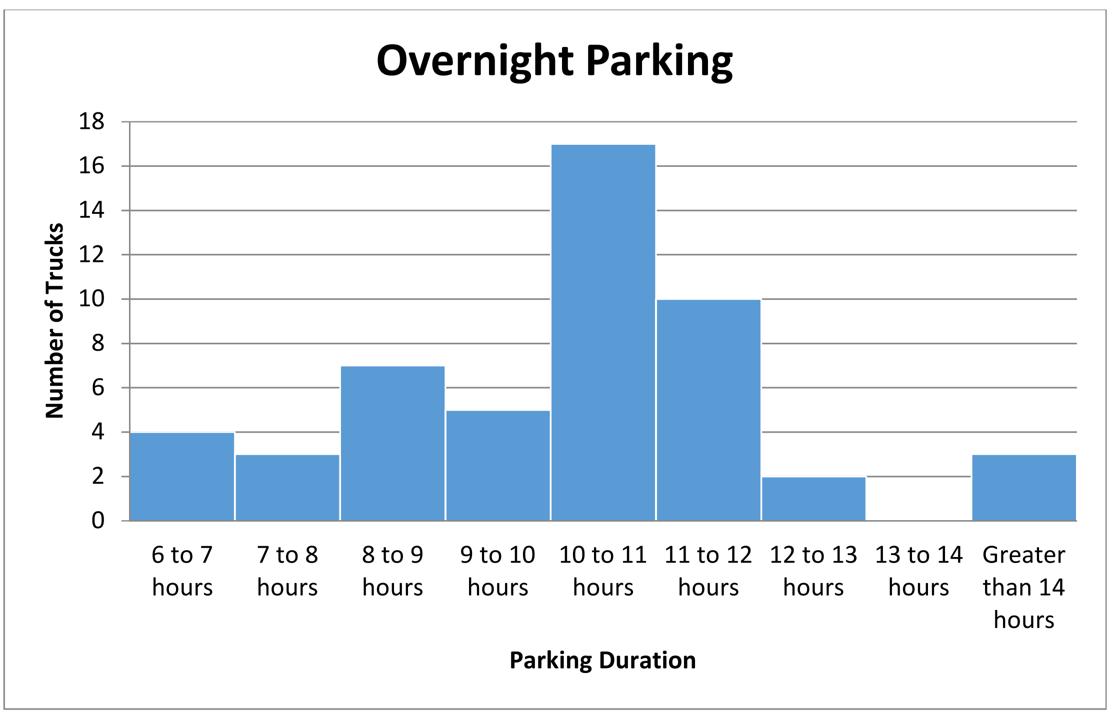
Time of Day

Truck parking hours (8/18/16 to 8/20/16 and 9/4/16 to 9/8/16):



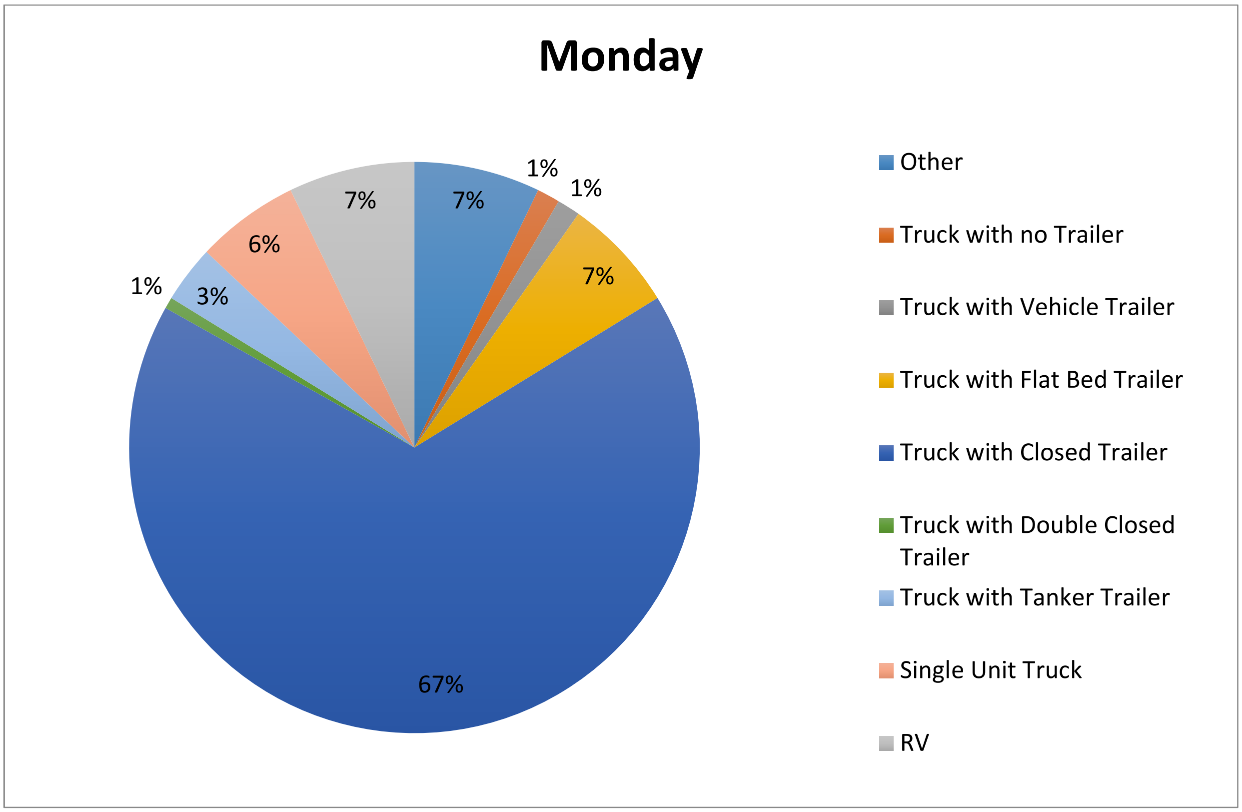
Average	Standard Deviation	Number of Observations
30 min 10 sec	3.63%	555



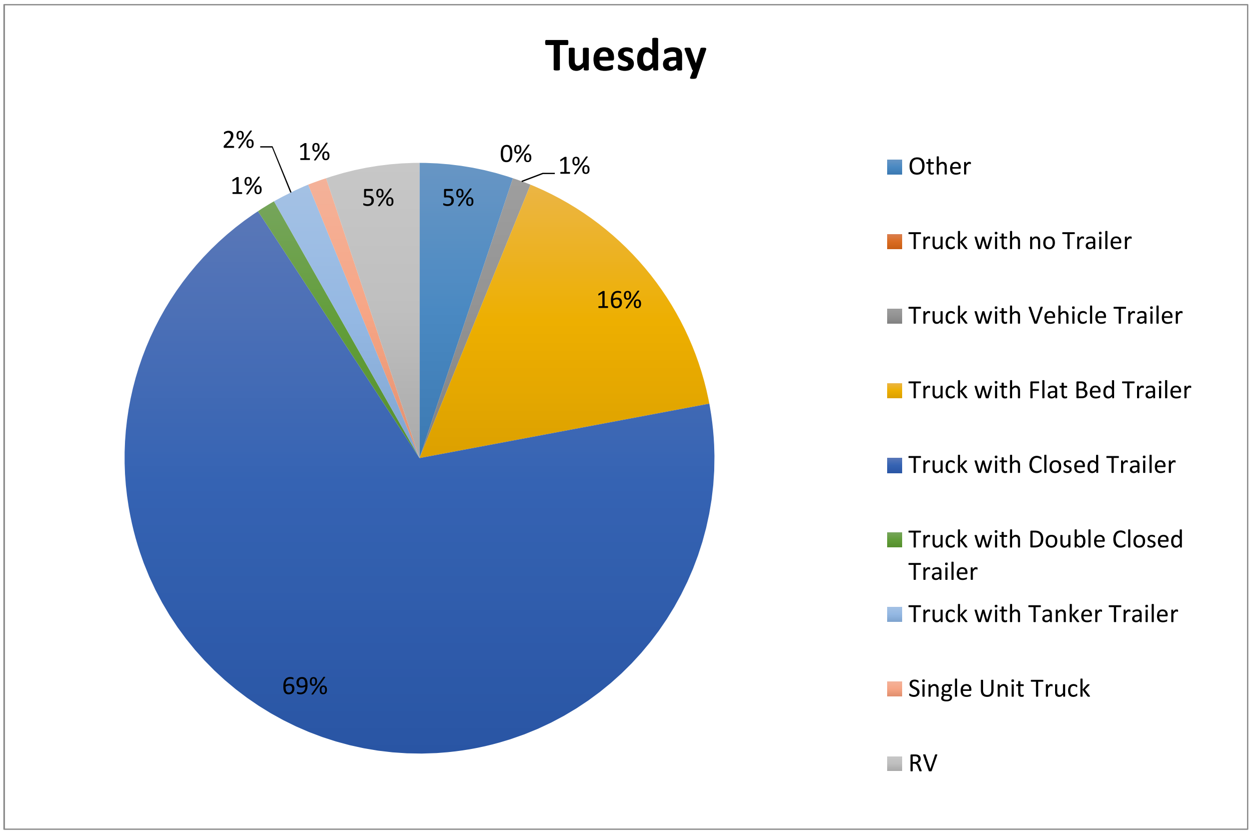
Average	Standard Deviation	Number of Observations
10 hrs 12 min 17 sec	9.32%	51

Parking vehicle type:

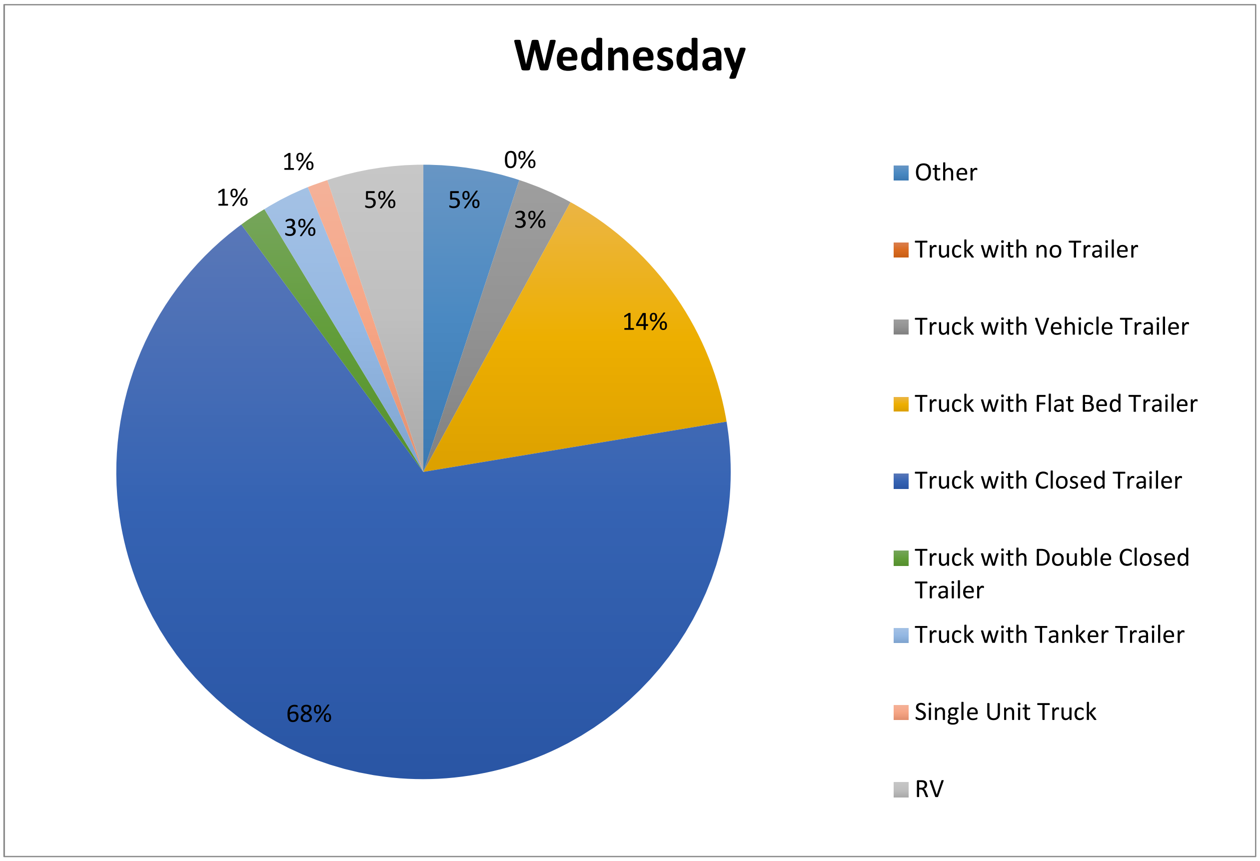
Monday	IPsens	CivicSmart	Sensys
Other	4	2	5
Truck with no Trailer	2	0	0
Truck with Vehicle Trailer	2	0	0
Truck with Flat Bed Trailer	4	1	5
Truck with Closed Trailer	42	20	41
Truck with Double Closed Trailer	0	0	1
Truck with Tanker Trailer	4	0	1
Single Unit Truck	8	0	1
RV	7	2	2
Total Number of Vehicles	73	25	56



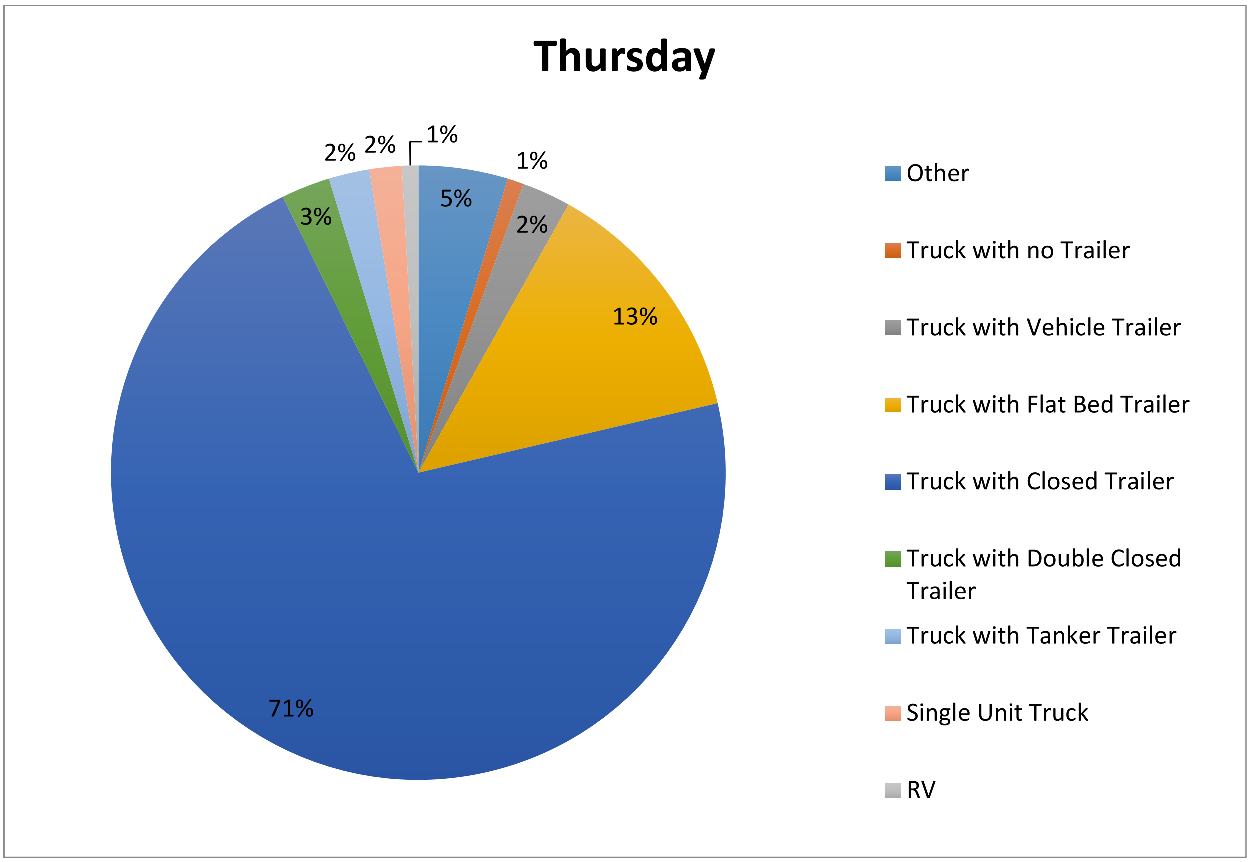
Tuesday	IPsens	CivicSmart	Sensys
Other	6		4
Truck with no Trailer	0		0
Truck with Vehicle Trailer	1		1
Truck with Flat Bed Trailer	19		12
Truck with Closed Trailer	99		35
Truck with Double Closed Trailer	1		1
Truck with Tanker Trailer	4		0
Single Unit Truck	2		0
RV	7		3
Total Number of Vehicles	139		56



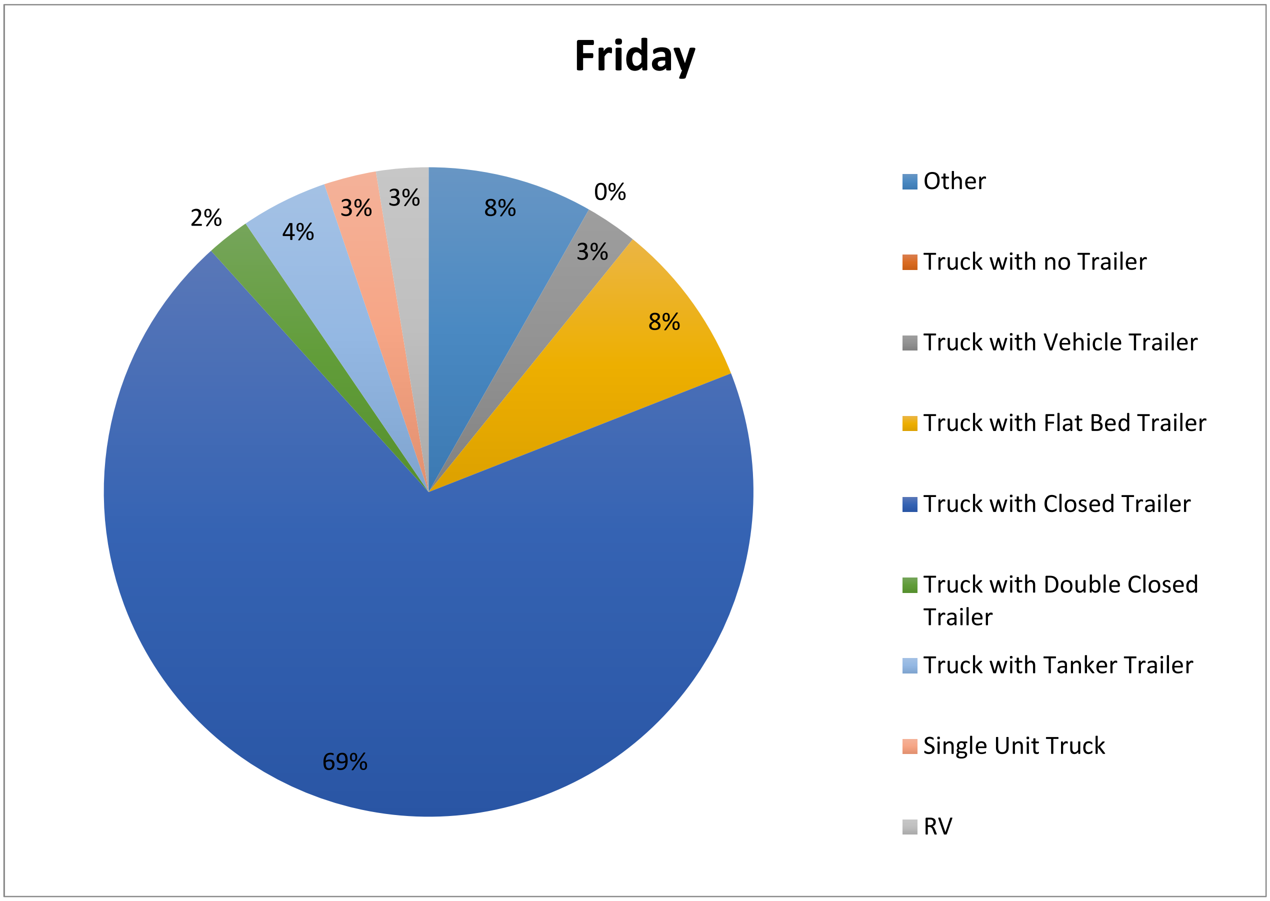
Wednesday	IPsens	CivicSmart	Sensys
Other	6	4	4
Truck with no Trailer	0	0	0
Truck with Vehicle Trailer	4	4	0
Truck with Flat Bed Trailer	16	12	12
Truck with Closed Trailer	91	54	42
Truck with Double Closed Trailer	1	2	1
Truck with Tanker Trailer	3	2	2
Single Unit Truck	2	0	1
RV	5	3	6
Total Number of Vehicles	128	81	68



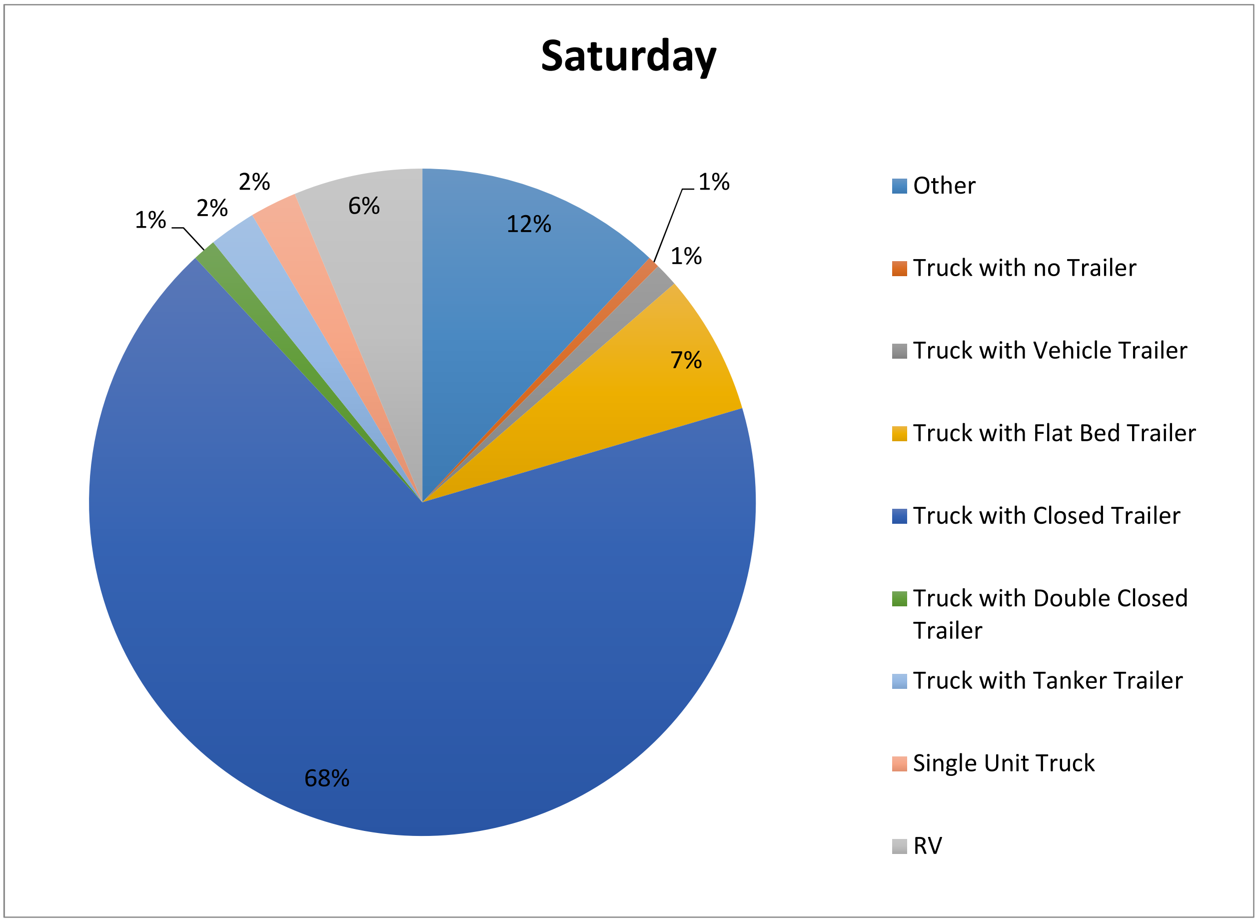
Thursday	IPsens	CivicSmart	Sensys
Other	6	4	1
Truck with no Trailer	2	0	0
Truck with Vehicle Trailer	4	2	0
Truck with Flat Bed Trailer	14	8	9
Truck with Closed Trailer	83	36	48
Truck with Double Closed Trailer	5	0	1
Truck with Tanker Trailer	4	0	1
Single Unit Truck	2	0	2
RV	2	0	0
Total Number of Vehicles	122	50	62



Friday	IPsens	CivicSmart	Sensys
Other	13	1	5
Truck with no Trailer	0	0	0
Truck with Vehicle Trailer	4	1	1
Truck with Flat Bed Trailer	9	6	4
Truck with Closed Trailer	78	48	34
Truck with Double Closed Trailer	2	1	2
Truck with Tanker Trailer	3	1	6
Single Unit Truck	3	2	1
RV	1	2	3
Total Number of Vehicles	113	62	56



Saturday	IPsens	CivicSmart	Sensys
Other	5	2	14
Truck with no Trailer	1	0	0
Truck with Vehicle Trailer	0	2	0
Truck with Flat Bed Trailer	3	2	7
Truck with Closed Trailer	57	30	32
Truck with Double Closed Trailer	2	0	0
Truck with Tanker Trailer	4	0	0
Single Unit Truck	3	0	1
RV	4	4	3
Total Number of Vehicles	79	40	57



Sunday	IPsens	CivicSmart	Sensys
Other	10	2	5
Truck with no Trailer	1	0	0
Truck with Vehicle Trailer	2	0	3
Truck with Flat Bed Trailer	4	5	3
Truck with Closed Trailer	48	28	40
Truck with Double Closed Trailer	3	0	0
Truck with Tanker Trailer	0	2	1
Single Unit Truck	1	1	2
RV	10	1	4
Total Number of Vehicles	79	39	58