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# **EVALUATION OF MDOT TRUCK PARKING INFORMATION AND MANAGEMENT SYSTEM**

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MANAGEMENT SYSTEM

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16. Abstract <p>This evaluation investigates the opinions of drivers exposed to the I-94 Truck Parking Information and Management System (TPIMS), first deployed in the summer of 2014 and fully operational throughout 2015. The TPIMS project on I-94 was conceived to advance methods and the use of technology to both assess parking availability at public and private facilities and to inform drivers of parking availability while on the highway. The goals of the project are to:</p> <ol style="list-style-type: none"> <li>1. Enhance highway safety by providing timely and reliable truck parking information</li> <li>2. Provide a sustainable and scalable truck parking solution</li> <li>3. Provide a secure solution that protects user privacy and data</li> <li>4. Maximize user acceptance of the system for truck parking decisions</li> </ol> <p>The I-94 TPIMS offers drivers several information sources that provide information about parking availability along segments of the I-94 corridor in Michigan. The information sources include dynamic truck parking signs, smartphone applications, websites, and in-vehicle display devices.</p> <p>The results of this evaluation confirm that the parking system was successfully implemented using modified off the shelf equipment and the output data was integrated with existing traffic management systems. Drivers overwhelmingly agreed that parking information systems were personally valuable to the driver and could save them time in driving. In general, drivers appeared to find the road sign sources both clear and useful, suggesting that acceptance of this source to be quite high. None of the other sources were rated as highly.</p>					
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## Introduction

This evaluation investigates the effectiveness of the I-94 Truck Parking Information and Management System (TPIMS), first deployed in the summer of 2014 and fully operational throughout 2015. The I-94 TPIMS offers drivers several information sources that provide information about parking availability along segments of the I-94 corridor in Michigan. The parking availability information sources include dynamic truck parking signs (DTPS), smartphone applications, websites, and in-vehicle display devices.

The need for parking information is in response to a long standing and growing problem with truck parking availability especially for long haul truckers. Hours of Service (HOS) regulations require mandatory rest periods and as the allocated driving period comes to an end it is imperative that drivers find safe and secure parking. Much of truck parking activity is driven by safety considerations and the associated need for adequate rest for drivers. The Federal Motor Carrier Safety Administration (FMCSA) HOS rules have undergone several changes in recent years, starting with a major revision in 2005 and culminating in the most recent amendments that were implemented starting on July 1, 2013. Some of these amended 2013 rules were suspended under the Consolidated and Further Continuing Appropriations Act of 2015 (passed on 12/16/14). These changes have involved fine-tuning of various elements of the rules, but a general underlying trend since 2005 has been the FMCSA's adoption of provisions aimed at improving safety through longer continuous rest periods for commercial drivers. Drivers cite two particular changes in the HOS rules in 2013 that have influenced changes in truck parking characteristics across the industry. These are:

1. Requirement for a continuous off-duty window under the "34-hour restart provision"; and
2. Requirement for drivers to take a 30-minute rest break during the first 8 hours of a shift.

In addition, there is no "sleeper berth provision", to allow drivers with sleeper cabs to break up their shift. The current rule requires that they take 10 full hours off after 14 hours on duty, no matter if they stopped and slept for 6 of those 14 hours already. Driver compliance with these new rules have strained parking resources because the average length of stay has dramatically increased.

Timing for deliveries and scheduling adequate rest is critical, driver's need to carefully consider parking needs in planning their routes and deliveries. At times public and private parking facilities reach their capacity leaving drivers searching for alternative locations. The search can be both frustrating and time consuming as many of the facilities are out of sight so their parking capacity cannot be judged by a passing driver. The I-94 TPIMS was conceived to advance methods and the use of technology to both assess parking availability at public and private facilities and to inform drivers of parking availability while on the highway. The goals of the project are to:

1. Enhance highway safety by providing timely and reliable truck parking information
2. Provide a sustainable and scalable truck parking solution
3. Provide a secure solution that protects user privacy and data
4. Maximize user acceptance of the system for truck parking decisions

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) legislation (PL 109-59) established the Truck Parking Facilities Pilot Program under Section 1305. Congress intended the Pilot Program to make funds available to address the truck parking shortage on the National Highway System (NHS). The Michigan Department of Transportation (MDOT) received a \$4.5 million competitive grant to develop the I-94 TPIMS, which consists of a parking detection and availability notification system compatible with 5.9 GHz telecommunication technology.

The I-94 corridor, located in southwest Michigan, was selected for the TPIMS pilot project because it is a major international trade corridor linking Western US to Canada through Chicago, Detroit and Port Huron. It serves as the main freight corridor between Chicago and Detroit with a direct link to Toronto and Montreal through HWY 401. The I-94 corridor has a high concentration of commercial vehicles with up to 30% of the average daily traffic (ADT) volume being commercial vehicles. This equates to approximately 10,000 trucks per day. In addition to the high truck traffic volumes, over a dozen private truck parking facilities and five public rest areas are located along the subject corridor. Ten of the private facilities and all five of the public rest areas are included in the TPIMS project.

The TPIMS incorporates a range of integrated technologies, which includes changeable truck parking signs, a connected vehicle system with 5.9 GHz Dedicated Short Range Communications (DSRC) transponders, integration with MDOT's existing Advanced Traffic Management System (ATMS) software and Mi Drive traveler information platform, and mobile applications. While none of the technologies are unique; prior to this demonstration project they had not been integrated for the purposes of estimating commercial parking availability.

## **I-94 Truck Parking Information and Management System—Human Factors Evaluation**

The goal of the human factors evaluation is to examine the level of driver awareness and acceptance of each of the parking availability information sources and, where possible, identify any human factor issues related to their operation.

The I-94 TPMIS project uses the following four basic supporting information sources: DTSP, smartphone applications, web-based information sites, and in-vehicle displays. The following sections describe each of these information sources in more detail.

## Dynamic Truck Parking Signs

DTPSs are used to display parking availability in advance of the rest area and exits with private truck parking facilities along the I-94 corridor. They are strategically positioned in advance of the off-ramp to provide the driver adequate decision making time. The DTPSs generally identify parking availability at three upcoming stopping points: typically one rest area and two exits. The sign dynamically lists the number of available parking spaces at each location. Examples of a DTPS are shown in Figure 1. When the count of available parking spaces falls below an established threshold, the word “LOW” is displayed instead of a precise number. The “LOW” threshold is used to account for the time between a driver viewing a sign and reaching a facility as well as providing a buffer for count accuracy. For exits where multiple parking areas are available, the DTPS displays the sum of available parking spaces. Thus, drivers may be required to visit several parking areas at the exit to secure a parking space.

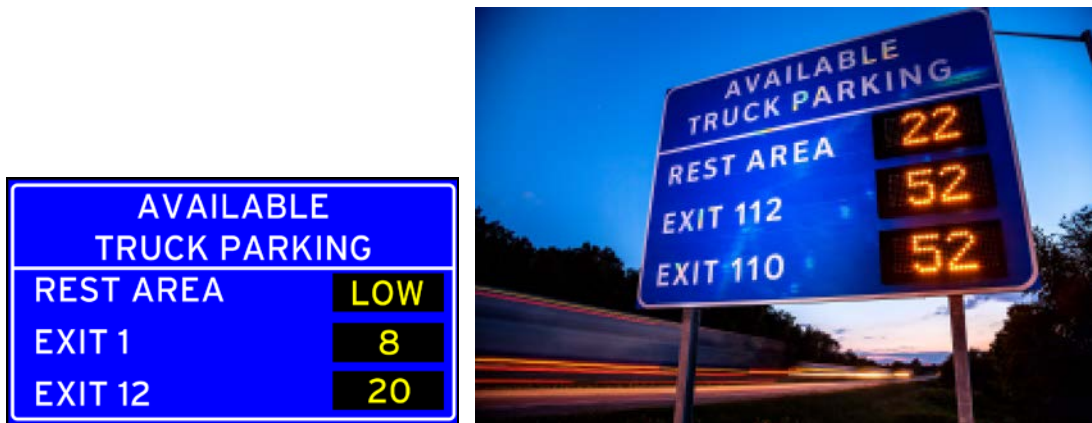


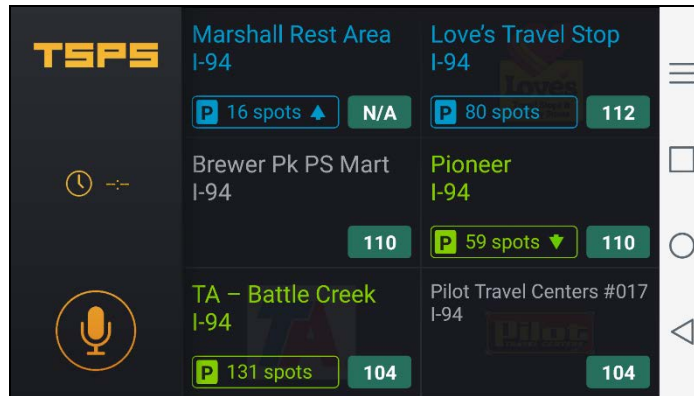
Figure 1. DTPSs identify the vacancy level at respective rest areas and exits.

## Smartphone Application

A smartphone application to display the parking availability at the participating I-94 private and public parking areas was made available through Google Play, for Android-based smartphones and through iTunes, for iPhone smartphones. The Truck Smart Parking Services (TSPS) smartphone application was specifically developed to support the I-94 TPIMS project and receives parking availability information directly from the TPIMS networked systems. In addition to parking availability, the smartphone application also provides extensive detail about the amenities available at exit areas such as fuel prices, dining, laundry, showers, ATMs, etc.

The smartphone application presents parking availability information for facilities based on the vehicles GPS location and direction of travel, both of which are determined from the application. An example of the application’s main availability display screen is shown in Figure 2, which lists the nearest to farthest parking availability from top to bottom on the screen. As the vehicle travels along the I-94 corridor, the display is updated so that passed locations are displaced with the next nearest forward locations.



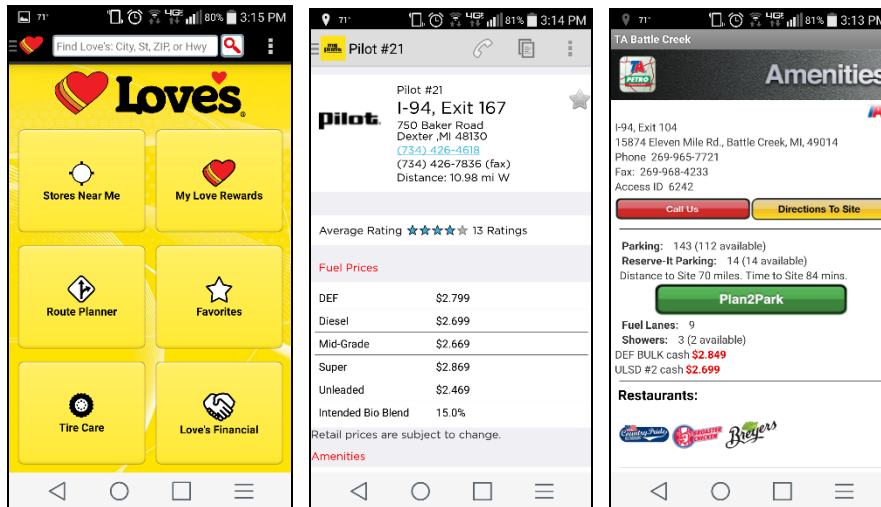


**Figure 2. Screenshot of TSPS smartphone application depicts parking availability at upcoming exits and rest areas along I-94.**

As shown in Figure 2, parking areas are color-coded to indicate the proportion of available spaces. When available spaces fall below 25% vacancy, the location is displayed in red; when above 25% and below 75%, the location is displayed in blue; when availability rises above 75% the location is displayed in green. Items displayed in gray are locations for which no information is available. Occupancy trends are indicated using arrows: an up-arrow indicates filling, a down-arrow indicates emptying, and no arrow indicates a steady trend.

Although the TSPS application has been available since December 2014, it has not been heavily promoted among the commercial fleet driver community. During the on-site driver survey, we found that some drivers confused the TSPS application with other smartphone applications affiliated with commercial truck-stops that provide information about the amenities at each site. Examples of these applications include: Love's Connect (Love's), myPilot (Pilot), and TruckSmart (TA/Petro). Example screenshots are shown in Figure 3. There are also smartphone applications that provide similar amenity information (and ratings) that do not have a commercial affiliation (e.g., Big Truck Stops (AllStays, LLC). These applications provide similar amenity information about truck stops but do not provide real-time parking availability information.

Of the commercially-affiliated applications, only the TruckSmart application provides parking availability information, updated every 1-2 hours via manual input from the truck stop operators. This information is exclusive for TA/Petro locations and provides a link to pay for reservations at select locations. The other commercially-affiliated applications list static information about amenities and overall parking capacity.



**Figure 3. Examples of trucker assistance applications describing roadside amenities. Pictured are Love's Connect, myPilot, and TruckSmart.**

*Truck Smart Parking Services(TSPS) Application Function and Operation*

Limited testing of the TSPS smartphone application was performed in a vehicle along the I-94 corridor during the summer months of 2015. During operation it was discovered that when the vehicle is stopped in place, the application does not display information for upcoming exits along the route. For example, with the vehicle stopped at the Marshall Rest Area, located along westbound I-94, information about upcoming exits was not displayed. It was determined that unless the vehicle is in motion, information about upcoming exits is not displayed. Based on discussions with the application developer, the vehicle's heading direction is indeterminate unless the vehicle is in motion. Without heading information, the application cannot distinguish exits ahead from exits behind. Moreover, the application is also designed to poll for information after traveling 800 meters. A driver who is unaware of these two contingencies might attempt to restart the application while the vehicle is in motion, resulting in some preoccupation with the application in the moving vehicle. This process creates a potential safety hazard. To avoid a potential safety hazard, it is suggested that either prior heading information be retained during stops or an explicit indication be provided that the two contingencies are in effect and that information availability will be limited until the vehicle is in motion.

A second human-factor design issue is less safety-critical. The color-coding of the available parking based on percentage availability may be confusing to drivers who are shown only the absolute number of available parking spaces. For example, a display of 20 available spaces could be shown in red if the total capacity of the facility is 100; the same availability would appear in green, if the total capacity is 25. Without explicit indication of the meaning of these colors, drivers cannot interpret their meaning without knowing the total capacity of each facility. A continuous depiction of percent capacity (like a bar graph) could provide a better indication to drivers of proportional occupancy. In addition, it should be determined whether percent availability is a meaningful measure to drivers, for example do drivers consider five available spaces out of 20 to be similar to 20 out of 100? The absolute number of available spaces may be the most meaningful

measure to commercial vehicle operators while percent availability might be generally disregarded.

### Website-based applications

There are two web-based applications that can provide parking availability information to drivers. Mi Drive (<http://mi.gov/drive/>) is hosted by MDOT and provides the number of total and available spaces for any selected parking area along I-94. This is shown in Figure 4. Alternatively, TSPS (<http://www.onlineparkingnetwork.net/map>) hosts a companion website to its smartphone application which also features camera-based views of the parking areas (shown in Figure 5). Each of the websites parking availability data is based on the TPMIS.

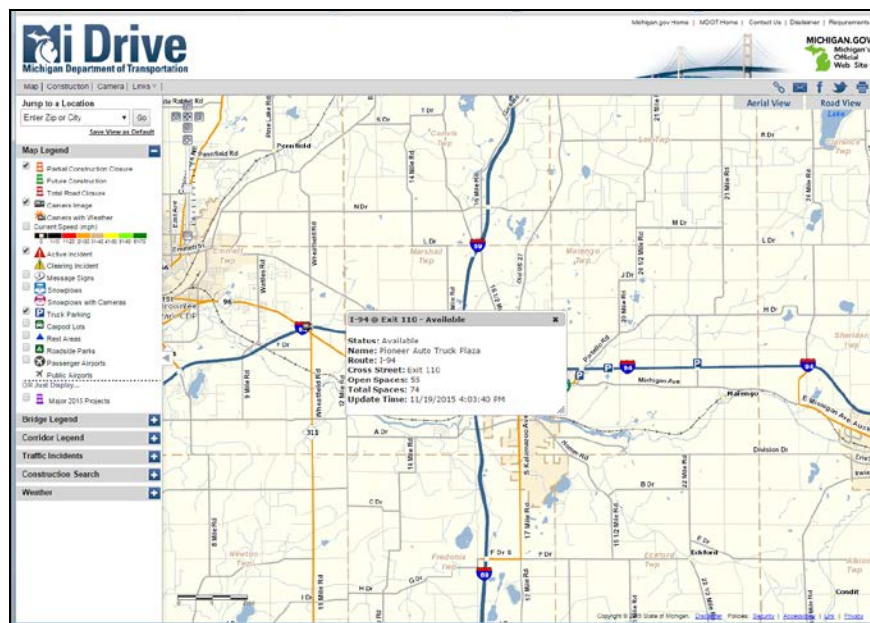
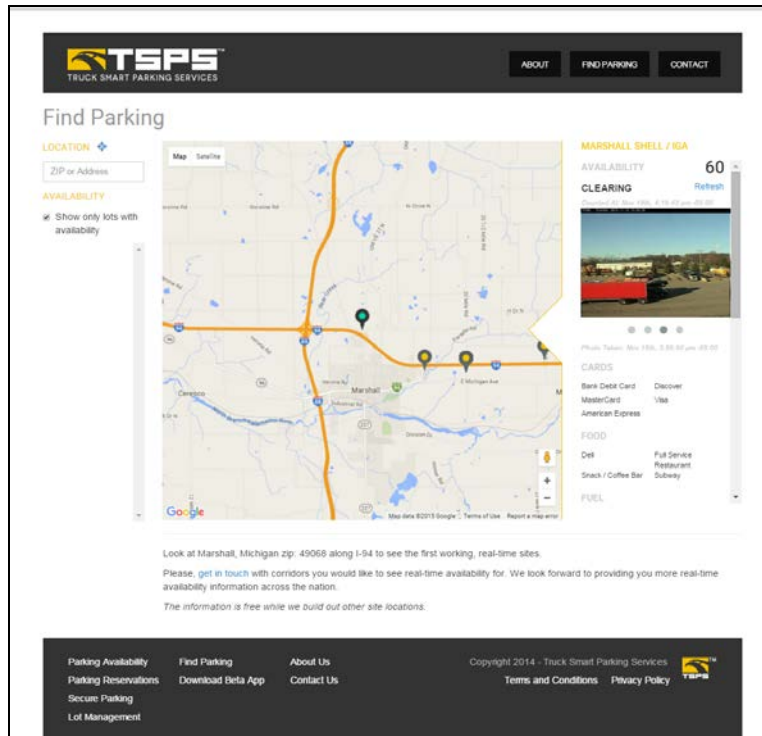


Figure 4. Screenshot of display of parking availability for exit 110 along I-94.

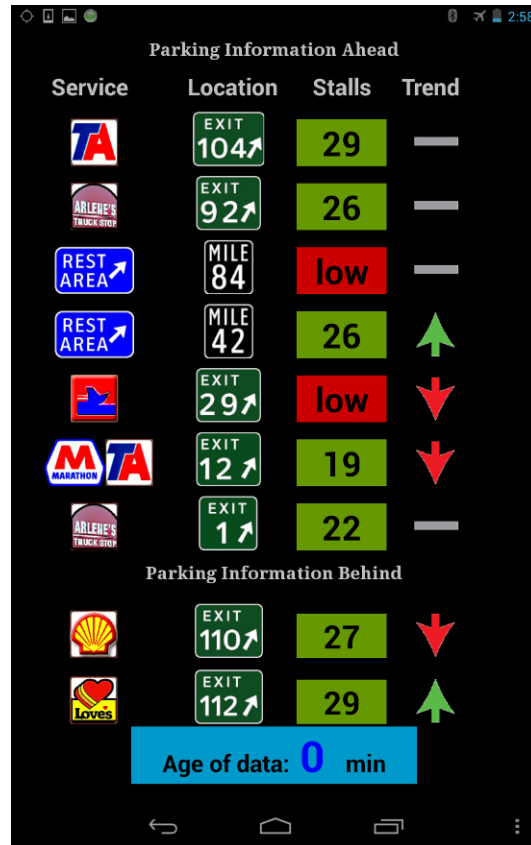


**Figure 5. Screenshot of TSPS website depicting parking availability for a selected location along I-94. This website also reports trending information (e.g., clearing, steady, filling).**

### **In-vehicle Display**

In-vehicle tablet-based display systems with accompanying DSRC on-board units were deployed in five trucks of a participating local commercial carrier. These systems receive DSRC data transmitted in the vicinity of five roadside units deployed along the corridor. This information includes parking availability and is displayed on a tablet mounted in the commercial vehicle cabin. Since these vehicles were each exclusively assigned to a single driver, there were five drivers who participated in this evaluation. An example of the tablet display is shown in Figure 6. The display shows the service, exit location, number of available parking spaces (stalls), a trend indication. The trend indication is color-coded to denote when the fraction of available spaces falls below 25 percent availability (red) or above 75 percent of availability (green), and whether the available parking is increasing, steady, or decreasing using an arrow symbol.

Parking availability is referred to using various different terms based on the source provide the information. The following provides a summary on the terms used: the Mi Drive website uses ‘spaces’; the TSPS application uses ‘slots’; the in-vehicle tablet-based I-94 Parking System uses ‘stalls’; the TSPS website avoids using any term other than ‘parking availability.’



**Figure 6. In vehicle I-94 Truck Parking System based on DSRC transmitted data. The system shows available spaces and filling and emptying trends.**

### **Survey of Drivers Use of the In-Vehicle I-94 Parking Availability Display**

This survey was developed with the specific focus on the in-vehicle tablet-based information display developed to provide parking availability information in a commercial vehicle (shown in Figure 6). The display hardware was a Nexus 7 Android 4.3 tablet, mounted in clear view of the driver. By default, the device used a text-to-speech interface which provides a speech interpretation of displayed information. The system is fully configurable to adjust display timeout duration, distance filters to limit the number of exits and rest areas displayed, availability filters to limit the display to only locations that meet availability criteria, and time of day filters to limit display of information to critical time periods.

Although there were five trucks equipped with the on-board device, feedback was received from four of the participants. The fifth equipped truck could not be located by the fleet operator. Two of the drivers provided very limited feedback: one reported limited travel along the I-94 corridor; the other driver claimed that the device was “no better than road signs,” and that the screen was also “locked” meaning that the system was somehow disabled. Two drivers completed the in-vehicle survey and their responses are discussed below.

### *Survey Construction*

To enable flexible deployment, the survey was developed using the Qualtrics survey design software hosted by the University of Michigan. The tool provides access to surveys online, provides some level of data validation, and guards against skipped responses. The initial plan had been to visit the commercial fleet to interview drivers directly. This plan was altered at the request of the fleet operator who felt that scheduling such meetings would be difficult, since driver schedules tended to be highly unpredictable. One alternative considered was to conduct the driver surveys over the phone. This was also considered unmanageable by the fleet operator. Consequently, a paper version of the survey was relayed to the fleet operator and distributed to the drivers of the vehicles equipped with the in-vehicle parking information system. Responses were collected and relayed to UMTRI for processing and summarization.

The survey was divided into six topical sections. The first section solicited information about driver demographics and driving experience, as shown in Figure 7. This included questions about gender, employment, age, driver experience, vehicle configuration, length of drive, usual driving conditions and general attitudes about technology. The second section, as shown in Figure 8, assessed the driver's familiarity and use of the in-vehicle system. It asked the driver to report his general level of exposure to the system. The third section of the survey determined if drivers made any changes to the default system configuration, as shown in Figure 9. The fourth and fifth sections collected driver opinions about how the system functioned, and how the drivers understood the information displayed, as shown in Figure 10 and Figure 11, respectively. The sixth section measured driver's overall acceptance and judgment of the system's value, as shown in Figure 12.

### *Demographic Summary*

To simplify reporting, response tallies are annotated in each of the six survey figures. Where the two drivers provide the same answer, the number 2 is indicated; where the drivers differ in their responses, the letters A and B are used to distinguish between the two drivers. Summarizing from Figure 7, both drivers were male, employees, between 45 and 64, drove other combination vehicles (11-axle), had between 11 and 20 years' experience, drove mostly regional loads, and did most of this driving in daylight. They also agreed on the usefulness of a parking information system, although they differed in the degree to which they felt accustomed to in-vehicle systems: driver B reported himself to be more accustomed to in-vehicle information systems.

### *Familiarity with In-Vehicle Systems*

Drivers differed in the degree to which they reported familiarity with the in-vehicle parking system: driver A was slightly familiar, while driver B was very familiar. The two drivers also diverged on the amount of exposure they reported to the in-vehicle system: driver A reported using it sometimes if driving along I-94, while driver B reported using it most of the time. Likewise driver A reported glancing at the display a few times along the route; while driver B reported glancing at the display often. The

responses are consistent with their earlier reports about their familiarity with the in-vehicle system.

**Driver Demographic Questions**

Gender?  
 Male -- 2 (drivers)  
 Female

Employment status?  
 Employee/Company Driver -- 2  
 Owner-Operator/Independent Contractor

Age?  
 Younger than 25  
 25-44  
 45-64 -- 2  
 65+

Primary vehicle configuration:  
 5-axle Dry Van  
 5-axle Flatbed  
 5-axle Tanker  
 Other Combination -- 2  
 Straight Truck  
 Other

Please rate your agreement with the following statements:

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
I am very accustomed to in-vehicle information systems (e.g., navigation, logistics, telematics)	<input type="radio"/> B	<input type="radio"/>	<input type="radio"/> A	<input type="radio"/>	<input type="radio"/>
Information about parking availability is valuable to me	<input type="radio"/>	<input type="radio"/> 2	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Information about parking availability will save me some time	<input type="radio"/>	<input type="radio"/> 2	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Average length of haul?  
 Local (less than 100 mile/trip)  
 Regional (100-499 miles/trip) -- 2  
 Long-haul (500+ miles/trip)

How long have you been driving commercial trucks?  
 Less than 5 years  
 5 to 10 years  
 11 to 20 years -- 2  
 More than 20 years

Please select driving conditions that are most similar to your average workday:  
 In Darkness  
 Mostly in Darkness, Some in Daylight  
 About the Same Amount of Daylight and Darkness  
 Mostly in Daylight, Some in Darkness -- 2  
 In Daylight

**Figure 7. In-vehicle survey section on driver demographics.**

**Familiarity and Use of In-Vehicle System**

How familiar are you with the I-94 Parking Information System mounted in your vehicle?

- Not at All
- Slightly Familiar -- A
- Very Familiar -- B
- Expert

Does the I-94 Parking Info System automatically turn on when the truck is started?

- Yes
- No -- 2
- Don't know

When do you turn on the I-94 Parking Info System

- Never
- Rarely
- Sometimes, if I'm on I-94 -- A
- Always When I'm on I-94
- Most of the Time -- B
- Always

Is the I-94 Parking Info System display normally visible when you are driving?

- Yes -- 2
- No

How often do you look at the I-94 Parking Info System display when you are traveling along the I-94 corridor?

- Never
- Hardly ever
- Sometimes
- A few times along the route -- A
- Many times along the route -- B

**Figure 8. In vehicle survey section that determines a driver's level of use of the system.**

*Configuration of In-Vehicle System*

Neither driver attempted to adjust the default configuration of the in-vehicle system (see Figure 9). The default settings were used in all cases.



**Configuration of In-Vehicle Device**

**I-94 Parking Info System configuration display**

Did you ever change any of the I-94 Parking Info System configuration settings?

Yes

No -- 2

Please identify which configuration settings you modified: *(drivers did not alter any configurations)*

Voice State

Show direction

Screen timeout

Distance to filter

Available spot threshold

Mile Marker filter

Time filter

If you modified the display screen timeout, did you:

Increase Timeout

Decrease Timeout

Did not Modify Timeout -- 2

**Figure 9. Survey questions related to the driver’s configuration of the system.**

*Usability I – Rating of Display and Sound*

Both drivers rated the volume settings and device brightness as “Just Right” and believed the system was not distracting. They differed in their ratings of ease in understanding the speech presented by the system and the ease of reading information from the display. Driver B reported generally less trouble than driver A. This is somewhat consistent with driver B’s reported familiarity and level of exposure to in-vehicle system. Greater exposure is likely to improve a driver’s ability to comprehend the system.

**Usability I – Rating of Display and Sound**

Please rate the volume setting of the audio from the I-94 Parking Info System device.

Too quiet  
 Just Right -- 2  
 Too Loud

Please rate how easy it was to understand the speech.

Difficult  
 Somewhat Difficult  
 Neutral -- A  
 Somewhat Easy -- B  
 Easy

Please rate the brightness of the I-94 Parking Info System display.

Too Bright  
 Somewhat Bright  
 Just Right -- 2  
 Somewhat Dim  
 Too Dim

Please rate how distracting was the I-94 Parking Info System while you were driving?

No Distraction -- 2  
 Minor Distraction  
 Moderate Distraction  
 Major Distraction

Please rate how easy it was to read information from the I-94 Parking Info System display screen.

Difficult  
 Somewhat Difficult  
 Neutral -- A  
 Somewhat Easy  
 Easy -- B

**Figure 10. Usability ratings of various characteristics of the in-vehicle information system.**

*Usability—Information Comprehension*

This series of questions was designed to reveal whether drivers understood the meaning of the information on the display (see Figure 11). Both drivers understood the displayed numbers to be absolute counts of available parking spaces. However, driver B misunderstood the up-arrow to mean that the lot is filling up, when it actually means the number of available spaces are increasing. The meaning of the arrow may be ambiguous to drivers and might require a clearer presentation. Driver B, the driver with more system exposure, also suggested that the display might show fewer rows of parking information and believed that the information was somewhat inaccurate. It is unclear what the driver based his evaluation of accuracy on, early anecdotal reports suggested that some drivers were assessing accuracy by comparing the in-vehicle display to the DTPS posted along the corridor. Because the two systems obtain their information from the same network source, they should always agree. Ideally, accuracy should be based on stopping at a site and verifying that the displayed information reflects the actual conditions at the site.

## Usability—Information Comprehension

I-94 Parking Info display screen.

Service	Location	Stalls	Trend
EXIT 104	EXIT 104	29	—
EXIT 92	EXIT 92	26	—
REST AREA	MILE 84	low	—
REST AREA	MILE 42	26	↑
EXIT 29	EXIT 29	low	↓
EXIT 12	EXIT 12	19	↓
EXIT 1	EXIT 1	22	—
Parking Information Behind			
EXIT 110	EXIT 110	27	↓
EXIT 112	EXIT 112	29	↑

Age of data: 0 min

Referring to the above display, the numbers in the column "Stalls" indicates:

- The exact number of available parking stalls. -- 2
- The Percent Filled stalls.
- The Percent Empty stalls.

Referring to the above display, the symbols in the column "Trend" indicates:

- The lot is filling up (up-arrow), clearing out (down-arrow), or not changing. -- B
- The number of available spaces is increasing (up-arrow), decreasing (down-arrow), or not changing. -- A

Referring to the above display, how many rows about parking information do you think is most useful?

- 1 – 2 -- B
- 3 – 4 -- A
- 5 - 6
- more than 6

Please rate how accurate was the parking information displayed on the I-94 Truck Parking Info System.

- Very Inaccurate
- Somewhat Inaccurate -- B
- Somewhat Accurate
- Very Accurate -- A
- Unknown Accuracy

**Figure 11. Survey section in which drivers reported their understanding of display elements.**

### *Acceptability*

Both drivers seemed to consider the in-vehicle system to provide some net benefits to drivers—they considered the information useful; they believed it could provide minor or modest improvements in compliance with the HOS regulations, and they believed that the system require little physical space inside the cab. This latter question was included to determine if the driver objected to the additional clutter new electronics might bring to their operating environment. Finally, the drivers believed that the system could improve their personal safety, or leave safety unaffected. While encouraging, these results must be considered limited since they are based on two respondents.

**Acceptability**

How useful do you think the I-94 Truck Parking Info System would be for truck drivers?

Useful -- 2

Somewhat Useful

Neutral

Somewhat Useless

Useless

How much do you think the I-94 Truck Parking Info System would improve general driver compliance with the HOS regulations?

Major Improvement

Modest Improvement -- B

Minor Improvement -- A

No Improvement

Considering the size and space occupied by the I-94 Truck Parking Info System, do you think it was:

Very Small -- 2

Somewhat Small

Neutral

Somewhat Large

Very Large

How do you feel the I-94 Truck Parking Info System affected your personal safety?

Significantly Improved Safety

Somewhat Improved Safety -- B

Neutral -- A

Somewhat Decreased Safety

Significantly Decreased Safety

**Figure 12. Rated acceptability and usefulness of the in-vehicle system.**

### **On-Site Survey of Driver's Preferred Source of Parking Information**

For this survey, four sites were visited in late August and early September of 2015 to ask drivers how they came to be aware that parking was available at the subject locations. The main purpose of this survey was to learn which of the available information sources drivers would use to determine availability. Secondary objectives were to determine driver awareness and preference for various information sources, and the extent to which drivers believed the source was convenient to use.

#### *Procedure*

Two research assistants visited each of four sites between the hours of 8:00 and 17:00. The sites visited were clustered around the Marshall and Battle Creek, Michigan areas along I-94. The parking areas included:

- The Marshall Rest Area at mile marker 113 (westbound).
- Love's Travel Stop at Exit 112.
- Pioneer Auto Truck Plaza at Exit 110.
- The Battle Creek Rest Area at mile marker 96 (eastbound).

For each site, a table, chairs, and canopy were set up along with a sign that urged commercial vehicle drivers to help us provide MDOT with feedback about the I-94 TPIMS. In rest areas, the survey station was located along the pathway to the restrooms; for exits the survey station was situated between the parking area and the convenience


store or restaurant. The two exit sites surveyed in this study each had one parking area and major convenience store. This is noted because exits can have more than one parking area and associated businesses.

Access to each site was directly negotiated with representatives of MDOT (for rest areas) and representatives from the commercial businesses at each exit (Loves' Travel Stops, and Walters-Dimmick Petroleum, Inc.).

Participation in the survey was voluntary and anonymous. While many drivers were directly interviewed by research assistants equipped with surveys and clipboards, many drivers preferred to complete the paper survey unassisted. One consequence of this reticence to directly engage with survey personnel is that drivers skipped many questions that they did not fully understand. For example, many drivers were unaware of the availability of smartphone apps or websites and simply skipped answering these questions.

#### *Survey Content*

The survey was divided into two main sections. The first section was focused on basic demographic information about drivers, the size of their haul, and their exposure and acceptance of technology. A facsimile of the first page of the survey is shown in Figure 13. Item 6 of the survey attempted to gauge each driver's perceived comfort with technology and their perceived need and utility of parking assistance.



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### I-94 Driver Opinion Survey of Smart Parking System




**Driver Info (check one)**

<p><b>1. Gender</b></p> <p><input type="checkbox"/> Male</p> <p><input type="checkbox"/> Female</p> <p><b>2. Employment Status</b></p> <p><input type="checkbox"/> Employee/Company Driver</p> <p><input type="checkbox"/> Owner-Operator/Independent Contractor</p> <p><b>3. Age</b></p> <p><input type="checkbox"/> Younger than 25</p> <p><input type="checkbox"/> 25-44</p> <p><input type="checkbox"/> 46-64</p> <p><input type="checkbox"/> 65+</p>	<p><b>4. Average length of haul:</b></p> <p><input type="checkbox"/> Local (less than 100 miles/trip)</p> <p><input type="checkbox"/> Regional (100-499 miles/trip)</p> <p><input type="checkbox"/> Long-haul (500+ miles/trip)</p> <p><b>5. Primary vehicle configuration:</b></p> <p><input type="checkbox"/> 5-axle Dry Van</p> <p><input type="checkbox"/> 5-axle Flatbed</p> <p><input type="checkbox"/> 5-axle Tanker</p> <p><input type="checkbox"/> Straight truck</p> <p><input type="checkbox"/> Combination (doubles, triples)</p> <p><input type="checkbox"/> Other (specify)</p>
---	---

**6. Please rate your agreement with the following statements:**

	Strongly Agree	Agree	Neither	Disagree	Strongly Disagree
• I am very accustomed to in-vehicle information systems.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Information about parking availability is valuable to me.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Information about parking availability will save me some time.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Page 1 of 4

**Figure 13. Page one of the onsite driver survey. These questions target basic driver demographics.**

The second page of the survey asked drivers to identify how they knew parking at the location was available. Answers covered a range of possibilities, including the sources under consideration here, as well as the driver’s reliance on past experience. Drivers were asked to select all options that they may have used at any time, as shown in Figure 14.

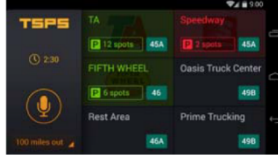
**Parking Availability**

7. How did you know that parking was available? (check all that apply)

- I didn't know parking was available.
- Based on past experience, I knew parking would be available.
- I saw the electronic parking information signs along roadside:



- I used a smart-phone application (Truck Smart Parking Services—TSPS):



- I checked M-DOT's Mi-Drive website or the TSPS website:



- I used an in-vehicle connected info-system:



**Figure 14. The questions in this section of the survey asked drivers to identify how they determined parking availability at the current site.**

In the final sections of the survey, drivers were asked to rate their preferences for different methods of receiving information about parking availability (Figure 15) and how clear and useful they found each information source (Figure 16).

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8. Please rate your preference for the different sources of parking info:

	Most Preferred	Preferred	Neither	Less Preferred	Least Preferred
Electronic road signs 	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Smart phone apps:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Website information sources:					
• MI Drive website	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Truck Smart Parking System website:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
In-vehicle information display:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Figure 15. The survey collected preference data for different sources of information about parking availability.**

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9. For each source used, rate the clarity and usefulness of the information:

		1 Least	2	3	4	5 Most
Electronic road signs 	Clear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Useful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Smart phone app: 	Clear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Useful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
MI Drive website	Clear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Useful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TSPS Find Parking website	Clear	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Useful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

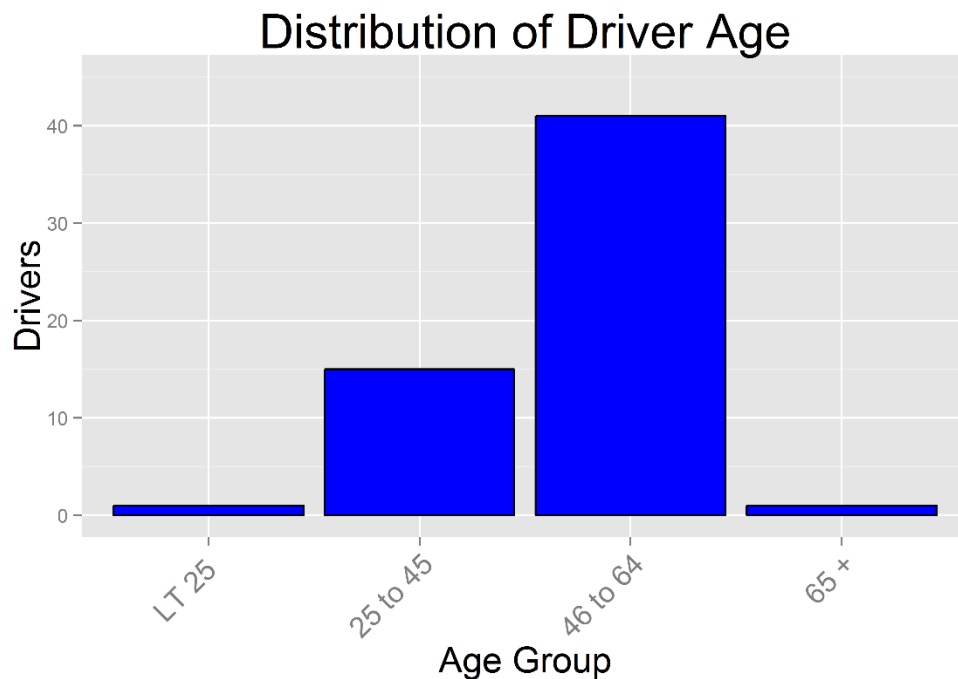
**Figure 16. This series of questions asked drivers to rate how clear and useful each information source was.**



## Survey Results

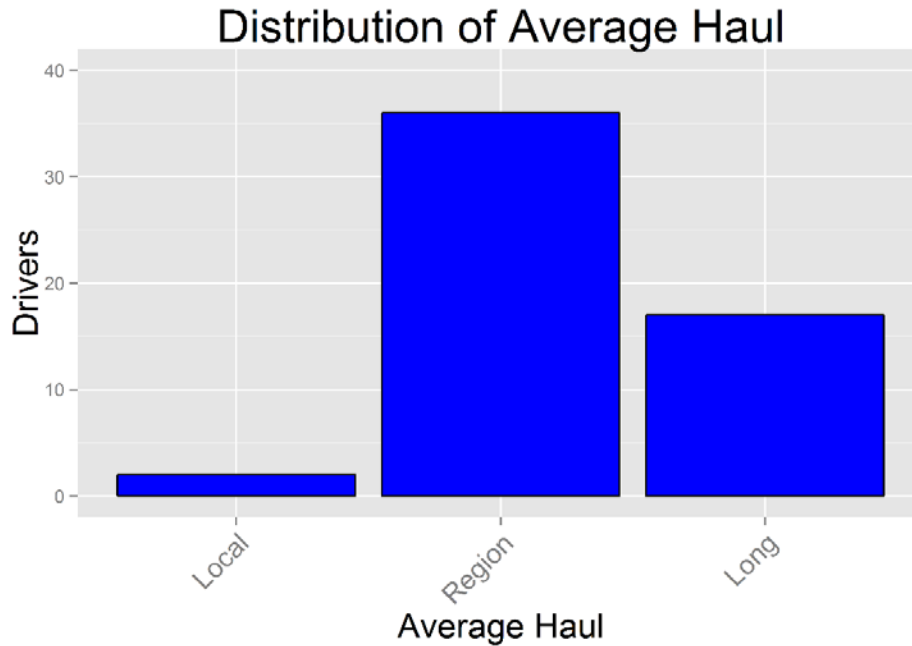
Overall, responses were collected from 60 respondents over the course of the four days of onsite canvassing. Omitted answers are excluded from all plots except for the ratings of clarity and usefulness (Figure 26 and Figure 27).

Most drivers were between 46 and 64 years of age. One driver was over 65; one driver was under 25. The distribution of driver age is shown in Figure 17. Two respondents did not report age. One female driver participated in the survey; 59 respondents were male. Ten drivers identified themselves as independent operators; 41 worked as an employee of a fleet operator; and 9 did not report their employment status.



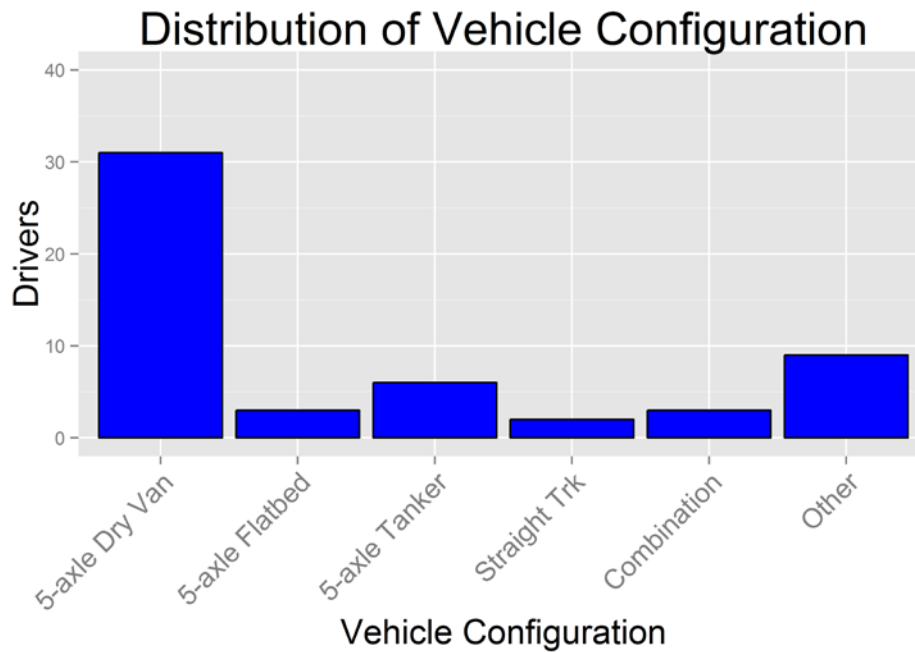
**Figure 17. Distribution of drivers' age in survey; two respondents did not report their age.**

The average haul characteristics of the sampled drivers was mostly regional (36), followed by long haul (17), and local (2). This distribution is shown in Figure 18.



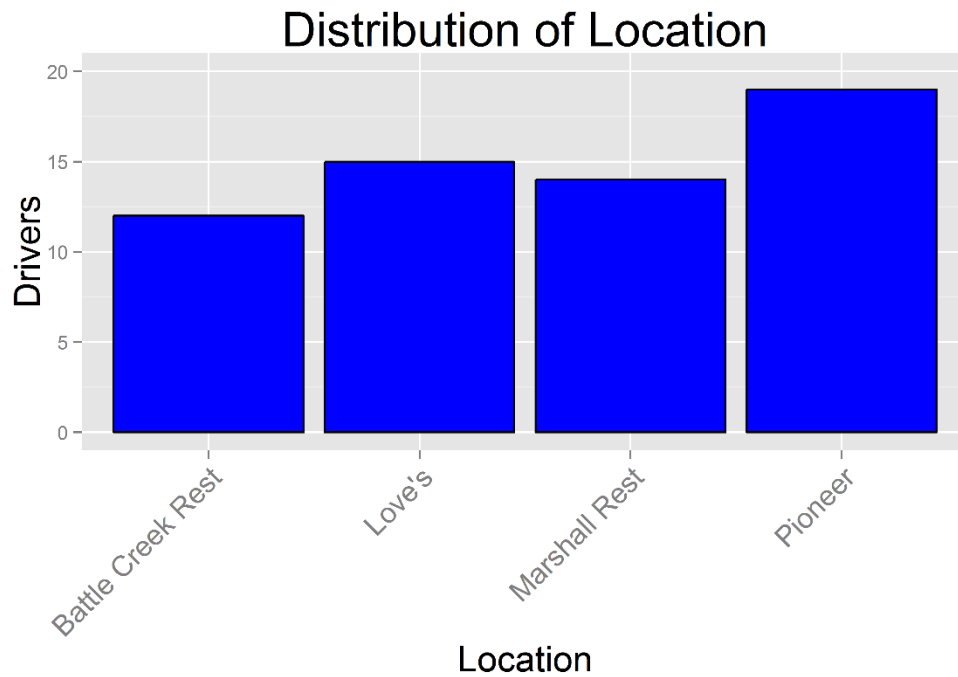
**Figure 18. Distribution of drivers among the categories of average haul length; 5 drivers did not respond.**

The distribution of the type of vehicle configuration among the sampled drivers is shown in Figure 19. Most vehicles were 5-axle dry vans; 6 drivers did not report vehicle configuration.



**Figure 19. Distribution of vehicle configurations among the 60 participating drivers.**

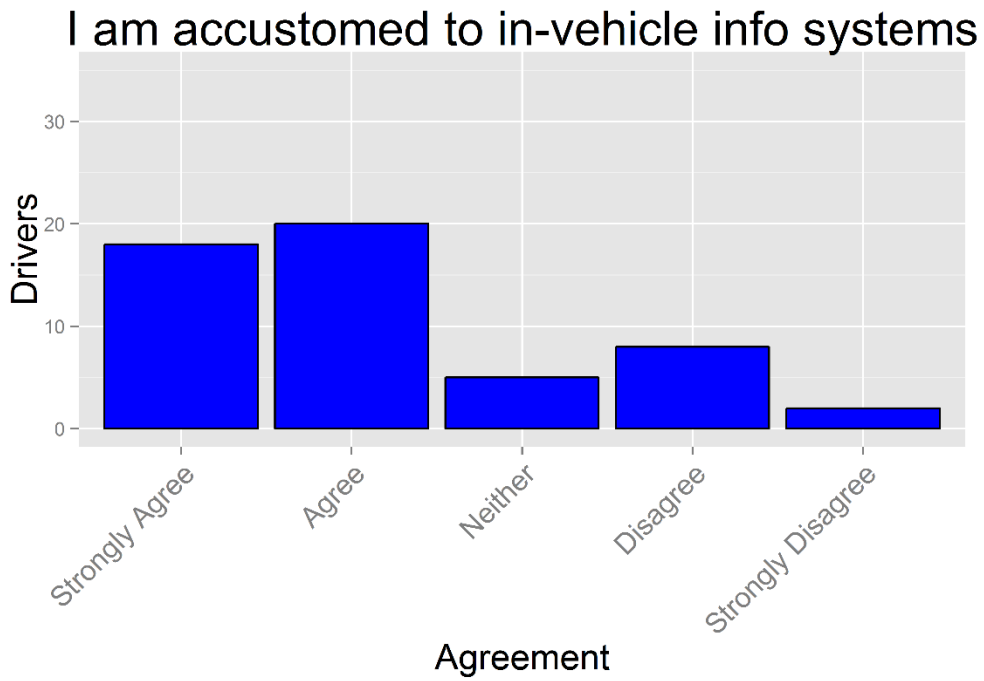
The location of the respondents were approximately equally distributed among the two exits and two rest areas canvassed. The distribution is shown in Figure 20.



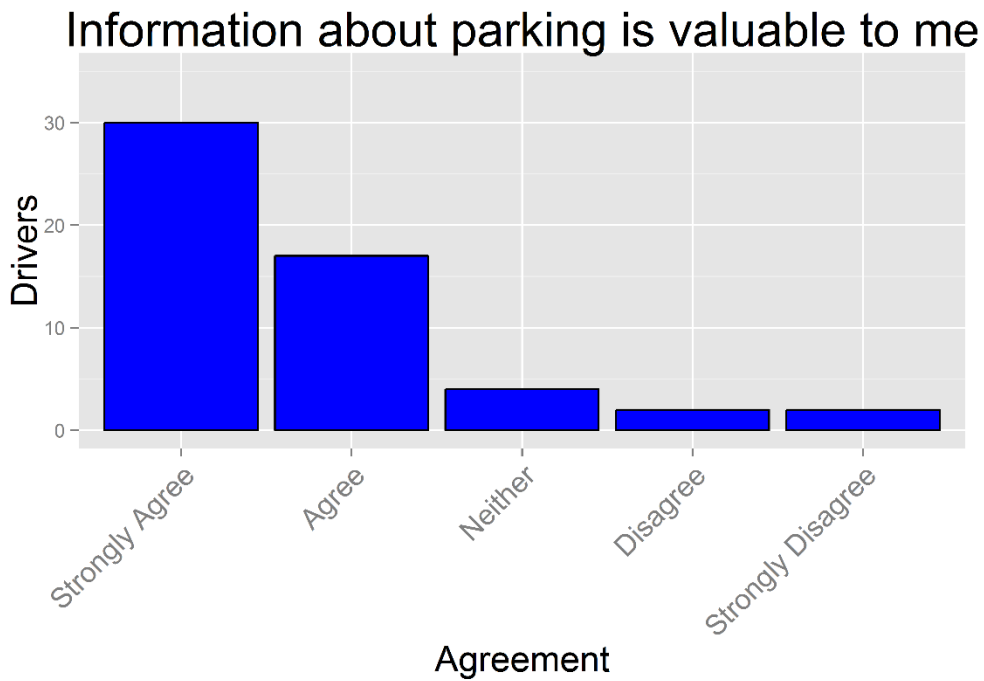
**Figure 20. Distribution of respondents. All 60 respondents are included in this sample.**

In general, the driver sample appeared to be generally acquainted with in-vehicle information systems (like navigation or logistics management systems)—38 drivers reported agreement or strong agreement with the statement that they are accustomed to in-vehicle systems; 7 drivers omitted answering this question (see Figure 21). Drivers overwhelmingly agreed that parking information systems were personally valuable to the driver and could save them time in driving (see Figure 22 and Figure 23). There were 5 and 6 omitted responses for these items, respectively.

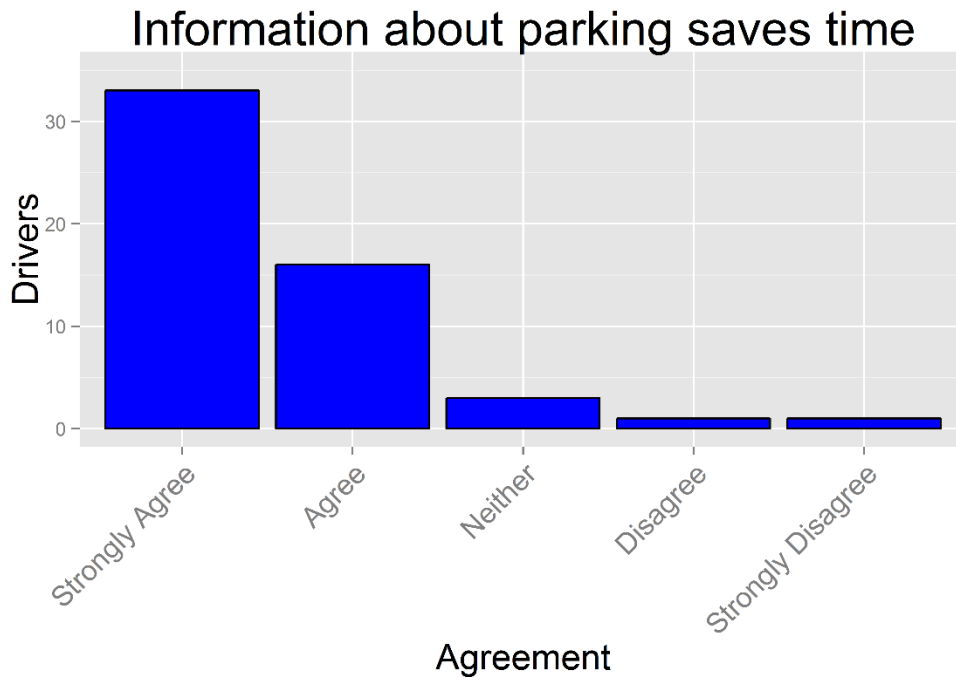
Overall, the sample of drivers was positively disposed to a system that could assist them in finding parking quickly.



**Figure 21. Distribution of drivers' opinions about how accustomed they are to in-vehicle information systems.**



**Figure 22. Distribution of level of agreement with statement that parking information is valuable.**

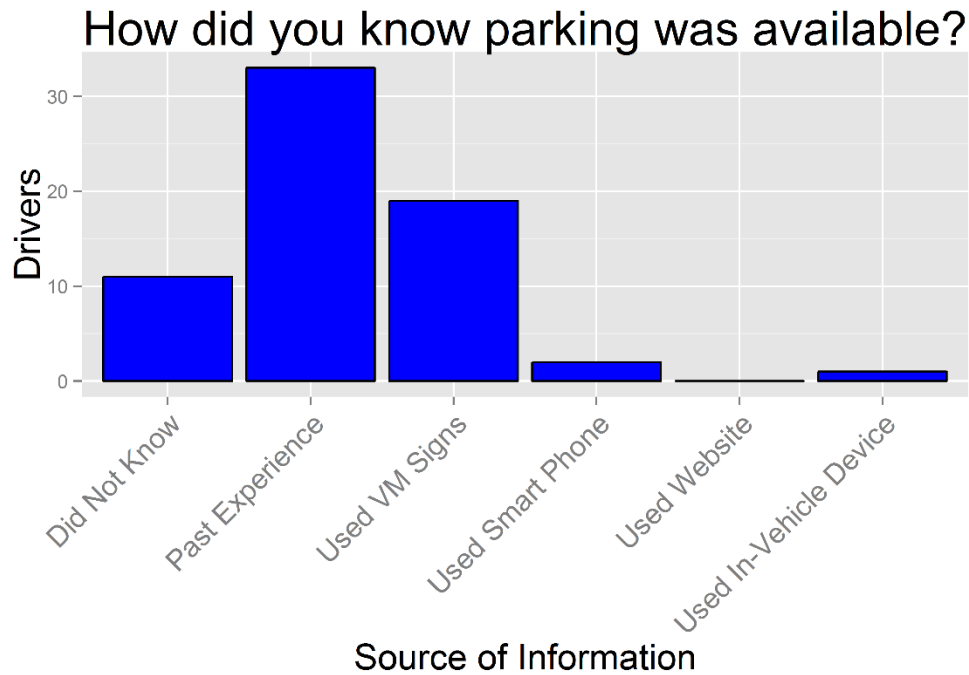


**Figure 23. Distribution of level of agreement with statement that parking information saves time.**

#### **Actual and Preferred Source for Parking Availability Information**

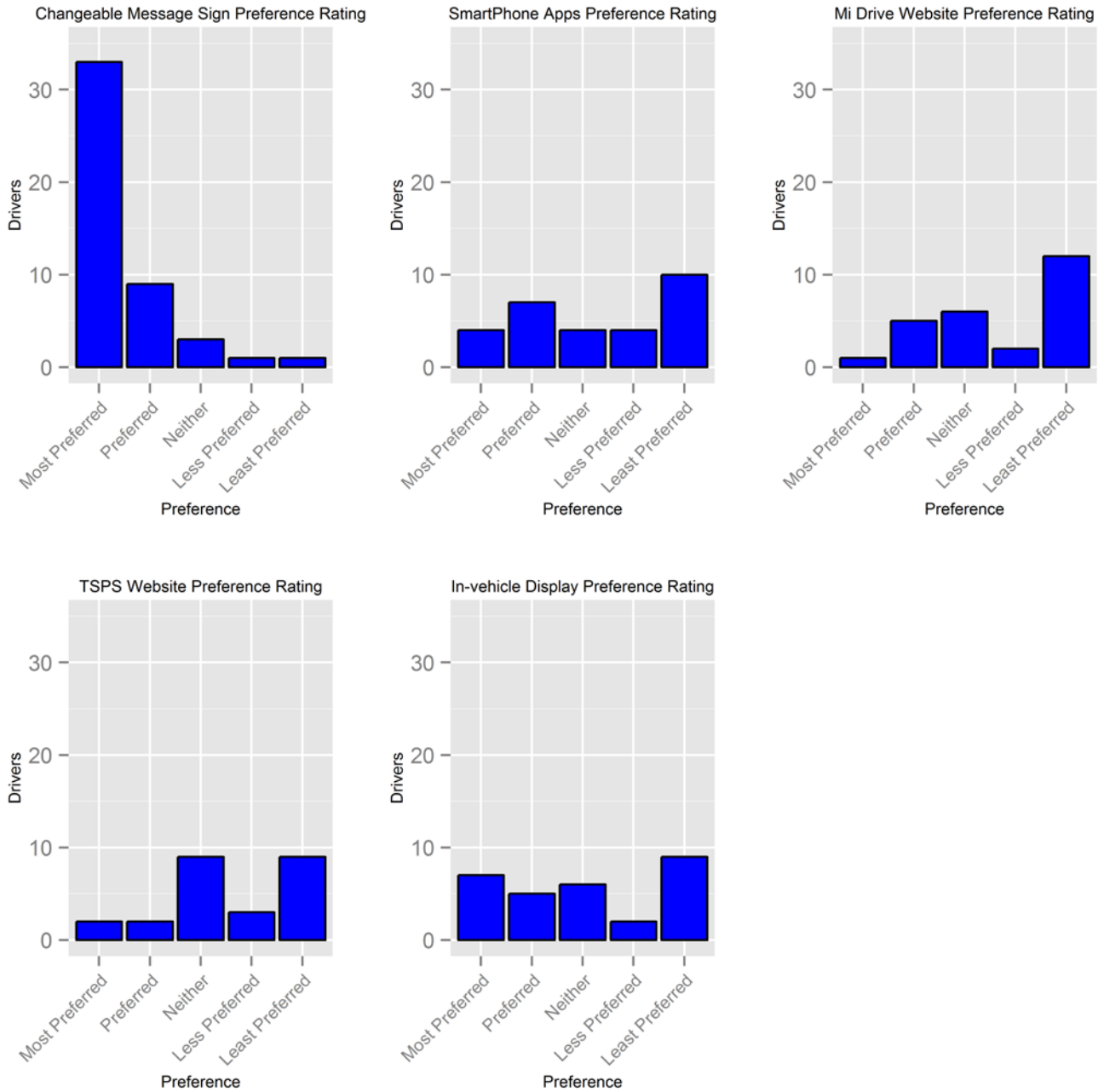
In practice, most of the drivers queried about how they knew about parking availability either said that they did not know parking was available (11 drivers) or that they based their decision on past experience (33 drivers). Of the other sources, 19 drivers reported using the DTSPS, 2 reported using a smartphone application, and 1 believed they had used an in-vehicle device. No drivers consulted websites to plan their rest stop. This is shown in Figure 24.

Of the two drivers that used a smartphone application, one was at the Love’s Travel Stop and the other at the Marshall Rest Area. The former driver did not identify the application used; the latter driver mentioned using the myPilot application (which does not provide parking availability information). Thus, reported opinions about smartphone-base applications are not necessarily associated with the TSPS application.



**Figure 24. Reported source of parking availability information at local parking areas.**

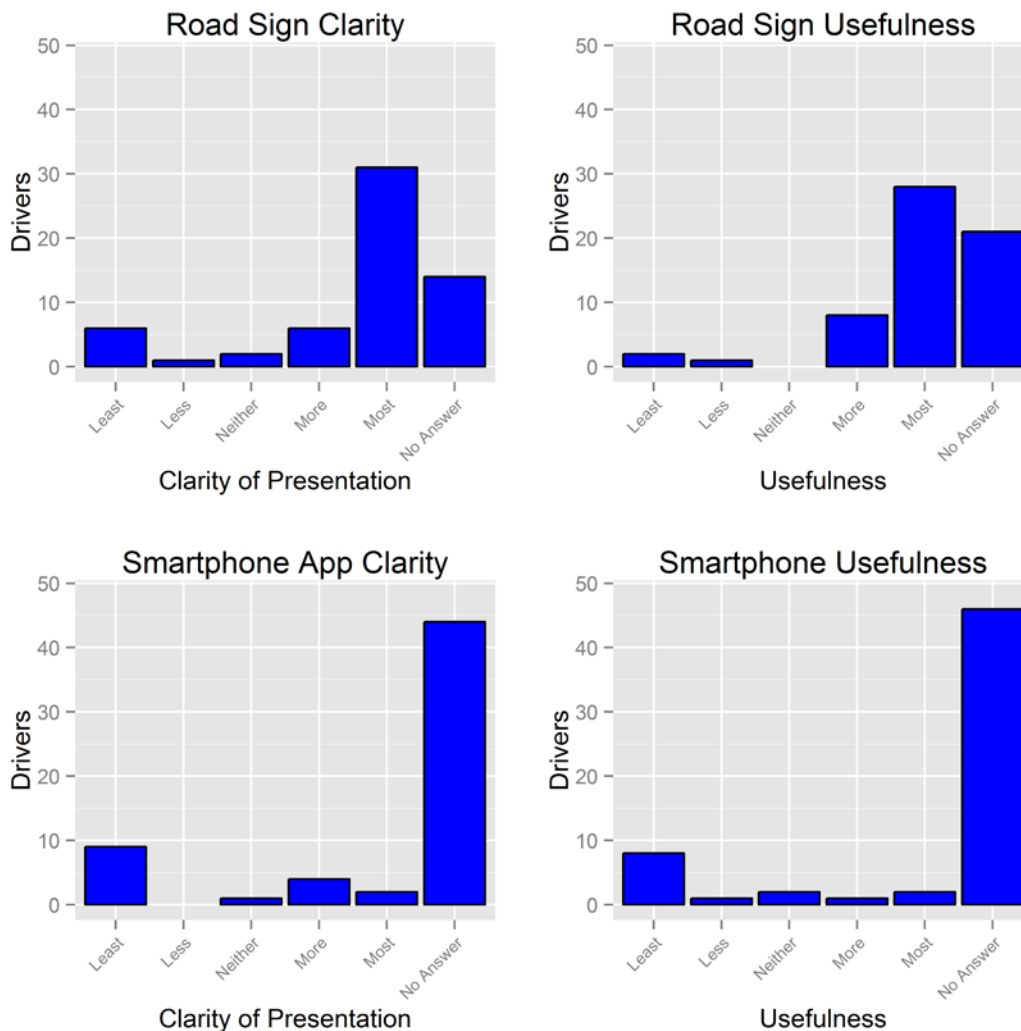
Preferences for each of the five parking information sources are shown in Figure 25. The plots show that there was a strong preference for the roadside sign displays (DTPS) of parking availability. 13 drivers omitted responding to this question. In contrast, more than half of the drivers omitted providing any preference information for smartphone applications, websites, or in-vehicle displays. Of those responding, there is a limited preference for in-vehicle and smartphone information sources, and less preference for either website-based solution.



**Figure 25. Preference ratings among the alternative sources of parking information. Among driver responses, most preferred to receive parking information from DTPS.**

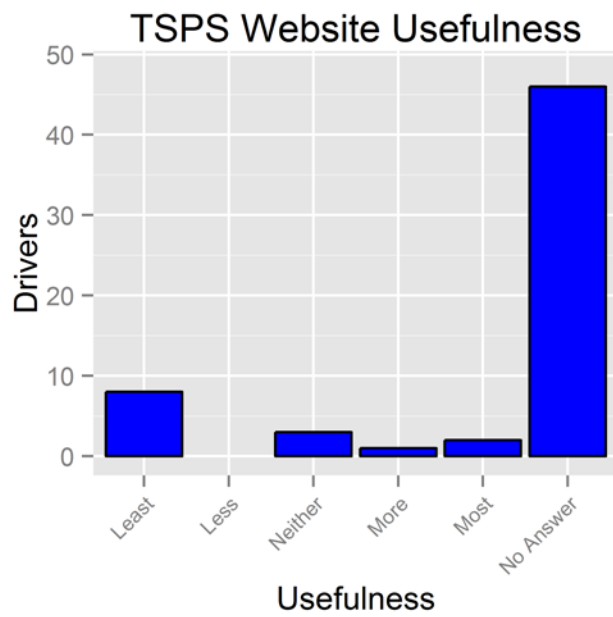
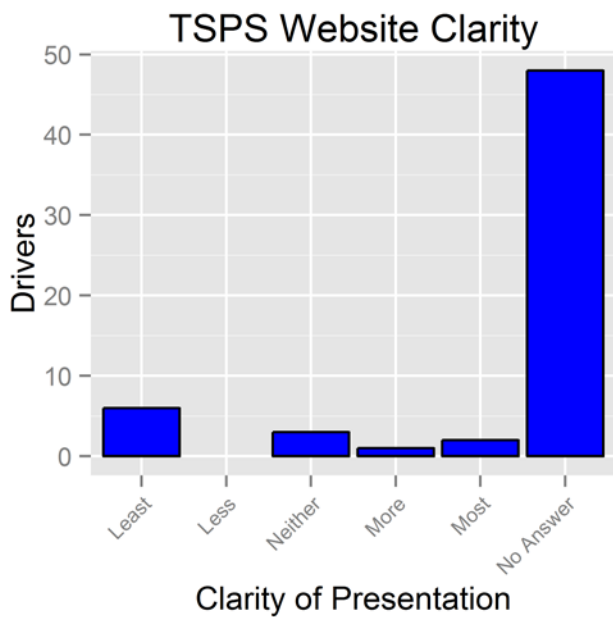
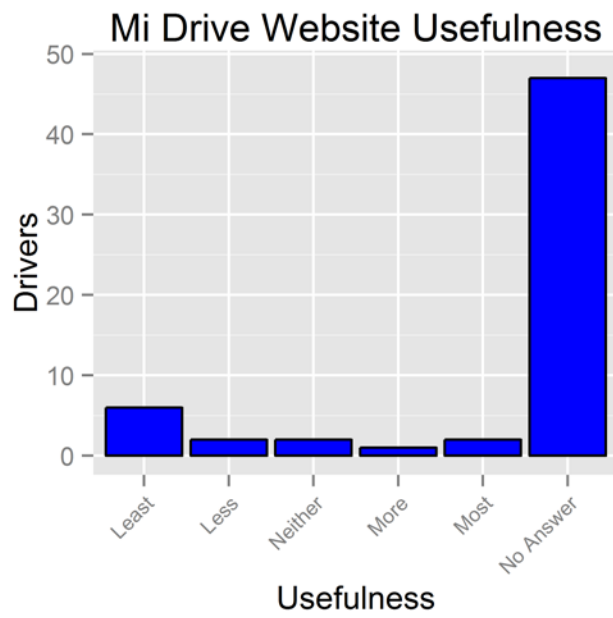
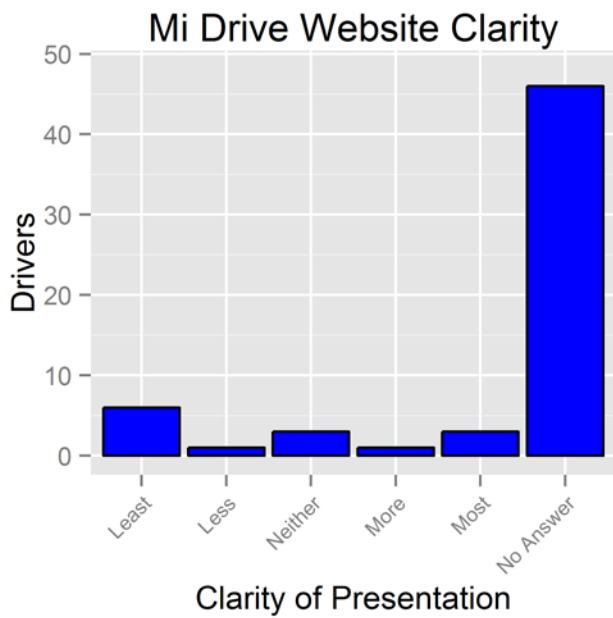
Finally, drivers were asked to rate the clarity and usefulness of each information source identified. Drivers used a 5-level scale ranging from Least Clear/Useful to Most Clear/Useful. The distribution of these ratings is shown in Figure 26 and Figure 27. Note that in these plots, the frequency of a “No Answer” response is also shown on the far right of each plot. The DTPS information source elicited ratings from about 71% of the drivers; the other three source categories (smartphone and the two websites) resulted in an average of less than 25% of the drivers providing any rating. Drivers appeared to be reluctant to provide ratings for sources that they were not familiar with.

In general, drivers appeared to overwhelmingly find the road sign sources both clear and useful, suggesting that acceptance of this source to be quite high. None of the other sources were rated as positively.



**Figure 26. Distribution of rated clarity and usefulness of DTPS and smartphone applications.**





**Figure 27. Distribution of rated clarity and usefulness of the two website truck parking information sources in the survey.**

## Safety Assessment

Although relatively sparse, there is some literature that shows that rest areas have a significant effect in reducing certain crash types related to fatigue. Note that these studies address the question of whether the presence of rest areas reduces crashes, while the current evaluation is of a parking-information system. The current project does not increase the actual number of parking spaces; it increases knowledge of the availability of existing spaces. However, if increasing a truck driver's information about the availability of parking spaces increases the utilization of the spaces, the effect may be the same.

A 1999 study of rest areas in Michigan focused on the presence and utilization of rest area parking, and its effect on single-vehicle truck crashes. It found parking shortages along I-94 between midnight and 4 a.m. Crash analysis showed that fatigue-related truck crashes, particularly single-vehicle crashes, increased significantly when rest areas were more than 30 miles apart. Among the recommendations were for additional truck parking spaces along I-94, as well as I-69, US 23, and I-75 at the first rest areas for trucks entering Michigan (Taylor, Sung et al. 1999).

A similar study was performed in Minnesota (SRF Consulting Group 2007), replicating the Taylor study in Michigan. They found that rest areas reduced single-vehicle truck crashes at all times of day. Where rest areas were heavily used—that is, a high percentage of capacity used at night—there was an increase in single-vehicle crashes downstream.

McArthur et al., focused on fatigue-related crashes, again using Michigan data. They used spatial analysis of rest areas and proximity to crashes, controlling for traffic volume. They found that rest areas significantly reduce the incidence of fatigue-related crashes. This study included all vehicle types, but the effects would be similar considering trucks alone. The study estimated an increase of 0.03 crashes per mile distance to a rest area, with the effect diminishing to zero beyond 20 miles. The protective effect was observed both for upstream and downstream road segments (McArthur, Kay et al. 2013).

Existing literature shows that providing parking spaces is associated with a reduction in crashes, especially single-vehicle crashes and crashes related to fatigue. However, the effects observed are relatively small and decline with distance from the rest areas. While the current project does not increase the actual amount of truck parking available, it is aimed at increasing knowledge of parking availability so it is reasonable to expect a similar safety effect, that is, a reduction in certain crash types. The safety assessment was designed to attempt to detect a safety effect, within the constraints of available data.

The studies of the effect of parking availability commonly used the following crash types as relevant to rest areas:

1. The driver was coded as fatigued.
2. Single-vehicle crashes where the driver not drugged or drunk.
3. Ran off road, struck fixed object crashes.

4. Parked vehicle crashes with at least 2 vehicles, one parked and at-fault driver not drugged or drunk.

These definitions were used in the present evaluation.

## **Data**

The safety evaluation was based on crash data from the state of Michigan. The data were coded from police crash reports, and compiled by the State. The Michigan crash data include all motor vehicle crashes in Michigan, reported by police officers on the State's standard crash reporting form, the UD-10. The Michigan crash data include variables to identify trucks, to identify crash types of interest, and to locate the crashes to the roadways of interest.

Data from crash years from January 1, 2012 through October 28, 2015, were used in the evaluation. The test period began August 25, 2014, when the truck parking information signs were activated. A special extract was requested from the Traffic Records program of the Michigan Office of Highway Safety Planning to acquire the latest crash data possible, and thus extend the evaluation period as long as possible. This special extract included crashes as late as October 28, 2015.

## **Definitions**

**Truck:** trucks were identified using the vehicle type variable from the UD-10, in combination with the truck type code field from those data. The primary field to classify motor vehicles on the UD-10 is the vehicle type field. Using this field to identify trucks is problematic, because the code level that would be used for trucks also includes buses. Commercial buses present a different problem with respect to HOS, so they were excluded from the analysis to the extent possible. The truck type code, which is coded as part of supplemental data collected for all trucks and buses, was used to exclude all vehicles identified as buses in that field. This method is the cleanest way to identify trucks in the Michigan crash data.

**Crashes:** crashes were categorized into "Before" and "Test" periods. The before was defined as January 1, 2012 through August 24, 2014, which was the date on which the truck parking information signs became fully operational. The test period was defined as August 25, 2014, through the last day for which data could be obtained for this project, October 28, 2015. Thus, the before period was two years and eight months long, and the test period was one year and two months long. The test period was as long as feasible given the constraints of the project end date, and the before period was about 2.3 times as long as the Test period.

Three crash types were identified as parking-related. These crashes are considered parking related as they either occurred because the truck was illegally parked or the driver was considered fatigued. Parking-related crashes included the following:

- All crashes where the truck driver was identified as fatigued or asleep.

- Crashes in which the truck was coded a parked in pre-event movement, but was not legally parked. These are all crashes in which a truck was parked along the shoulders of highways, along ramps, or in rest areas but not within defined parking spaces. The striking vehicle could be another truck or any other vehicle type.
- Single-vehicle crashes where a truck ran off the road and rolled over or struck a fixed object.
- Crashes coded as alcohol- or drug-related were excluded.

The single-vehicle crash type is typically included to capture crashes in which the truck driver may have been fatigued. These are crashes in which the truck went off the road under control, that is, not skidding, and there was no other explanation, such as the driver being under the influence of alcohol or drugs. Excluding prior loss of control eliminates single-vehicle crashes that might be explained by slick roads or a vehicle failure such as a tire blowout.

The pilot stretch of road was defined as I-94 from the Indiana border to the eastern border of Jackson County, approximately 153 miles. The eastern-most truck parking location included in the study was located at Exit 128 near Parma, Michigan, which is located in Jackson County. Exit 128 on I-94 is about 25 miles from the eastern border of Jackson County. Studies have suggested the positive effect of rest areas on trucking crashes disappeared beyond 20 miles. The area described encompasses the approximate area where a safety effect would be expected, if it could be detected.

A set of comparison roads were selected, with the purpose of finding roadways that would be similar to the pilot roadway, except for the presence of the TPIMS, as represented by the signage and other means of communicating the availability of truck parking availability along the pilot stretch of road.

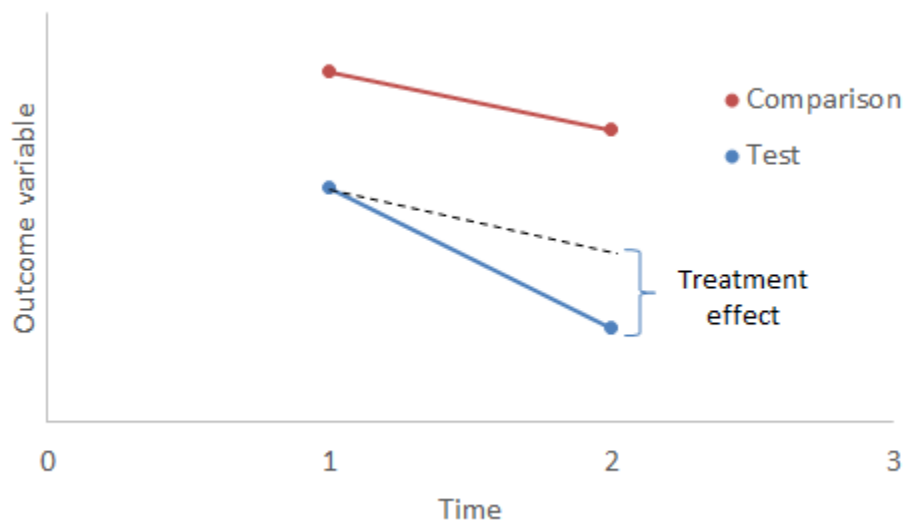
The roads selected were all limited access, as was the pilot roadway, with significant truck traffic. The pilot test was conducted on I-94, which is one of the major east-west truck routes in Michigan, so we wanted the comparison roads also to be limited access as well as a major truck route. In addition, the comparison road should be sufficiently far from the pilot roadway as to not be influenced by the pilot. Research had shown that the effect of the provision of parking spaces dissipated beyond 20 miles, so limited access roads within 20 miles of the pilot roadway were excluded. Those criteria limited selection to I-96 from Ottawa County to Livingston County, I-69 in Branch County, and I-75 in Monroe, Genesee, and Saginaw Counties. These highways all serve industrial areas of Michigan, or are used to transport freight between them. Urban interstates were excluded.

## **Method**

The goal of the evaluation was to identify the effect of the treatment—the Pilot TPIMS—on safety, that is, the occurrence of truck parking-related crashes. Crash data from the before period as well as from the test period, when the “treatment” was being administered, was used in the analysis. The most direct evaluation would have been to

compare crash rates, before and after. However, vehicle miles traveled (VMT) data for the time periods of the evaluation were not available in time, so it was not possible to compute crash rates and evaluate the effect of the TPIMS directly on crash rates per mile traveled. That would have been the preferred method, because it allows for direct control of exposure.

Since VMT data were not available, an indirect method of controlling for exposure was selected. The evaluation proceeded through a “natural experiment,” by finding a comparable road where the treatment was not administered, and comparing the change in proportion of parking-related crashes, before and during the treatment period. This method is a version of the “difference-in-difference” design, which may be used when appropriate exposure data are not available. In this method, the difference between the before and the treatment period is computed for the test group and for a comparison group to which the treatment was not administered. If the treatment had no effect, the difference between the before and treatment period for the test group would be the same as for the comparison group. However, if the treatment had an effect, the difference between the before and treatment period in the test group would be different (greater or lesser) than the comparison group. Figure 28 illustrates the method graphically. In the current case, the outcome variable is the percentage of parking-related crashes. The test group is the stretch of I-94 on which the TPIMS was implemented and the comparison group consists of the set of comparable roads that did not have a TPIMS.



**Figure 28: Difference between the before and treatment period**

### *Results*

#### **Characteristics of parking-related crashes**

Parking-related crashes were defined as those in which the truck driver was coded as fatigued or asleep, the truck was parked or single-vehicle crashes in which there was no prior loss of control and the pavement was dry. Over the entire period, January 2012 to October 28, 2015, about 6.5% of truck crash involvements on the test roadway met the

criteria for “parking-related.” (Please see Table 1.) Parking-related involvements accounted for 136 of the 2,086 truck crash involvements over the period on the pilot test stretch of the road. Most of the parking-related involvements were single-vehicle crashes, as defined, but 22 (1.1%) were driver-fatigued and 25 (1.2%) were crashes in which the truck was parked along the roadway, on a ramp, or in proximity to a rest area (presumably illegally parked).

**Table 1 Parking-related and other crash types on pilot roadway**

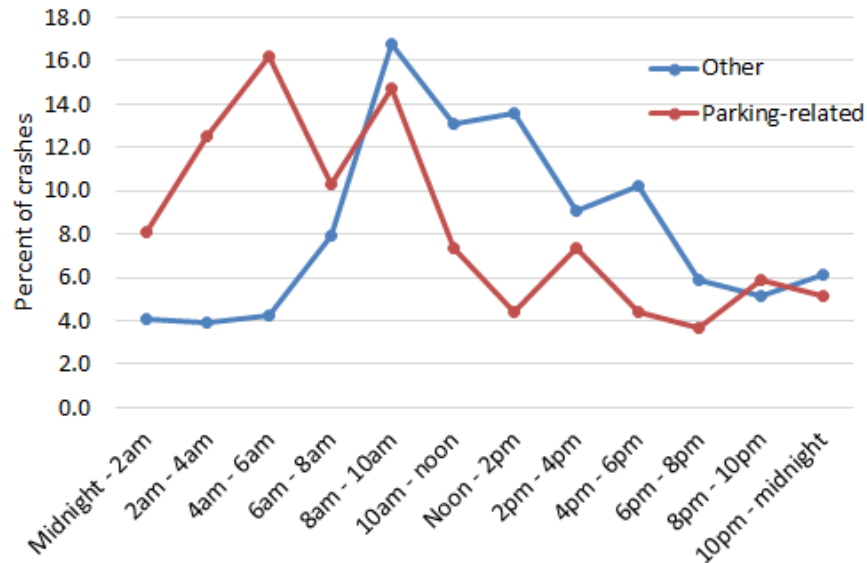
Crash type		N	%
Parking-related	Fatigued	22	1.1
	Parked	25	1.2
	Single-vehicle	89	4.3
Other crashes		1,950	93.5
Total		2,086	100.0

Parking-related crashes may have been somewhat less severe than other truck crashes though the differences were slight. Overall, 75% of parking-related crashes resulted in no injury, compared with 72.9% of all other truck-involved crashes. On the other hand, 7.5% resulted in serious injury, including a fatal or incapacitating injuries. These occurred primarily in single-vehicle truck crashes, which involved running off the highway and rolling over or colliding with a fixed object such as a bridge.

**Table 2 Percent distribution of most severe injury in crash on pilot road**

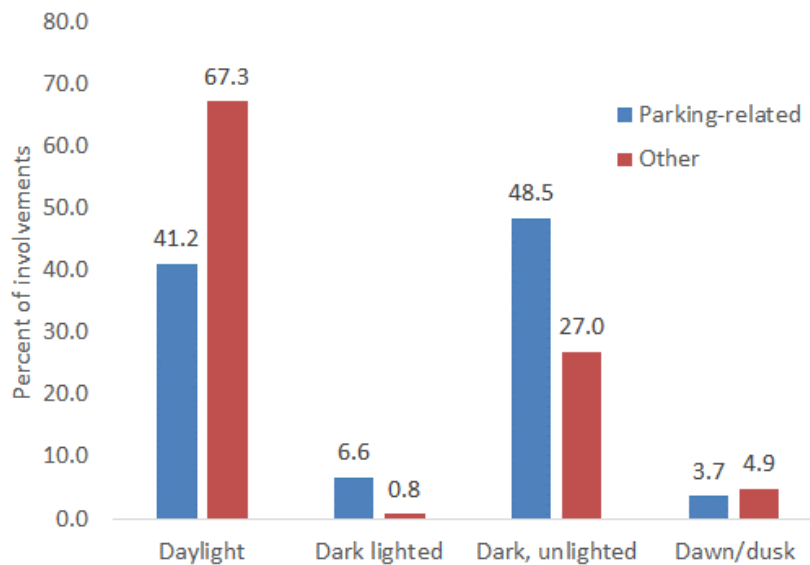
Crash severity	Fatigued	Parked	Single-vehicle	All parking-related	Other crashes	All truck crashes
Fatal	0.0%	0.0%	2.2%	1.5%	2.4%	2.3%
A - injury	9.1%	4.0%	4.5%	5.1%	5.7%	5.7%
B - injury	9.1%	8.0%	2.2%	4.4%	5.3%	5.2%
C - injury	18.2%	28.0%	9.0%	14.0%	13.7%	13.8%
No injury	63.6%	60.0%	82.0%	75.0%	72.9%	73.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Parking-related crashes had a significantly different pattern of occurrence across the hours of the day (Figure 29). Most parking-related crashes (52%) occurred between 10 pm to 8 am, compared with 23% of other crashes. In contrast, about 63% of non-parking-related crashes occurred between 8 am and 6 pm, peaking between 8 am and 10 am. The set of parking-related crashes defined to capture crashes related to driver fatigue and rest, both when fatigue precipitates a crash directly or when a driver pulls off the road in order to rest. The figure shows two-hour groups because the data is sparse over the short period of time covered by the test phase of the evaluation.



**Figure 29 Distribution of parking-related and other crashes by hour of day  
Pilot roadway**

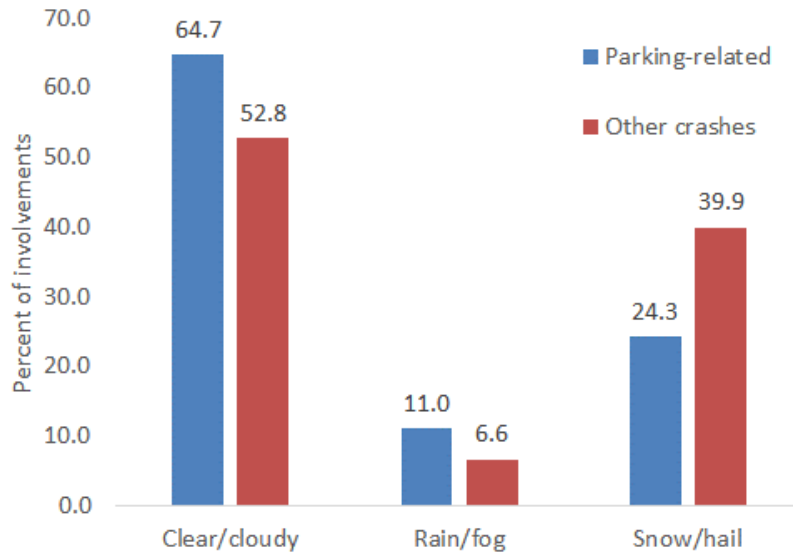
The distribution of light condition also reinforces the point that the crash types defined as parking-related tend to occur more often at night. Figure 30 shows that about two-thirds of non-parking-related crashes occurred in daylight, while only 41.2% of parking related crashes occurred in daylight. In addition, almost half of parking-related truck crash involvements occurred in unlighted darkness, that is, away from artificial lighting, such as on unlighted shoulders, ramps, and unlighted areas near rest areas.



**Figure 30 Distribution of parking-related and other crash types by light condition  
Pilot roadway**

Parking-related crash involvements also tended to occur in somewhat better weather conditions than other crash involvements (Figure 31). Almost two-thirds occurred in clear or cloudy weather, compared with 52.8% of all other crash involvements. In contrast,

almost 40% of other crashes were in snow, blowing snow, sleet, or hail, compared with 24.3% of parking-related. This makes some sense because the other crashes here include two- or more-vehicle crashes, which may have increased in inclement weather. Also, note that the percentage of crashes in snowy weather may seem high, at 40%. As shown below, the stretch of road used in the pilot project included counties along Lake Michigan that are subject to lake-effect snowfalls, and the winters in the study period proved to be unusually snowy.



**Figure 31 Distribution of parking-related and other crash types by weather Pilot roadway**

### *Effect of TPIMS Pilot*

Table 3 presents the raw data on parking-related and other crashes along the TPIMS pilot roadway, divided into crashes occurring in the before period and during the test phase, when the DTSPs were activated. The before period was about twice the length of the test phase, so the frequencies are not instructive by themselves. However, the bottom portion of the table gives percentages of the different crash types for the before and test periods. Parking-related crashes accounted for 6.6% of truck crash involvements in the before period and 6.4% in the test period. This slight decline of 0.2% was not statistically significant.



**Table 3 Parking-related and other crashes on TPIMS pilot road**

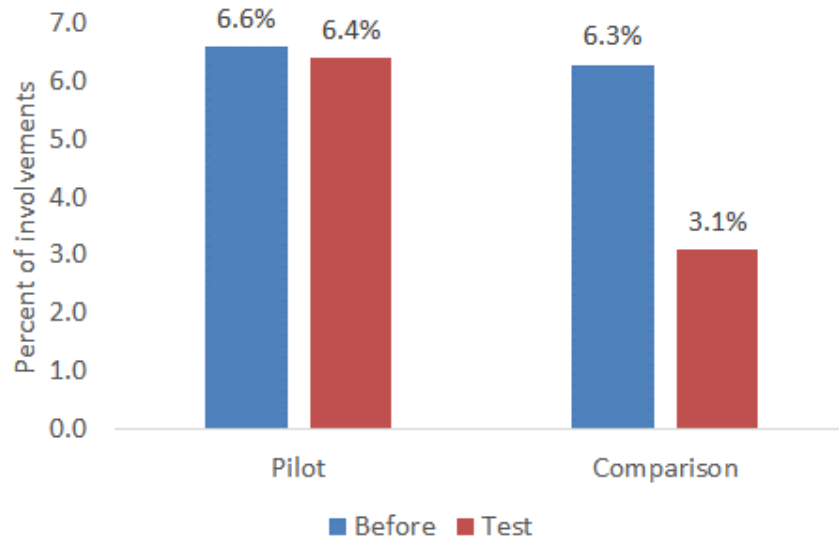
Period	Fatigued, asleep	Parked	Single vehicle	Sum of parking-related	Other crash types	Total
Before	11	14	64	89	1,261	1,350
Test	11	11	25	47	689	736
Total	22	25	89	136	1,950	2,086
	Fatigued, asleep	Parked	Single vehicle	Sum of parking-related	Other crash types	Total
Before	0.8%	1.0%	4.7%	6.6%	93.4%	100.0%
Test	1.5%	1.5%	3.4%	6.4%	93.6%	100.0%
Total	1.1%	1.2%	4.3%	6.5%	93.5%	100.0%

Table 4 provides the raw data for the comparison roads. The table shows that the percentage of parking-related crash involvements declined from 6.3% of all truck involvements to 3.1%. The percentage of each individual parking-related crash type declined, though most of the decline was accounted for by the reduction in single-vehicle crashes. A t-test of the difference in the proportions of parking-related crashes was statistically significant, meaning that it was unlikely that the difference was the result of random fluctuation.

**Table 4 Parking-related and other crashes on comparison roads**

Period	Fatigued, asleep	Parked	Single vehicle	Sum of parking-related	Other crash types	Total
Before	8	12	62	82	1,223	1,305
Test	3	3	12	18	565	583
Total	11	15	74	100	1,789	1,889
	Fatigued, asleep	Parked	Single vehicle	Sum of parking-related	Other crash types	Total
Before	0.6%	0.9%	4.8%	6.3%	93.7%	100.0%
Test	0.5%	0.5%	2.1%	3.1%	96.9%	100.0%
Total	0.6%	0.8%	3.9%	5.3%	94.7%	100.0%

Figure 32 shows the proportion of target truck crash types in the before period and the test period, on the stretch of I-94 where the pilot took place and the comparison roadways. The pilot road showed only a slight decline in the percentage of parking-related crash involvement between the before and test phase. In contrast, the comparison roadways showed a substantial decline between the two periods, dropping by more than half.



**Figure 32 Percentage of parking-related crashes on pilot and comparison roads before and test periods**

*Discussion*

Realistically, it was not expected that it would be possible to detect a significant reduction in the target crash types during the test phase. It makes sense that there would be a positive safety effect from increasing the awareness of parking availability among truckers. Even though sparse, prior research has shown that the presence of rest areas reduces crashes and increases safety. But the literature also shows that the effect is relatively small. Moreover, the few studies available used data over many years to detect the effect. In the present evaluation, there was only approximately one year of data from the test phase, over a relatively short stretch of road (approximately 150 miles). It was unlikely to be able to detect a safety effect given these constraints.

However, the substantial difference between the experience on the pilot and comparison roadways presents a problem of interpretation. The hypothesized decline in parking-related crashes seems to have occurred on the comparison roads, but not the pilot road, the reverse of what was expected. The drop in parking-related crash types on the comparison roads was statistically “real,” but what does that mean? One interpretation would be that there was some overall force driving down the target crash types that was somehow attenuated on the pilot road during the test phase. This is exceedingly unlikely, as it is hard to see how providing truckers with information on parking availability would actually drive crashes up.

A more likely explanation is that the comparison roads did not provide a genuine control. The assumption of the approach used here is that the comparison roads were similar to the pilot road except for the presence of the TPIMS information. That is, the method requires that the pilot and comparison roads be effectively identical, with respect to safety, other than the addition of parking availability information to truck drivers. But the most plausible explanation for the anomalous result is that there was some factor or

factors that are uncontrolled between the pilot and comparison roadways that explain the difference.

Details of the crash environment of the pilot and comparison roads suggest that the comparison roads likely did not provide an effective control. The pilot stretch of road is on the main east-west corridor for trucks in Michigan, while the comparison roads are more of a mix. There were differences where the trucks were registered between the pilot and comparison roads. On the pilot road, only 36.0% of crash-involved trucks were registered in Michigan. Drivers of Michigan registered trucks are more likely to be familiar with local rest options. They are also probably less likely to need them, being closer to home or the base of the truck. About 46.6% of the trucks were registered in other U.S. states. Moreover, 16.5% of the trucks were foreign-registered, chiefly in Canada. In contrast, over half (50.3%) of the trucks on the comparison roads were registered in Michigan, 36.1% were registered in other U.S. states, and 12.4% were registered outside of the country, chiefly Canada. These differences in registration location hint at possible operational differences that might explain some of the difference between pilot and comparison roads. During the test period, the proportion of Michigan-registered trucks on the comparison roads actually increased to 53.0%. Michigan-based trucks would be more likely to be operating closer to home and thus less likely to need parking information.

Differences in crash weather conditions between the pilot and comparison roads were also called out above. Overall, about 40% of truck-involved crashes on the pilot stretch of road, I-94 from the Indiana border to Jackson County, were coded as occurring in snow, blowing snow, sleet, or hail. This compares with about 20%, half the percentage, on the comparison roads, which included I-96 from Ottawa County to Livingston County, I-75 in Monroe, Genesee, and Saginaw Counties, and I-69 in Branch County. The pilot road runs through counties along Lake Michigan and east to Jackson County, which are subject to lake-effect snow falls. And in fact, crashes in two counties, Berrien and Van Buren, accounted for two-thirds of the snow-related truck crashes on the Pilot road. Adding Kalamazoo County, which is also part of the area most affected by lake-effect snows, increased the proportion of 84%. By contrast, only a smaller proportion of comparison roads were proportionately affected snowy conditions. Forty percent of truck crashes on the comparison road (I-96) in Ottawa County in the period covered by the evaluation were in snowy or blowing snow conditions. On average on the rest of the comparison roads, the proportion of truck crashes in snowy conditions were around 20% or less.

For these reasons, and because the results were so anomalous, it was concluded that the comparison roads did not provide adequate control for the pilot road. Several different combinations of roads were evaluated, but none were found to provide reasonable control.

Two primary conclusions may be drawn from the safety evaluation. The first is that the safety effect was not detectible in the crash data. Prior research on the effect of rest areas showed that they provide a real protective effect, reducing crashes along the roads where

they are located. Thus, there is good evidence to believe that providing information about the availability of truck parking would have a protective effect. While such information does not increase the actual amount of truck parking, it should have an effect by notifying drivers who would not otherwise know of the spaces. However, given the experience of previous studies, the test period was too brief and the pilot road was too short to be able to find an effect, given its likely size.

A second conclusion is that a different analytical technique is likely needed to evaluate the effect of the TPIMS. A set of adequate comparison roads could not be identified. The problem was likely related to differences in the population of trucks that use the road and are likely to need access to truck parking areas. That stretch of road is a primary freight route from other U.S. states and into Canada, more so than the other limited access roads that could be used. I-75 in Monroe County has a lot of interstate and international truck travel, but the road is too short and proximate to the dense urban area of Detroit. The effect of rest areas was found to be primarily on stretches of road between urban areas, not within. Thus, a different approach is probably needed in Michigan. More data provided by a long evaluation period would be useful, as well as using truck VMT to normalize crash rates and control for differences between roads.

## **System Technical Assessment**

### **System Description**

Private truck stops are by nature complex facilities providing many services including food and amenities for drivers, fuel for trucks as well as parking areas intended to allow truck drivers to rest in accordance with hours of service regulations. This complex mix of activity requires a very open parking architecture with several entry and exit locations. The complexity of activity and layout makes private facilities incompatible with wireless magnetometers that are used at MDOT public rest areas to collect vehicle entry and exit data for the purpose of tracking parking space availability. Therefore private facilities use elevated cameras to assess space availability.

Two different strategies for detecting/counting trucks at rest areas were considered practical. Entrance/exit detection where vehicle counts are made at driveways was found suitable for public rest stops. The other method, per-space presence detection where the number of occupied or available spaces are counted using cameras was the preferred option for private facilities, however entrance/exit detection was used as discussed below.

As the data is collected from the detection cameras at private truck stops, it is fed via the Internet to TSPS (<http://trucksmartparkingservices.com>). Likewise, MDOT collects data from the wireless magnetometers at public rest areas. TSPS shares its private truck stop data with MDOT and MDOT shares public rest area data with TSPS through application program interfaces (API) developed during the project. All involved parties have a full set of data for all 15 parking areas in the project. TSPS also transmits the parking data through its website and supports free iPhone and Android applications. MDOT transmits the data through its Mi Drive website and applications, DTSPS and the DSRC connected vehicle system developed as part of the project.

The DTPS consist of three lines and six bits of information that are populated through cellular modem communications (Figure 33). Each sign provides information on the nearest rest area and two alternates.



**Figure 33: Dynamic sign consisting of three lines and six bits of information**

### **MDOT Public Rest Area Characteristics**

MDOT public rest areas are single purpose facilities with dedicated entry and exit ramps located along the highway. They are not part of an adjoining road system like private truck stops. The entrance and exit driveways for the public rest stops are uni-directional and have separate driveways and parking areas for trucks versus cars. They also have striping to delineate parking spaces. An example showing the typical size and design of public truck parking lots at rest areas on I-94 is shown in Figure 34.



**Figure 34: Truck parking lot at New Buffalo rest area**

At times public rest areas become overcrowded and trucks will park illegally within the parking areas as shown in Figure 35. This figure shows an example of some of the challenges encountered while implementing truck parking management systems. The cones visible in Figure 35 have been placed to discourage parking where it would interfere with mobility and wireless radio communications with sensors. This intervention had little or no effect on illegal parking as the cones were moved onto the grass (presumably by truck drivers) and the illegal parking continued.



**Figure 35: Truck parking lot at Battle Creek rest area**

## Private Truck Stop Characteristics

Private truck stops are usually adjacent to exits at overpasses and are located close to but off of the Interstate. The private facilities have varying surface conditions (pavement, gravel, dirt) and use bi-directional driveways, many with mixed use of cars and trucks. Striping or other delineation of parking spaces is not present in all lots. In addition, trailer drops occur near the Michigan/Indiana Border (exit 1), occupying parking spaces even after a cab leaves the site. Because of the challenges with variable surface conditions and variable use areas, detection was installed at the driveways.

Determining the total number of “available spaces” in each lot was also not straight forward. Because of the sprawling nature of the private parking lots and lack of striping at many, the total number of spaces is different each night depending on how drivers park their vehicles. To accommodate this variation an average number of total spaces for each facility was determined through repeated manual counts of trucks when the lots are at or near capacity. Discussions with private facility representatives helped refine the estimate of how many trucks a particular facility can hold.



**Figure 36: Challenges of designing the placement of traffic detection cameras**

Given the variation in layout of private facilities, there were significant challenges in the placement of traffic detection cameras to maximize the reliability of the system as shown in Figure 36. Because the only viable option was to place the camera on the side of the driveway, it was difficult to fit the entire driveway in the field of view. This photo also shows how the top of the vehicles would miss the virtual detection loops in this particular configuration.

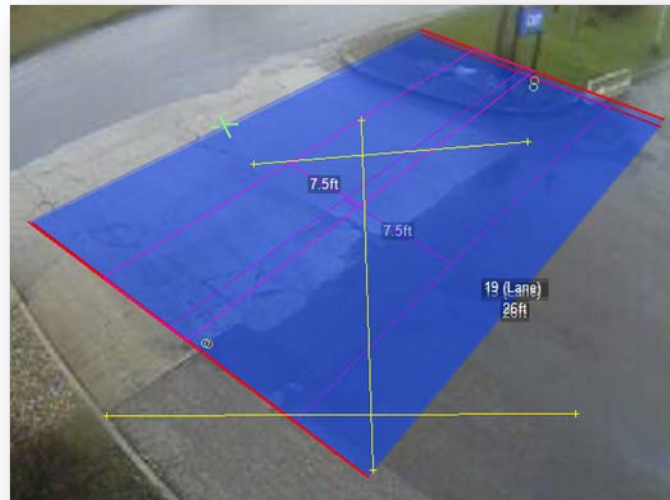


## Technology Assessment – Detection Type

This MDOT project examined both public and private parking facilities. Public rest areas have been studied previously, however the private truck stops present unique challenges as does the combination of the two facility types within a common reporting system. Technologies used on individual spaces for “presence detection” can be very expensive, especially considering the need for multiple sensors in large truck spaces. Presence detection also presents many challenges with some of the facilities involved in this project – gravel lots, unique geometry, no striping, and poor lighting.

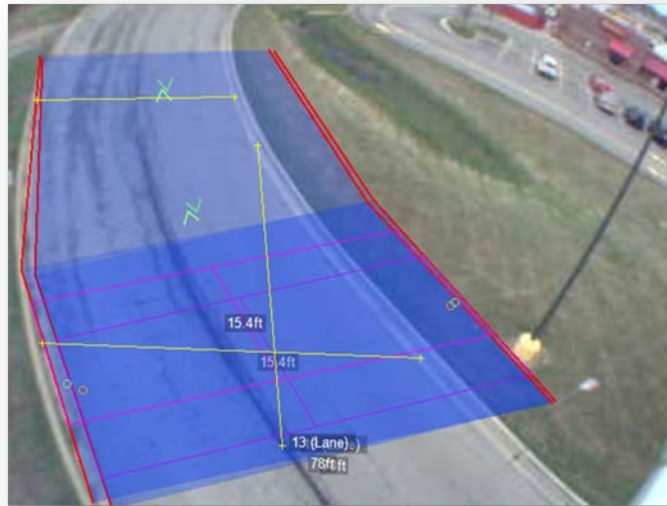
Two approaches for determining parking space availability were considered; these were space occupancy counts and entrance and exit difference counts. Error propagation for both methods was a major consideration in the system design. So too was cost, operational burden and system sustainability. Individual electromagnetic sensors in parking spots were considered impractical because of gravel parking areas and the lack of parking space striping in private facilities and because of the cost of the transducers. For private rest areas, classification and direction of traffic were critical requirements.

Figure 37 shows how traffic detection zones are configured at driveways. The zones are set up based on the geometry of the driveway as well the angle of view of the camera.



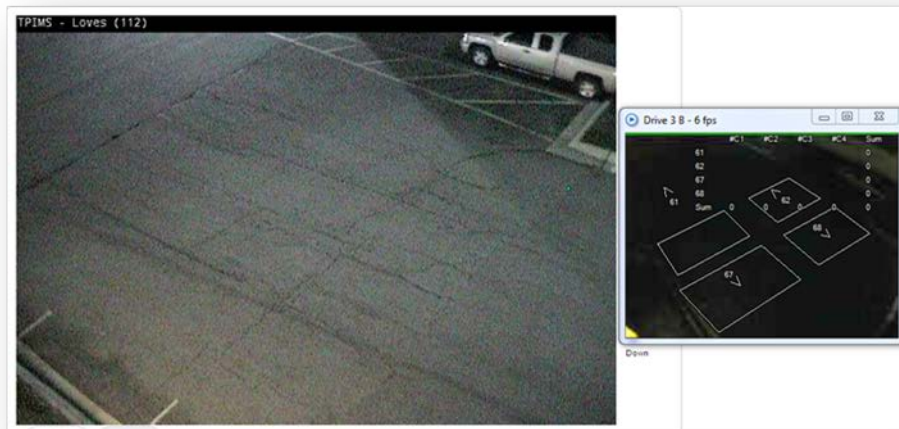
**Figure 37: Setting up traffic detection zones at driveways**





**Figure 38: Traffic detection zones for curved driveway**

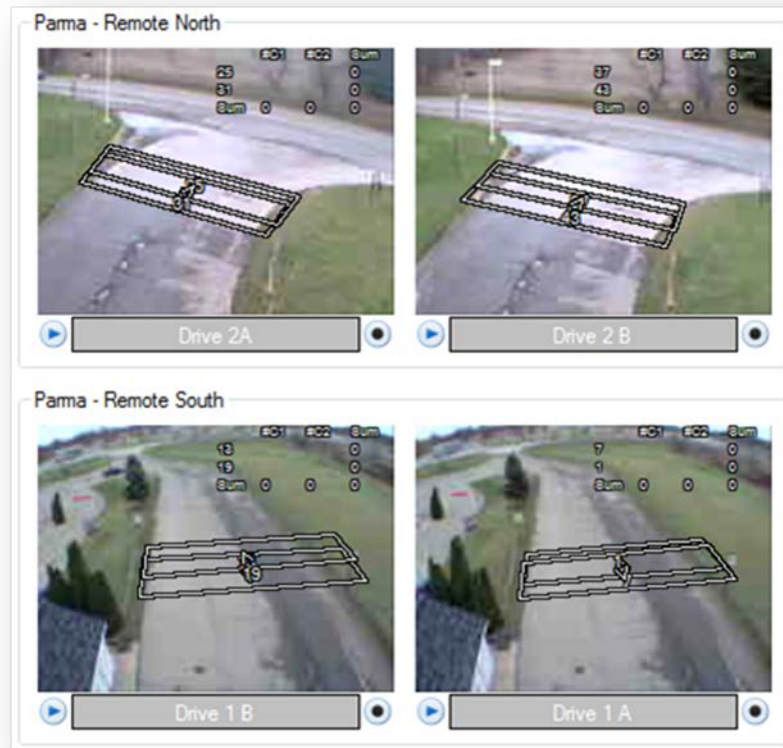
Road curvature presents additional challenges as shown in Figure 38. This photo illustrates how the geometry of the curved traveled way can add to the complexity of configuring detection zones.



**Figure 39: Comparison of low-light and traditional cameras at a poorly lit driveway**

Light levels during night time hours in poorly lit parking areas impairs the functionality of some camera systems. Figure 39 is an example of how this limitation can be addressed through the use of low-light cameras (left). The use of low-light cameras was found to improve the accuracy of traffic detection in dark locations.

Figure 40 shows a site with favorable geometric conditions allowing detection cameras to operate in an optimal manner. The traffic detection cameras worked best when the view is aligned with the direction of travel as opposed to an offset/side angle.



**Figure 40: Ideal configuration of traffic detection cameras**

### **Integration with Existing Software**

MDOT uses Delcan Intelligent NETWORKS advanced traffic management systems in all Transportation Operations Centers (TOC) for traffic management. The devices used for parking space availability assessment at rest areas and DTPS were integrated with the existing Delcan traffic management system. The active devices include closed-circuit television (CCTV) cameras, DTPS, automatic response plans, manual resets and public rest area magnetometers. The integration of the above devices allows the ATMS to calculate availability at each public rest area and post parking availability data to the corresponding DTPS. This is done through the use of automatic response plans. This feature has potential use in speed warning or back of queue systems, allowing automatic responses to be posted without operator intervention.

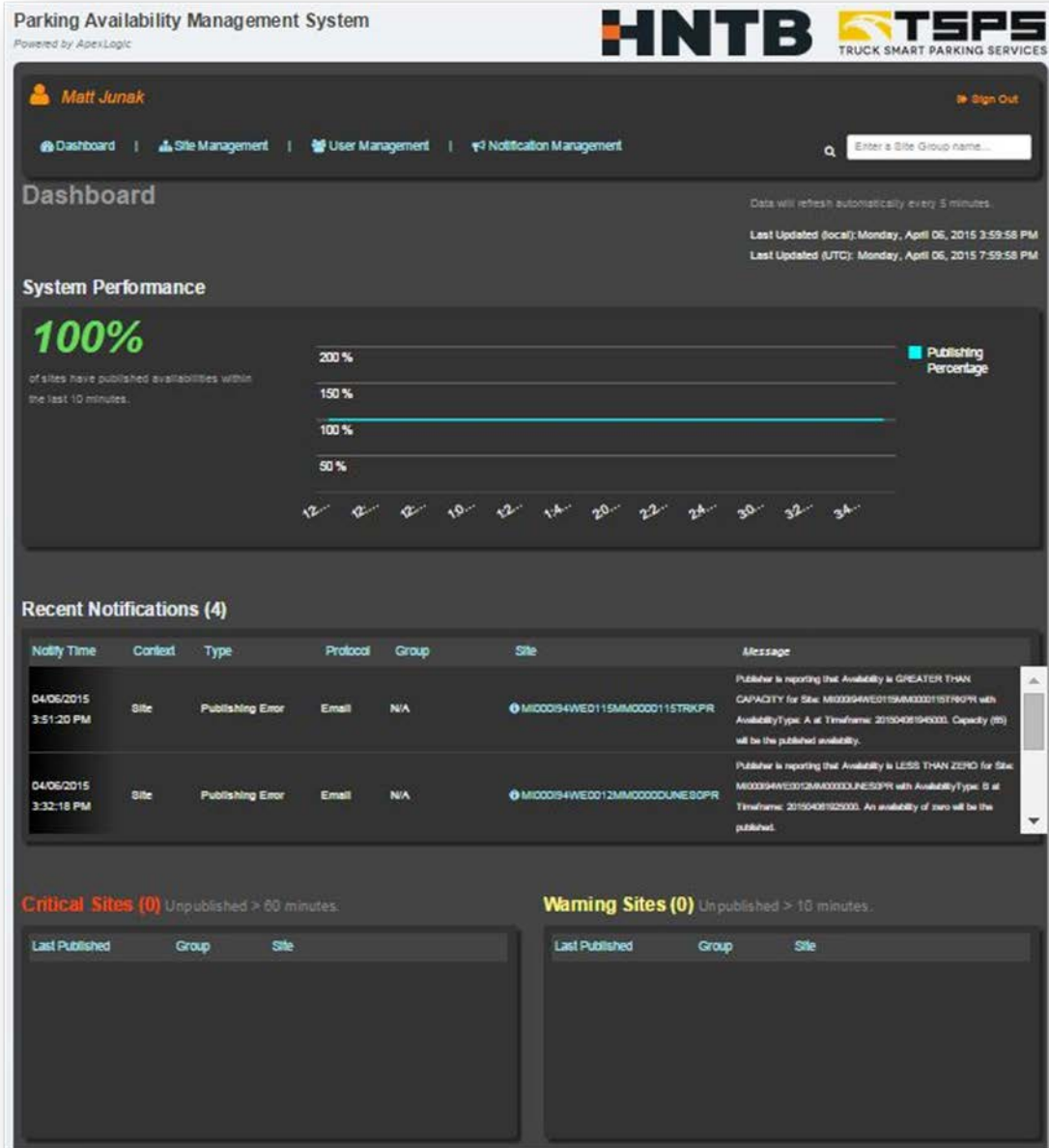
One of the main goals of the system integration was to minimize the burden on TOC operators and to minimize unnecessary information clutter flowing to the ATMS. In

order to achieve this goal, certain devices and/or processes function in the background and are not visible to the TOC operators.

Mi Drive, MDOT’s traveler information website, integrated the TPIMS much like the ATMS interface. Mi Drive users are able to see truck parking lot icons on a map and can select each lot to see the current status of each lot and the current parking availability. The Mi Drive mobile application allows users access to the same map interface, but also gives users access to a list view where all truck parking lots can be scrolled through as shown in Figure 41. An example of Parking Availability Management System output is shown in Figure 42.

Type	Parking Lot Name	Roadway	Cross Street	Mile Marker	City	Total Spaces	Available Spaces
P	Arlenes Truck Stop	I-94 W	Exit 92	92	Battle creek	37	21
P	Dunes Auto Truck Plaza	I-94 W	Exit 12	12	Sawyer	15	0
P	Loves Travel Shop	I-94 E	Exit 112	112	Marshall	109	107
P	Parma Travel Center	I-94 W	Exit 128	128	Parma	62	10
P	Pioneer Auto Truck Plaza	I-94 W	Exit 110	110	Marshall	74	74
P	Plaza 1 Truck Stop	I-94 E	Exit 1	1	New Buffalo	90	79
P	Pri-Mart Fuel Center	I-94 E	Exit 29	29	Benton Harbor	40	14
P	TA Battle Creek	I-94 W	Exit 104	104	Battle creek	171	94
P	TA Travel Center	I-94 E	Exit 12	12	Sawyer	174	174
P	The 115 Truck Stop	I-94 W	Exit 115	115	Marshall	65	49

**Figure 41: Example of parking information output.**



**Figure 42: Example of Parking Availability Management “back end” output used to calculate and publish availability.**

## **System Performance**

Table 5 and Table 6 contain data from the private and public facilities for six month periods shortly after the systems began operating in August 2014 and more recently a second six month period ending in September / October 2015. The tables contain information for each parking facility that was subject to this study. There is missing data in Table 5 for the period June 2015 through October 2015 for the Dunes, which MDOT decided to terminate due to lot size, and TA-Sawyer and TA- Battle Creek as these private operators elected to terminate their participation in the study because they launched their own proprietary parking information system.

The tables contain information on the number of parking spaces at each facility, the average number of vacant spaces during relatively stable time periods of 3:00PM to 5:00PM and 3:00AM to 5:00AM. Average daily calibration correction data is also provided as percent error relative to capacity. Every time the parking space availability was observed and reset the system availability number was compared to the actual observed number of available parking spaces and the difference was divided by the capacity of the lot to arrive at the calibration factor. The system calibration was conducted at each site twice on weekdays and once over the weekend and as needed if there was an outage or major event such as severe weather. The calibration numbers reflect the six-month average for the time period reported. Also included in the tables are the average numbers of system malfunctions per month.

There is good consistency in the parking space occupancy during the two time periods. The calibration corrections are significant for both the private and public rest areas however they show improvement in the second six month period. The number of malfunctions per month was reduced in the second six month period.

**Table 5: Private facility parking and calibration data**  
(October 2014 through March 2015 and June 2015 through October 2015)

<b>Private Facilities</b> <b>(Time Period October 2014 through March 2015)</b>						
Exit #	Rest Facility	Number of Spaces	Avg. Availability 3-5 am	Avg. Availability 3-5 pm	Avg. Daily Calibration Correction	Avg. Number of Malfunctions per Month
	Dunes	15	7	8	75.49%	2.0
128	Parma	62	46	47	17.92%	0.8
115	The 115	65	57	57	13.36%	1.0
112	Loves	109	58	85	63.37%	0.8
29	Pri-mart	40	15	22	31.46%	1.2
1	Plaza 1	90	62	90	30.77%	2.5
110	Pioneer	74	45	61	11.64%	1.7
92	Arlene's	37	26	24	17.15%	0.7
	TA-Sawyer	74	96	139	22.72%	1.8
	TA- Battle Creek	171	80	115	25.27%	3.5
	<b>TOTAL AVG</b>	<b>84</b>	<b>49</b>	<b>65</b>	<b>30.92%</b>	<b>1.6</b>

<b>Private Facilities</b> <b>(Time Period June 2015 through October 2015)</b>						
Exit #	Rest Facility	Number of Spaces	Avg. Availability 3-5 am	Avg. Availability 3-5 pm	Avg. Daily Calibration Correction	Avg. Number of Malfunctions per Month
	Dunes	NA	NA	NA	NA	NA
128	Parma	62	32	43	16.34%	0.6
115	The 115	65	55	55	19.24%	1.6
112	Loves	109	53	85	9.87%	0.8
29	Pri-mart	40	9	17	63.23%	0.4
1	Plaza 1	90	79	79	6.09%	0.6
110	Pioneer	74	42	62	29.85%	1.6
92	Arlene's	37	24	25	17.56%	0.8
	TA-Sawyer	NA	NA	NA	NA	NA
	TA- Battle Creek	NA	NA	NA	NA	NA
	<b>TOTAL AVG</b>	<b>68</b>	<b>42</b>	<b>52</b>	<b>23.17%</b>	<b>0.914</b>

**Table 6: Public facility parking and calibration data  
(October 2014 through March 2015 and April 2015 through September 2015)**

Public Facilities (Time Period October 2014 through March 2015)					
Rest Facility	Number of Spaces	Avg. Availability 3-5 am	Avg. Availability 3-5 pm	Avg. Daily Calibration Correction	Avg. Number of Malfunctions per Month
New Buffalo	35	10	28	22.40%	1
Watervliet	53	19	35	83.28%	2
Galesburg	39	10	31	12.26%	0.833
Battle Creek	25	9	20	30.54%	0.833
Marshall	22	7	17	15.65%	0.5
<b>TOTAL AVG</b>	<b>35</b>	<b>11</b>	<b>26</b>	<b>32.83%</b>	<b>1.03</b>

Public Facilities (Time Period April 2015 through September 2015)					
Rest Facility	Number of Spaces	Avg. Availability 3-5 am	Avg. Availability 3-5 pm	Avg. Daily Calibration Correction	Avg. Number of Malfunctions per Month
New Buffalo	35	6	29	19.06%	0.667
Watervliet	53	28	51	12.21%	1.167
Galesburg	39	7	27	7.21%	0.667
Battle Creek	25	8	19	30.50%	0.833
Marshall	22	6	16	6.26%	0.667
<b>TOTAL AVG</b>	<b>35</b>	<b>11</b>	<b>28</b>	<b>15.05%</b>	<b>0.80</b>

**Lessons Learned**

Through the process of this parking pilot a number of lessons were learned particularly with respect to the challenges involving vehicle operations. For example, at rest areas inconsistent vehicle speed at the detection points lead to detection errors as did variations in vehicle type or classification. The practice of illegal parking within parking areas added further complication to the task of measuring available space. The type of illegal parking that was most problematic were vehicles parking on the shoulders of the parking entrance and exit lanes when the designated parking spots were occupied. These problems were, for the most part, overcome through detection sensitivity adjustments, timeslot modifications, the installation of additional repeaters, no-parking signs and targeted police enforcement.

This particular pilot utilized “off the shelf equipment” in an effort to deliver a low cost solution to parking space availability measurement (MDOT bid estimates averaged \$115k per rest area, and HNTB estimates \$65k or less per private site). Video analytics have been used for many years for presence detection at intersections and, more recently, counting and classifying vehicles on highways. Normally, video surveillance/detection equipment of this type is deployed on highways, with consistent vehicle speeds in well-defined lanes, making counting vehicles quite reliable. When it was deployed at private truck stops, cameras were placed at driveways where trucks are moving slowly, in many cases turning, stopping and restarting. Such maneuvers are problematic for existing optical evaluation systems. To improve system accuracy under such conditions, HNTB worked closely with the manufacturer of the video system to improve count reliability through equipment modification and refining system algorithms.

Modifications included unlocking detection width of each zone from the standard lane limitation of 15 feet. While the 15 feet restriction worked well for typical traffic lanes on open roads, many driveways at truck stops were much wider. Another modification was the addition of a variable background reset feature to accommodate trucks that stopped within the monitored zones for a long period of time. Each driveway was monitored and adjusted to a reset time that fit the nature of this particular traffic movement characteristic.

After the modifications to the equipment and algorithm were implemented, the camera image sensors were manually adjusted to adapt to the various lighting conditions at each driveway. In several cases the camera field of view was adjusted to an area with greater contrast or in some cases, additional external lighting was added.

One of the most important contributions of this particular parking pilot program is the demonstration of lower cost off the shelf technology and integration within the existing traffic management system. This approach offers the potential for a cost-effective and sustainable solution with respect to sensor technology and scalability through the use of a common traffic management system. The project proved that off the shelf technology can be adapted to this application however there is a parking count accuracy penalty at least at this proof of concept stage. Based on the experience gained during this pilot, it can be concluded that with more resources directed to detector and system optimization, parking count accuracy can be improved. The next logical step is to focus on accuracy improvement through technology and system optimization including the use of predictive algorithms.

## **Conclusions**

The results of this evaluation confirm that the parking system was successfully implemented using modified off the shelf equipment and the output data was successfully integrated with existing traffic management systems. While factors attributed to the technology and parking facility characteristics translate to parking space availability error, efforts to improve accuracy did reduce error leading to the conclusion that with more resources directed to detector and system optimization, parking count accuracy can



be improved. The next logical step is to focus on accuracy improvement through technology and system optimization including the use of predictive algorithms.

Drivers overwhelmingly agreed that parking information systems were personally valuable to the driver and could save them time in driving. Overall, the sample of drivers was positively disposed to a system that could assist them in finding parking quickly.

In general, drivers appeared to overwhelmingly find the road sign sources both clear and useful, suggesting that acceptance of this source to be quite high. None of the other sources were rated as highly.

Because of the limited area of implementation of the pilot parking information system, it is not surprising that the safety effect was not detectible in the crash data. Prior research on the effect of rest areas showed that they provide a real protective effect, reducing crashes along the roads where they are located. Thus, there is good evidence to believe that providing information about the availability of truck parking would have a protective effect.

Analysis of data indicates that there is good consistency in the parking space occupancy during the duration of the pilot. The calibration corrections are significant for both the private and public rest areas however they show improvements over time. Similarly, the number of malfunctions per month showed improvement towards the end of the pilot period.

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