SMART PARK: TRUCK PARKING FIELD OPERATION TEST RESULTS

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ABSTRACT

As part of its SmartPark program, the Federal Motor Carrier Safety Administration (FMCSA) conducted a field operations test of two technologies, video imaging and magnetometry, to assess their suitability for determining the occupancy of truck parking areas. Neither technology met its established performance targets, particularly for vehicle classification. The test also revealed a number of user behaviors (such as dropped trailers) indicating that the successful use of automated detection technology for a truck parking area will require accurate vehicle classification and will be more challenging than that for a car parking area with only one type of vehicle and controlled access.

Key words: truck parking, intelligent transportation systems, ITS, driver fatigue, video-imaging, magnetometry, real-time information

INTRODUCTION

Driver fatigue is a known cause of large-truck crashes. In fact, over 8% of truck crashes are fatigue related (1). Contributing to fatigue is the difficulty truckers have in finding safe parking for rest breaks. After sponsoring a 2005 white paper on truck parking issues (2), the Federal Motor Carrier Safety Administration (FMCSA) funded a field operational test of two inexpensive Intelligent Transportation Systems (ITS) technologies, video imaging and magnetometry. They were chosen because they could detect and classify vehicles by length.

The immediate objective was to detect and classify vehicles in order to determine the occupancy of a truck parking area. The larger goal is to convey parking availability to truckers on the road in real-time. The FMCSA funded the work and managed the contractors. They asked the Volpe National Transportation Systems Center to provide independent evaluation and technical support for the project. This paper reports the results of these tests, which were conducted at two public rest areas and one private truck stop.

Detection technologies and parking management systems that measure available parking have been commercially available for automobile parking, especially for parking garages and similar facilities. This is the first known test of commercial off-the-shelf detection systems to try to perform this function for truck parking facilities. Truck parking poses unique challenges, in particular the much greater variety in vehicle size and the often unmarked and more poorly defined parking spaces.

REQUIREMENTS

TECHNOLOGY

Several stakeholder needs were seen as key to the success of such a system. These needs imply certain technical requirements.

Credibility

First and most important, the system must be credible. If truck drivers don't trust it or find it useful, they won't use it. That means the technology chosen must have the reliability to work 24 hours a day, 7 days a week. It must work in all weather conditions day and night. Moreover, in all conditions it must be able to accurately determine the number of available parking spaces.

Cost

For the transportation authorities responsible for deploying and managing such a system it needs to be low cost. If the cost is too high, the system won't see widespread deployment. Low cost suggests that the system must be based on Commercial off-the-shelf (COTS) or near-COTS equipment. It should be technology that is easily retrofit into existing truck parking facilities. The system should not require any onboard equipment in the truck. Lastly, it should be scalable so that it can be rolled out to many parking facilities in order to provide wide regional coverage on the highway system.

Growth

Looking to the future, such a system should eventually provide ongoing usage information to aid state and local transportation agencies in planning and provide convenience to the truck drivers. In particular this implies the capability to track parking history and for truckers to be able to make reservations at parking facilities.

TEST SITES

There were also requirements to try to ensure that the test sites chosen would provide the best test results. Parking facilities with insufficient parking were desired so that in Phase II the system could provide real-time warnings on the highway upstream of the facility to divert trucks to another site. Facilities receiving complaints about the capacity or with significant observed illegal parking were considered good candidates.

The FMCSA wanted to test at both public rest areas and private truck stops to capture any differences. The contractor's technology would obviously have to work in the terrain, weather and traffic at the site they chose. A site also had to be located so that it was possible and useful to notify approaching truckers 50 miles and 1 mile before the parking facility. Figure 1 shows the locations of the selected test sites.

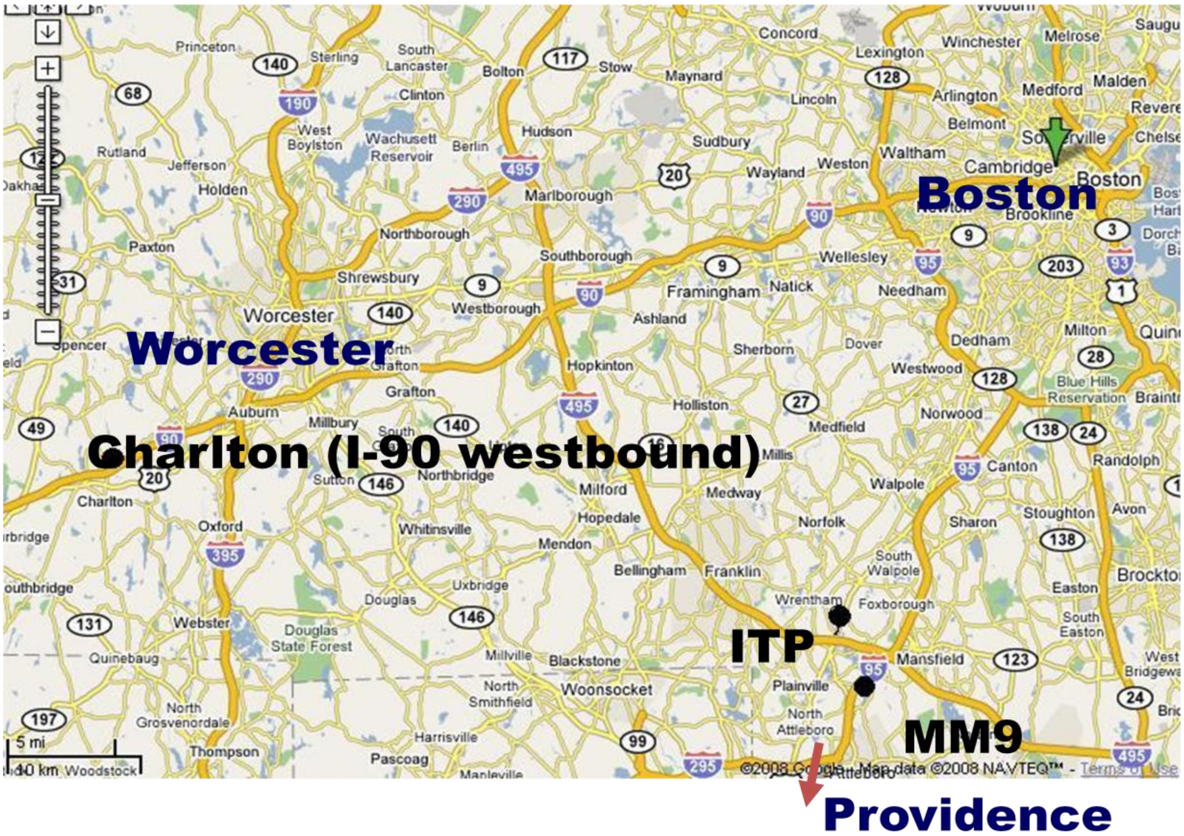

Figure 1. Smart Park Test Sites in Eastern Massachusetts

APPROACHES

VIDEO IMAGING (3)

The video imaging approach used the Autoscope Solo Terra camera video detection system with a trip line algorithm to classify and count vehicles at the entrance and exit to the parking area. The contractor proposed to calculate the difference, and subtract that difference from the parking capacity to estimate parking occupancy. Initially they would also subtract the occupied spaces at start up. A wireless connection linked the cameras to a computer in the building at the rest area and an internet connection from there to the off-site control center.

The video imaging system was tested at a public rest area (Charlton Westbound) on I-90 in Massachusetts. This facility provides free parking 24 hours a day. It has only one entrance and one exit with physically separated car and truck parking areas. The truck parking consists of roughly 30 unpaved and unmarked spaces. One camera was placed at the entrance to the truck parking area, the other at the exit. In addition, 4 roof-mounted web cameras were used to provide a manual check of the lot. Figure 2 gives the overhead view of this site. The colored lines mark the approximate fields of view of the roof-mounted web cameras.

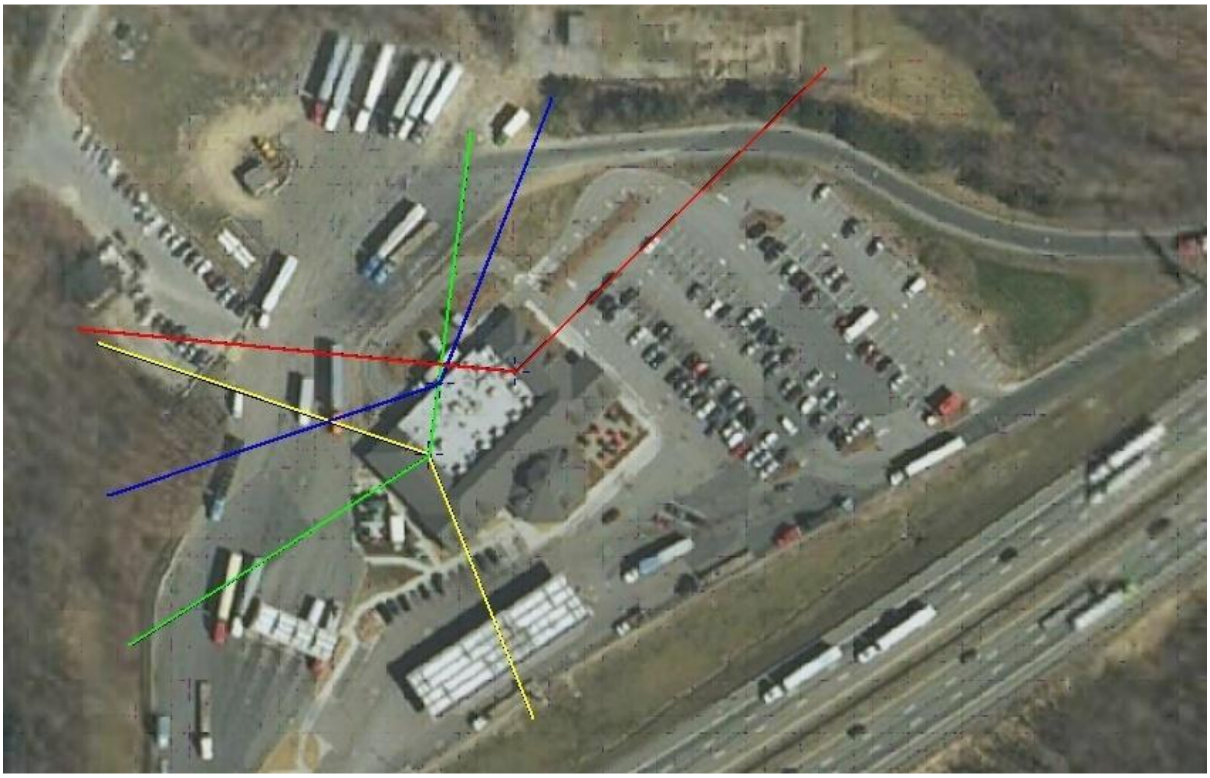

Figure 2. Charlton test site (Video)

MAGNETOMETRY (4)

The magnetometers were tested at both a public rest area (Mile Marker 9 (MM9) on I-95 in Massachusetts) and a private truck stop (Interstate Travel Plaza (ITP) on U.S. 1 in Wrentham, Massachusetts). Pairs of magnetometers, spaced 6 feet apart in the center of the lane, were embedded in both entry and exit lanes of MM9 and ITP to classify and count vehicles, and similarly, to calculate parking occupancy. The magnetometers communicate to local area controllers, which communicate to a master site controller, which in turn is linked by cellular telephony to a remote control center.

Additional magnetometers were also installed in the individual marked parking spaces in the MM9 rest area. However, data collection from the parking space magnetometers was ceased when trucks were observed not parking within the markings but parking laterally so as to occupy two or more spaces.

The public rest area at Mile Marker 9 (Figure 3) provides free parking 24 hours per day. The car and truck parking are physically separated with 27 marked legal spaces in the paved truck parking area. There is one entrance and one exit.

The Interstate Travel Plaza (Figure 4) is a private fee-based facility with approximately 45 unmarked legal unpaved truck parking spaces. There is no car parking. Parking is available 24 hours per day with the fuel and retail center open 18 hours per day.

Figure 3. Mile Marker 9 test site (Magnetometer)
(“I” & “O” mark the entrance and exit to the truck area respectively.)

Figure 4. International Travel Plaza test site (Magnetometer)

FIELD OPERATION TEST

TEST RESULTS

The two technologies were tested in 2008- 2009. Video monitoring was used to provide a ground truth. This was backed up with site visits and manual counts by US DOT personnel. Initial testing of the video detector showed a very high number of false positive detections and missed classifications, especially at night and in the rain. After the trip-line algorithm was reprogrammed in 2009, the false positive rate improved significantly. Table 1 summarizes the findings for both video and magnetic sensors. Neither met the 96% accuracy requirement set by the vendors. Furthermore, the missed classifications occurred with a simple 2 or 3-class scheme, basically car versus truck.

Sensor	Location	Observations	False Counts	Missed Counts	Classification Error
Video (after reprogramming)	Charlton-Day 2009	433	2%	5%	8%
	Charlton-Night 2009	268	6%	2%	3%
Magnetometer	ITP	1241	0	4%	21%
	MM9	2056	0	4%	8%

Table 1. Field Operational Test Results

DISCUSSION

Technical Issues

Both vendors needed to make changes to their initial installations in order to obtain the results reported above. Initial testing of the video detector showed a high number of false positive detections and missed classifications in all conditions. After the vendor's trip line algorithm was reprogrammed by the integration contractor in 2009, the false positive rate improved significantly but was still problematic at night and in the rain. Headlights were sometimes counted as two separate vehicles. False detections were also caused by birds, human shadows and police lights. These results are consistent with results from Hawaii reported in 2010 (5). The video system also suffered a weather related failure which filled a camera up with water and took it out of action for the remainder of the test program.

Wireless communications on the magnetometer installation experienced significant dropped data. This was addressed by allowing certain parts of the magnetic signature data to be interpreted at the site rather than being transmitted to the control center. The bandwidth capacity was also initially underestimated by a factor of 40 which led to a latency problem until steps were taken to increase capacity. Both vendors experienced computer crashes. Sufficient bandwidth and reliable computers are necessary for reliable communications.

Truck lengths vary much more than automobile lengths, requiring a detection system with a larger measuring range. This challenge contributed to the classification errors that occurred.

Behavioral Issues

Both installations were affected by unexpected driver behavior. These behaviors suggest that any successful detection system must be able to work at all speeds, must be able to detect direction of motion, and must be able to both detect and classify vehicles. In fact, some level of re-identification may be necessary. The separate monitoring via video and site visit was valuable in revealing these unexpected behaviors. Table 2 summarizes the observed behaviors.

Category	Behavior	Error
Driver Behavior		
	Sloppy parking (e.g., taking more than one space)	Capacity
	Unexpected driver behavior (e.g., exiting at entry)	Count
Changing Vehicle Lengths		
	Trailers dropped and left in parking lot	Count
	Trailers picked up from parking lot	Count
Count Violations		
	Towing	Count
	Loading and unloading	Count
Vehicle Mix		
	Large variation in vehicle length	Classification

Table 2. Challenges and induced error

Sloppy parking generally means a vehicle takes up more than one space though it also includes vehicles penetrating other spaces like the travel lanes. The system would count one entrance but capacity is reduce by more than one space leading to an overestimate of available parking. The opposite can occur as shown in Figure 5. There you see two large trucks utilizing one space as well as a small passenger van taking up an entire truck space. Trucks frequently park in places other than the designated spaces. That would lead a count-based system to underestimate available parking.

Figure 5. Two trucks in one parking space (MM9).

Unexpected behaviors like vehicles stopping and/or backing up over the sensors and driving the wrong way on the access road will cause the system to miscount unless it measures the direction of travel and uses that in the counting algorithm. Vehicles were even seen crossing the grass separating the car and truck areas which would also throw counts off. Figure 6 shows an automobile entering the truck parking exit.

Figure 6. Automobile entering the truck parking exit (MM9)

Passenger cars using the truck parking area also introduces error. The error depends on the type of parking area. If the system has marked spaces a car might take up an entire truck space though the system may have counted it as a car and ignored it or assumed it takes up less space. In an area without marked spaces, if the car is counted the same as a truck but takes up less space the system will have more space available than it would calculate.

Simple length based vehicle classification is vulnerable to vehicles changing length in the parking lot. For example, we observed dropped trailers. That is where a tractor-trailer enters, drops its trailer, and then the tractor then exits. There is an entry, an exit, ***and*** a net increase in parking occupancy. The opposite occurs when a tractor comes alone and exits with a trailer that had been occupying a parking space. A tow truck entering alone and leaving with a disabled vehicle has the same effect (Figure 7). Figure 8 shows a case where one vehicle entered, dropped the trailer and departed as 2 vehicles (pickup truck and motorcycle). Counts would indicate a space became available even though an additional space was occupied. Therefore length based classification must have more resolution than a simple 2 or 3 class scheme. Alternatively, a way to measure other features that can detect and separately count trailers would be another possible solution.

Figure 7. Vehicle tow (MM9)

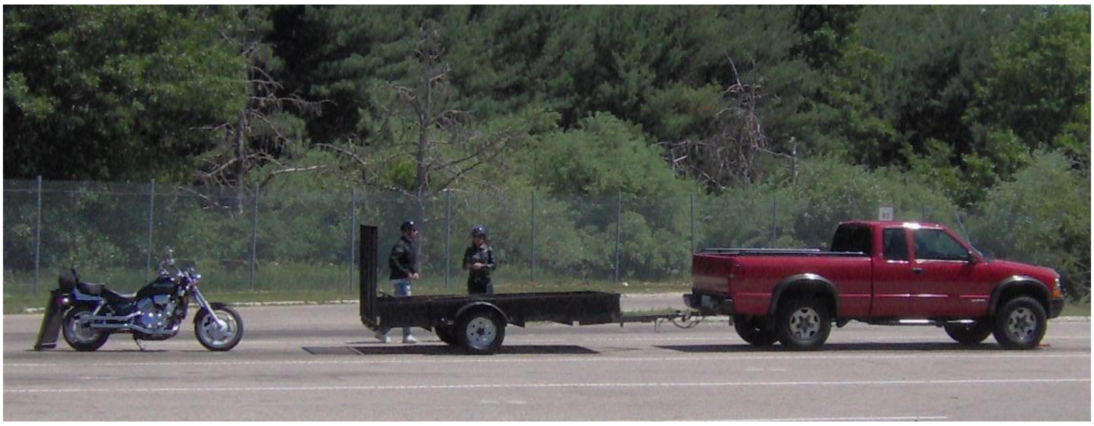

Figure 8. Vehicle dropping trailer and unloading another vehicle (MM9)

We observed a car carrier unloading cars in the rest area. In this case, the system would detect one entrance and many exit counts leading to a large overestimation of available space. Truck parking facilities are sometimes used for other loading and unloading operations as shown in Figure 9.

Figure 9. Dropped trailer used for loading and unloading cargo.

Given these behaviors, a successful system must, at a minimum, be able to reliably classify vehicles both by length and by whether a vehicle is being towed, to distinguish trucks from cars, and tractor-trailers from bobtail tractors (tractor without trailer). In fact, classification by length alone may not be sufficient. Other features or re-identification may be required to recognize merged vehicles (such as a tow) or split vehicles (such as a dropped trailer). Measuring other characteristics such as vehicle height profiles, shape, number and spacing of axles might be required.

CONCLUSION

Contributions of this work include the following:

1. A test of two detection / classification technologies that provided quantitative results in real-world conditions for the truck parking application.
2. A better understanding of actual driver behavior, suggesting that the successful use of automated detection technology for a truck parking area will be far more challenging than that for a car parking area with only one type of vehicle, the absence of trailers, and controlled access.
3. The need to either improve the performance of the two tested technologies or select a different technology other than video imaging or magnetometry, to determine truck parking space occupancy. Night and all weather operation cannot be taken for granted. Neither can communications reliability using COTS equipment.
4. Classification of vehicles is necessary, but length does not suffice for classification. Classification needs to take into account whether vehicles or trailers are being towed. Improvements must also include better length measurement, measuring vehicle speed and direction and the ability to separate closely following vehicles.
5. Periodic recalibration is necessary to zero out over and undercounts due to the challenges mentioned above. This is necessary to prevent count errors from

accumulating. So far the best way to do this has been manual counting in person or remotely via real-time web cameras.

This improved understanding of user behavior can be used to inform the system requirements for future truck parking field operation tests, thus increasing the likelihood of their success.

ACKNOWLEDGEMENTS

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