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U.S. Department of the Interior

Cape Cod National Seashore
Wellfleet, MA

Cape Cod National Seashore
Parking Management System Pilot Synthesis

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Volpe The National Transportation Systems Center

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Research and Innovative Technology Administration

Contents

Report notes

This report was prepared by the U.S. Department of Transportation John A. Volpe National Transportation Systems Center, in Cambridge, Massachusetts. The project team was led by William Baron of the Security and Emergency Operations Division, and included Darryl Song of the Security and Emergency Operations Division and Joshua Hassol of MacroSys Research and Technology LLC. The team was managed by Frances Fisher of the Transportation Planning Division.

This effort was undertaken in fulfillment of PMIS 162900, *Cape Cod ITS Parking Pilot.* The project statement of work has spanned two agreements. Design and installation of the system was included in the August 2012 modification (no. 05) to the interagency agreement between the National Park Service Northeast Region and the Volpe Center (NPS agreement F4505087777). Analysis of the pilot was included as part of a new interagency agreement signed August 2013, P13PG00424, which will also fund development and installation of the system across all of the NPS-owned parking areas at the Cape Cod National Seashore.

Cover Photograph: Little Creek parking area entry booth taken by Volpe Center Staff, July 31, 2013.

Acknowledgments

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Definitions

The following terms are used in this report:

4G LTE	4^{th} Generation Long-Term Evolution Wireless Broadband Service
AC	Alternating Current
CACO	Cape Cod National Seashore
DOT	Department of Transportation
DVR	Digital Video Recorder
NPS	National Park Service
PC	Personal Computer
PMS	Parking Management System
RS-232	A serial data transmission standard established by the Electronic Industries Assn.
TIS	Traveler Information System
Volpe Center	John A. Volpe National Transportation Systems Center

1. Introduction

The Cape Cod National Seashore (CACO) has undertaken a program to improve parking management at its beach parking lots, and to provide information about parking availability to CACO visitors. This project will build upon work already accomplished, to develop a networked Parking Management System (PMS) and Traveler Information System (TIS) covering the seven CACO-managed beaches (and, potentially, town-managed beaches within CACO), along with multiple systems for disseminating parking information to the public.

On September 26, 2012, the Volpe Center conducted a site survey of the beach parking lots throughout the Seashore. Included in this survey were all six of the NPS-operated parking lots, as well as eight town-operated parking lots located within the Seashore. The site survey assessed existing wireless communications coverage, networking, AC power, and other factors pertinent to deployment of parking management system components at each of the parking areas.

On June 20, 2013, as a first step toward deployment of the full parking management system, the Volpe Center installed a pilot system at the Little Creek parking area, which serves Coast Guard Beach. The pilot system was in operation for the duration of the 2013 summer season (through September 30) with a few periods when the system was not operational.

This report provides details on the pilot parking management system's components, location, installation, testing and monitoring. It also provides the Volpe Center's findings and conclusions.

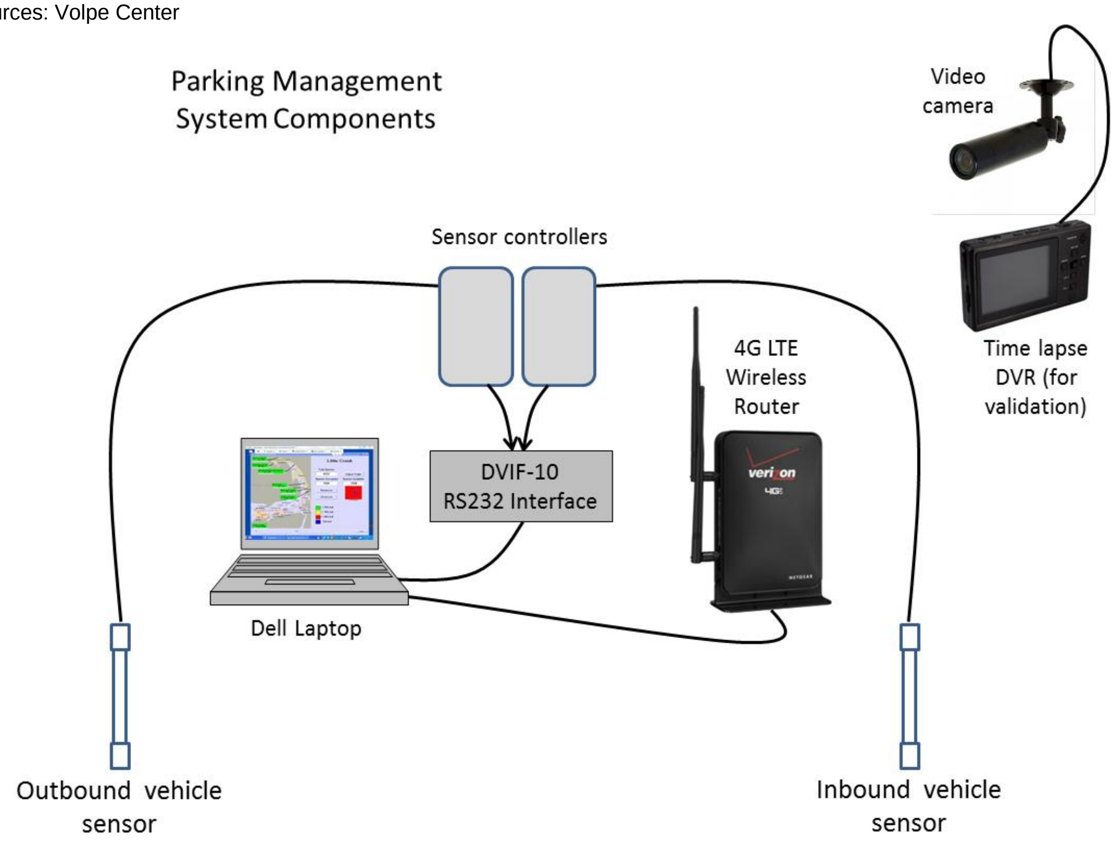
2. Pilot Parking Management System Installation

This section describes the key components of the parking management system, including hardware, software and implications of the location of the vehicle sensors.

2.1 Hardware

The pilot system consists of low-cost, commercially-available, off-the shelf components as illustrated in Figure 1, and described below.

Figure 1
Pilot System Hardware
Sources: Volpe Center



Vehicle sensors and associated controllers

Two passive, magnetometer-based vehicle sensors (inbound and outbound) record passing vehicles as they enter and leave the parking area. These sensors register disruption in the magnetic field that large, metal objects cause when they move past the sensors (stationary metal objects do not trigger the sensors). This particular lot sees little bicycle traffic, but bicycles generally do not trip the sensors unless they pass within about two feet of the sensor. Each sensor simply acts as a trigger; when a vehicle moves past it, it sends a small voltage signal to its controller, which passes the signal to the DVIF-10 interface.

DVIF-10 RS232 Interface

The DVIF-10 is an alarm contact interface module manufactured by ComPPage Inc. It acts as a bridge between the vehicle sensors/controllers – which only provide contact closures – and the digital Dell laptop PC running the PMS software. When the DVIF-10 interface receives a voltage signal from a sensor controller, it sends one of two small data packets (corresponding to either the inbound or outbound sensor) to the Dell laptop. The parking management software is programmed to recognize this data as indicating a car either entering or leaving the parking area.

Dell laptop PC

The laptop PC runs the parking management software, and connects to the 4G LTE wireless router.

4G LTE Wireless Router

The wireless router provides 4G cellular connectivity and enables the Volpe Center and NPS to monitor the parking management system, and to download data remotely.

Video Camera and Digital Video Recorder

To corroborate the data the vehicle sensors collect, the pilot system includes a video camera and digital video recorder. The video camera captures time-stamped images of the parking lot at a rate of 1 frame per second, which are periodically downloaded onsite from the DVR and compared with sensor data from the same dates.

Figure 2 is a photograph of the pilot system. Visible in the photograph are the laptop computer, the wireless router, the DVR, and one of the sensor controllers.

Figure 2
Prototype PMS System Components as Deployed
Source: Volpe Center

2.2 Software

The pilot system contains two software modules. The first module is the parking management software, which the Volpe Center developed in-house. This module was adapted from another PMS prototype that was deployed at the Sandy Hook unit of the Gateway National Recreation Area in 2002. It uses inbound and outbound vehicle count data from the vehicle sensors, along with data on the parking lot's total capacity to track parking availability, and to predict what time the lot will be full. When deployed, the full parking management system will use this predictive information to issue "lot full" notices in advance of a given parking area actually being at capacity, to account for visitors already en-route to that location.

Figures 3-5 are screen shots of the software, showing different parking conditions. The software uses an algorithm that the Volpe Center developed that that uses a rate of arrival/departure over the previous 5 minutes to determine the expected time the lot will fill. If it will not fill prior to 6pm. then the clock is replaced with "OK". In Figure 3, parking occupancy is considered low with only 41 of 422 spaces filled and therefore the status is "OK." In Figure 4, with 57 of the spaces are filled, the algorithm predicts that the lot will fill at 5:10 PM. In Figure 5, all 422 spaces are filled and the clock shows the current time as when fill will occur and the status shows "FULL."

Figure 3
Parking availability and prediction for June 23, 2013, 9:48 AM
Source: Volpe Center

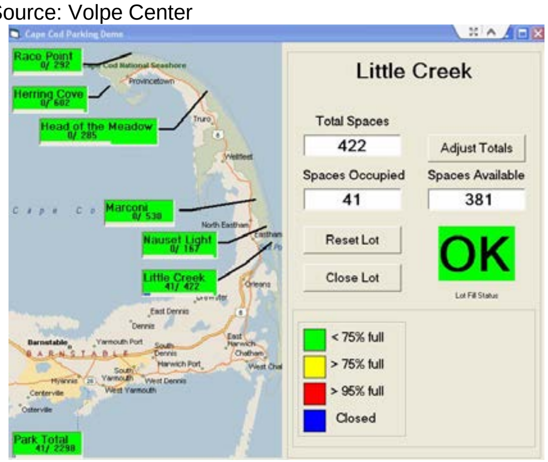


Figure 4
Parking availability and prediction for June 23, 2013, 10:07 AM
Source: Volpe Center

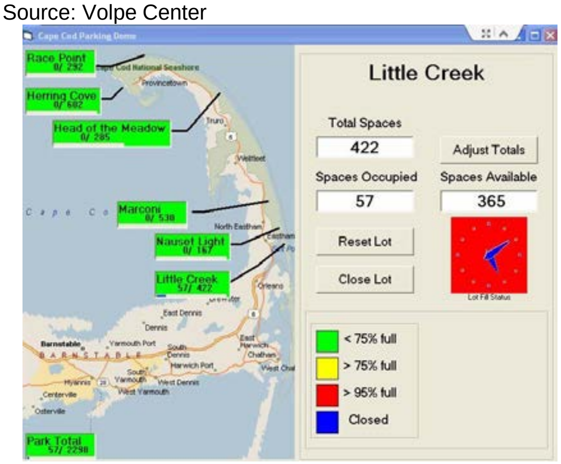
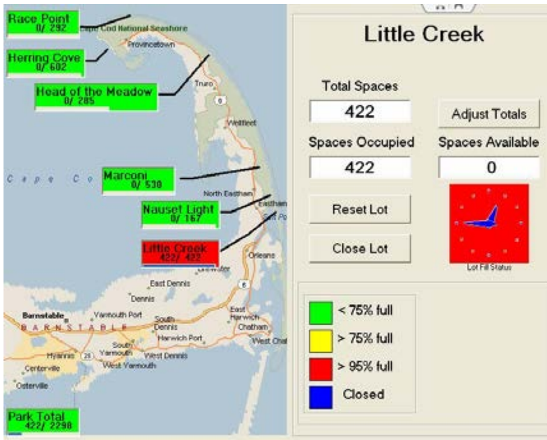


Figure 5
Parking availability and prediction for July 4, 2013, 12:45 PM
Source: Volpe Center



The second software component is TeamViewer, a commercially-available product that enables remote control of computers via the Internet. Using TeamViewer, the Volpe Center was able to monitor the system continuously, and could access all the features of the software, including test functions.

2.3 System Location

After completing the site survey, the Volpe Center initially recommended that the pilot system be installed at the Nauset Light parking area, based on the availability of 110V AC power, adequate cellular service, size of the lot, and other factors. A subsequent site visit revealed that the town of Eastham operates its own entrance to the lot and reserves a portion of the parking spaces for Eastham residents, so achieving accurate parking counts would require two sets of vehicle sensors, and a more complex algorithm to predict lot fill times. These issues will be relatively easy to address during full system deployment, but for the pilot system a simpler site configuration was needed. The National Seashore and the Volpe Center agreed to select the Little Creek parking area serving Coast Guard Beach in Eastham as the pilot test site. Figure 6 shows the entrance booth to the Little Creek parking area. The outbound vehicle sensor is visible at the bottom of the post in the left foreground. The other system components are inside the NPS booth, in the space between the ceiling and the roof, except for the video camera, which is mounted under the eave on the back side of the booth.

3. Findings from Pilot

The pilot system operated properly for most of the season from June 20 – September 30, 2013. There were a few periods when the system was not fully operational including June 21, June 25-28, July 10-12 and August 9-19*. Issues causing the outages included an automatic reboot following a Windows update, a power outage, and the system becoming accidentally unplugged. However,

* Volpe was unable to address the cause of the shutdown in mid-August because the period of performance for Volpe's work had expired.

sufficient data from operations during the remainder of the season provided clear results. The key findings are as follows:

3.1 Vehicle Spacing

Performance of the vehicle sensors is the key to the system's performance. It was discovered early in the field test that the magnetometers were not functioning as well as expected due to the nature of the traffic. Observation revealed the magnetometers did not accurately record vehicles that were closely spaced and entered the parking area in rapid succession (tailgating). This occurred in cases where several successive vehicles had season passes and therefore did not need to stop at the entrance booth (the Rangers waved them through). The vehicle sensors require several seconds between vehicles in order to reset themselves, so when there were several vehicles entering in rapid succession, the entrance sensor recorded the first vehicle, and typically missed the subsequent vehicles. This "successive vehicle" problem is potentially significant; strings of successive vehicles with season passes are common during CACO's peak summer season. The problem also could occur at the outbound sensor, depending on the volume of exiting traffic (e.g., late in the day when many visitors are leaving the parking area).

3.2 Sensor Placement

The performance of the magnetometers was affected by their placement. At the pilot site, traffic cones were used to narrow the entrance and exit lanes slightly to ensure that vehicles pass close enough to the sensors. If magnetometers are used in the final installations, it may be desirable to embed the sensors in the pavement so that vehicles pass directly over them.

In a limited number of cases the pilot system's inbound sensor double-counted vehicles. This occurred in cases when a vehicle "overshot" the entrance booth, and pulled to a stop past the doorway. In these cases, the vehicle triggered the sensor. Because magnetometers are motion sensitive, once the vehicle stopped moving the sensor reset itself. Then, when the vehicle pulled away from the booth it triggered the sensor again, and the system counted the vehicle twice. This issue would be resolved by locating the sensor several feet past the entrance booth. Vehicles would trigger the sensors only after they had completely cleared the booth.

3.3 Sensor Choice

Since all sensors have unique strengths and weaknesses, the Volpe Center decided to replace the magnetometers during the field test. On July 29, 2013, the Volpe Center installed two sets of breakbeam sensors. The sensor chosen was the Dakota BBA-2500 wireless breakbeam system. Its features include a design that is intended for outdoor use, an integrated solar charging system and a transmitter that enables the sensors to be located up to a half mile from the receiver with no cabling. Using breakbeam sensors by themselves at the fee booth would not work well because rangers, beachgoers and others sometimes walk or stand outside the booth and could repeatedly trip the sensors. Because the roadway leading to the Little Creek parking facility is divided in some places, it was possible to place the sensors about 150 feet from the fee booth and still achieve lane separation. The sensors use a single 4-channel receiver which replaced the two magnetometer controllers inside the fee booth. The normally open relay contacts were connected directly to the DVIF-10 which sends RS-232 signals to the computer.

Performance of these sensors seemed to more accurately match the fill rates of the lots as seen by the video.

Figure 6
Breakbeam Sensors installed at Little Creek
Source: Volpe Center

Figure 7
Still Image from Video recorded at Little Creek, July 5, 2013
Source: Volpe Center

3.4 Video

The video camera that was installed by Volpe to provide a measure of ground truth to corroborate the performance of the system, proved to be a valuable tool. Access to live images from each of the parking areas should be incorporated into the final system if possible. Even when there is reliable data, live video provides a measure of confidence in the system. It can have ancillary benefits as well, including staff safety and forensic information if recorded.

3.5 Algorithm

The accuracy, and in fact the need for the fill rate prediction algorithm came into question over the course of the field test. Traffic tended to arrive in waves, which caused the anticipated fill time of the lot to change significantly over the course of the day. In looking towards the next phase, there are many other ways in which this algorithm might be approached by taking into consideration the known fill patterns of a particular lot. Experienced rangers could tell you that if a lot hasn't filled by a particular time, it never will. Temperature, cloud cover, day of the week, shark threat and point in the season all play a role in the demand for parking, and there are ways these might be taken into account. Since beachgoers generally only care if a lot is currently OPEN or FULL, it may be sufficient for the PMS to know simply that a lot has reached 95% of its capacity, at which time travelers might be directed to other facilities. As this project enters its next phase, other approaches to handling lot fill rates will be considered.

4. Conclusion

The 2013 field test of the pilot parking management system indicates that the hardware and software functioned as intended. The performance of the vehicle sensors will continue to need to be assessed to determine the best combination of sensors to handle the variety of conditions and traffic situations that are present at this and other NPS parking facilities. While the breakbeam sensors performed more reliably than the magnetometers in this scenario, the layout of the entrances at other parking facilities will, in some cases, preclude the use of these types of sensors. Ultimately it will be the accuracy of the sensors that will determine the effectiveness of the parking management system.

In looking toward the next phase, it makes sense to work towards a system whose vehicle counting technology is adaptable to a variety of situations. In addition, there were reliability problems associated with using a Windows-based computer in this environment. It makes sense to build the final system using a programmable logic controller that processes the data locally, and is more tolerant of high temperatures, humidity and autonomous operation. There are intelligent video-based systems that can be customized to specific scenarios, and can be programmed to process the data internally. The Volpe Center will investigate the potential for using these systems because they may resolve all of the issues encountered during the field test.

Also, as we proceed, additional consideration will need to be given toward technologies that can disseminate parking situation information to the public. NPS and the communities along the Seashore will need to determine how the information should be disseminated to the public. Once the preferences on how to deliver the data have been determined, the technology can be adapted to accommodate them. These could include variable message signs, highway advisory radios and mobile web applications. The final parking management system design will accommodate any of these alternatives.

Appendix A – Total Vehicle Entries Recorded

Table 1 below shows the total number of vehicles recorded as entering per day during the 2013 season. Although the capacity of the lot is 422 spaces, more vehicles than that entered on some days and were either turned around when the lot was full or entered later in the day as others exited. Dates where the system was not operating properly due to technical difficulties are noted with an asterisk.

Table 1
Daily recorded entries
Source: Volpe Center

Date	Entries	Date	Entries	Date	Entries	Date	Entries
20-Jun	69	16-Jul	560	11-Aug*	0	6-Sep	1
21-Jun	0	17-Jul	572	12-Aug*	0	7-Sep	233
22-Jun	359	18-Jul	557	13-Aug*	0	8-Sep	110
23-Jun	417	19-Jul	458	14-Aug*	0	9-Sep	1
24-Jun	358	20-Jul	503	15-Aug*	0	10-Sep	1
25-Jun*	0	21-Jul	430	16-Aug*	0	11-Sep	1
26-Jun*	0	22-Jul	388	17-Aug*	0	12-Sep	0
27-Jun*	0	23-Jul	288	18-Aug*	0	13-Sep	0
28-Jun*	60	24-Jul	569	19-Aug*	32	14-Sep	155
29-Jun	175	25-Jul	203	20-Aug	577	15-Sep	157
30-Jun	234	26-Jul	91	21-Aug	607	16-Sep	1
1-Jul	211	27-Jul	674	22-Aug	460	17-Sep	1
2-Jul	360	28-Jul	351	23-Aug	404	18-Sep	0
3-Jul	577	29-Jul	501	24-Aug	468	19-Sep	3
4-Jul	626	30-Jul	633	25-Aug	517	20-Sep	0
5-Jul	712	31-Jul	578	26-Aug	174	21-Sep	111
6-Jul	712	1-Aug	495	27-Aug	106	22-Sep	58
7-Jul	562	2-Aug	338	28-Aug	201	23-Sep	2
8-Jul	428	3-Aug	251	29-Aug	176	24-Sep	0
9-Jul	219	4-Aug	587	30-Aug	441	25-Sep	0
10-Jul*	0	5-Aug	551	31-Aug	375	26-Sep	3
11-Jul*	0	6-Aug	589	1-Sep	268	27-Sep	0
12-Jul*	126	7-Aug	565	2-Sep	204	28-Sep	122
13-Jul	358	8-Aug	269	3-Sep	5	29-Sep	90
14-Jul	540	9-Aug*	0	4-Sep	2	30-Sep	16
15-Jul	589	10-Aug*	0	5-Sep	0		

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