Accelerating SmartPark Deployment Strategic Plan

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

June 2019

FOREWORD

This report describes a plan for the U.S. Department of Transportation (USDOT) to speed widespread deployment of SmartPark systems. A SmartPark system is a system for notifying truck drivers of real-time parking availability along their routes. The report reflects knowledge collected from current SmartPark pilot projects, interviews with experts, and research into the relevant legal, institutional, market, and technical environments. The intended audience is any entity within USDOT with a role in promoting or facilitating SmartPark projects. Industry stakeholders may also find the report useful as an articulation of how USDOT understands the need for improved access to truck parking and one means of providing it.

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16. Abstract

This document describes a plan for the U.S. Department of Transportation (USDOT) to promote wider deployment of SmartPark systems. A SmartPark system is a system that provides truck drivers with real-time parking information. The plan maps out barriers to deployment, including financial, institutional, technical, and user-acceptance considerations, along with means of overcoming or mitigating these barriers. The plan concludes with nine recommended steps to accelerate SmartPark system deployment.

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SI* (MODERN METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		Length		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		Area		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	Acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		Volume (volumes greater than 1,000L shall be shown in m^3)		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		Mass		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		Temperature (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		Illumination		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		Force and Pressure or Stress		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

Approximate Conversions from SI Units				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		Length		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		Area		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
Ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		Volume		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		Mass		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		Temperature (exact degrees)		
°C	Celsius	1.8c+32	Fahrenheit	°F
		Illumination		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		Force and Pressure or Stress		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003, Section 508-accessible version September 2009

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LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

Abbreviation	Definition
API	application programming interface
ATA	American Trucking Associations
ATRI	American Transportation Research Institute
BUILD	Better Utilizing Investments to Leverage Development Discretionary Transportation Grant Program
CCTV	closed circuit television
DMS	dynamic message sign
DOT	(State) Department of Transportation
ELD	electronic logging device
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
HOS	hours of service
HP-ITD	High-Priority Innovative Technology Deployment
HTTP	hypertext transfer protocol
INFRA	Infrastructure for Building America
ITS	intelligent transportation systems
ITS PCB	Intelligent Transportation Systems Professional Capacity Building Program
IVR	interactive voice response

JSON	JavaScript Object Notation
MAASTRO	Mid America Association of State Transportation Officials
MNDOT	Minnesota Department of Transportation
MOU	memorandum of understanding
MUTCD	Manual on Uniform Traffic Control Devices
NCTP	National Coalition on Truck Parking
O&M	operations and maintenance
P3	public-private partnership
RESTful	representational state transfer
RFID	radio frequency identification
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SOAP	simple object access protocol
TA	TravelCenters of America
TAPCO	Traffic and Parking Control Company, Inc.
TIGER	Transportation Investment Generating Economic Recovery
TPIMS	Truck Parking Information Management System
TRB	Transportation Research Board
U.S.C.	U.S. Code
USDOT	U.S. Department of Transportation
XML	extensible mark-up language

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EXECUTIVE SUMMARY

PURPOSE

The U.S. Department of Transportation (USDOT) recognizes that truck parking is essential to safe highway freight transportation. Along with other efforts to ensure truck drivers can reach a legal parking spot, USDOT is working to deploy SmartPark systems. A SmartPark system is a system that disseminates real-time parking availability information to drivers. Initial efforts have seen modest success, but wider deployment has been slow. The Federal Motor Carrier Safety Administration (FMCSA) commissioned this study to accelerate the deployment of SmartPark systems by assessing market forces, attitudes, technology, and other opportunities and barriers.

The purpose of the study was to provide the Agency with a plan to promote deployment of Intelligent Transportation Systems (ITS) technology to direct truck drivers to suitable parking. This deployment aligns with FMCSA's mandate to reduce crashes and promote safety by helping drivers find safe places to park at the end of each day, reducing driver fatigue. This is one of many efforts to address the truck parking situation.

KEY FINDINGS AND DEPLOYMENT RECOMMENDATIONS

Persuading decision-makers to invest in SmartPark systems is currently difficult due to the lack of quantitative information about project effectiveness. Information from current projects will help spur investment in SmartPark systems. In the meantime, USDOT can still encourage widespread deployment of SmartPark systems by concentrating on a few key steps out of the total of nine recommended steps:

Start Projects Where the Potential Cost-Benefit is Greatest

Barriers to accelerating SmartPark system deployment are more financial than technical: functions of financial priority rather than technical capability. Even if a SmartPark system can be shown to improve highway safety, State decision-makers will question whether a SmartPark system will be as cost-effective as building new parking capacity. Furthermore, private truck stop operators will need to know the business case for their participation in deploying a SmartPark system, to decide whether to participate.

Involve Private Parking Providers

A comprehensive SmartPark system must include private parking providers. Nationwide, private truck stops have seven times as many truck parking spaces as do public rest areas. The institutional barrier between public and private entities must be overcome, and public and private entities must strive to cooperate for a variety of valid but complex reasons in addressing the truck parking problem. These reasons differ from State to State and from business to business.

Publicize Early Successes

Projects currently underway will serve as models for future projects, producing performance and cost data that will enable decision-makers to evaluate proposed SmartPark system efforts.

Current SmartPark system efforts can also serve as public relations instruments. The most important component of the proposed plan is that even modest projects can measurably relieve parking problems. The USDOT can publicize these success stories to generate credibility and interest. Hesitant decision-makers can be encouraged to start small programs within available budgets, achieve near-term benefits where most needed, and then expand. Publicizing early successes will help overcome the user-acceptance barrier to SmartPark systems.

Establish Consensus on Data Formats

Currently, there is no national consensus standard for data feeds and data formats for truck parking information. Each State and private parking provider seems to have its own approach; this can confuse truckers who are looking for available truck parking and amenities. In the short term, a reference guide would help mitigate the fragmentation issue, but in the long term a national consensus, authoritative standard for data feeds and data formats for truck parking information is needed. Adoption of such a standard would facilitate a uniform sharing of truck parking information across State lines and with private entities. A starting point could be the data format in use by the Mid-American Association of State Transportation Officials (MAASTO); all MAASTO States as well as Colorado are using the same format. A national consensus standard will overcome the major technical barrier to SmartPark system deployment.

1. INTRODUCTION

The U.S. Department of Transportation (USDOT) recognizes the need for adequate capacity for legal parking. Parking is necessary for drivers to rest and comply with hours-of-service (HOS) regulations and to stage for pickups and deliveries. Accordingly, USDOT has already taken a leadership role to address truck parking through participation in the National Coalition on Truck Parking (NCTP), grants for truck parking projects, and other efforts intended to address capacity and other parking-related needs.

This report offers a plan for USDOT to deploy a nationwide "SmartPark" system. A SmartPark system is a system of technology that helps truck drivers find a safe and available place to park for rest. A SmartPark system works by collecting real-time information about nearby parking availability and communicating it in real-time to drivers.

Some channels for communication already exist. For years, transportation agencies have developed electronic communication technologies that provide information to travelers. Through these technologies, generally falling under the area of Intelligent Transportation Systems (ITS), drivers receive expected travel times and locations of traffic incidents, reports on road conditions, and synchronized traffic signals along a travel corridor. Information is provided to drivers through dynamic message signs (DMSs), 511 phone lines, and websites. In emerging applications, vehicles can communicate with one another to improve traffic flow and enhance safety.

Instrumenting truck parking locations to sense parking availability and providing truck drivers with current information is a natural extension of ITS, and USDOT has funded several studies and pilot implementations of SmartPark systems through contracts and grants. The plan outlined in this document will guide USDOT in expanding deployment of ITS to facilitate truck parking.

1.1 PURPOSE OF THIS DOCUMENT

This document presents a series of specific actions that USDOT can take to accelerate the deployment of SmartPark systems throughout the United States. It includes short-term activities and long-term programs.

Chapter 1 provides a basic introduction to the topic and an outline of the report.

Chapter 2 describes four sets of barriers to SmartPark system deployment:

- **Financial:** paying for deployment and operation.
- **Institutional challenges:** applying lessons from limited demonstrations to create successful ongoing deployments, and coordinating collaborative efforts among public and private entities with diverse interests.
- **Technology:** making the right technical choices to ensure cost-effectiveness and system scalability.

- **User acceptance:** winning system support from the necessary stakeholders while negotiating possible ramifications.

Chapter 3 discusses opportunities and strategies for overcoming these barriers. A key component of these strategies is the experience from current SmartPark system deployments. SmartPark systems are already operating on short segments of corridors in various parts of the country. These projects have demonstrated that more than one kind of truck-sensing technology is viable. They have also demonstrated, though not formally quantified, benefits from SmartPark systems.

Finally, Chapter 4 presents the steps of the plan. It describes actions the Department can take almost immediately. It also sets forth more involved programs that will require developing stakeholder consensus in the wider community. Winning consensus from so many stakeholders will likely require an iterative process and gradual motion toward agreement. Chapter 4 outlines this process.

1.2 BACKGROUND

1.2.1 Truck Parking Concerns

Time spent searching for parking incurs economic costs by decreasing productivity and cutting into drivers' earning potential. Federal HOS regulations require that a driver stop and rest after 11 hours of driving within a maximum of a 14-hour work day. A driver who violates HOS regulations can be fined or placed out-of-service.(1) A survey by the Kansas Department of Transportation shows that a driver can spend 30 minutes or more searching for available authorized parking. Forty-seven (47) percent of drivers spend from 30 minutes to 1 hour trying to find parking each day, and 37 percent spend more than 1 hour.(2) A report by J.B. Hunt estimates that a driver spends 1 hour of their 11 allowable hours in a service day searching for a location to park.(3) This translates to inconvenience, frustration, and lost income to the driver. Parking time is lost productivity for the customer and an economic cost for all.

Further, there are several safety consequences to the truck parking shortage: first, tired drivers may continue to drive because they cannot find a place to park for rest; second, there is a correlation between catastrophic truck and bus crashes and commercial driver fatigue; third, truck drivers may choose (or feel compelled) to park at an unsafe location such as the shoulder of the road, exit ramps, or vacant lots, heightening the possibility of a crash.(19) Similarly, a survey of truck drivers belonging to the American Trucking Associations (ATA) and the Owner Operator Independent Drivers Association (OOIDA) found 60–80 percent regularly (one or more times per week) had trouble finding safe parking locations.(19) Almost 90 percent of surveyed drivers reported difficulty finding safe overnight parking from 7 p.m.to midnight and 60 percent from midnight to 5 a.m.(19)

1.2.2 Technology to Help Alleviate Truck Parking Concerns

SmartPark technologies have been proposed to alleviate these concerns. Previously conducted research suggests that technology to help drivers locate parking is an effective and feasible solution to the truck parking problem.(4) The main goal of a SmartPark system is to help truck drivers find safe, available parking at the end of the work day by communicating the real-time

availability of nearby truck parking locations. A nationwide system for tracking parking availability and presenting the information to drivers could provide significant benefits.

However, in most parts of the Nation, such systems are nonexistent. Where a system does exist, coverage is incomplete, and a driver must consult many phone applications and websites to get a complete picture of parking availability. The flaws of current systems demonstrate the need to improve coverage and make information more accessible to drivers.

1.2.3 Stakeholder Objectives

Several parties have objectives for a SmartPark system:

- USDOT, State departments of transportation (DOTs), and metropolitan planning organizations want to reduce fatigued driving, HOS violations, and unauthorized parking.
- Political jurisdictions recognize that improved freight flow will benefit their economies.
- Drivers want to maximize their productive driving time within the HOS regulations. At the end of a shift, they want safe, quiet places to sleep.
- Private truck stop operators want to serve their customers and make a profit.

1.2.4 Other Considerations

With some exceptions, truck drivers are required to use an electronic logging device (ELD) to track their HOS. This strict record of the time drivers go off duty increases the importance of quickly finding safe, legal parking. Many ELDs, either as applications on phones or fleet management systems, perform many functions beyond simple recordkeeping. This presents an opportunity to communicate parking availability information through devices already available to drivers.

On June 7, 2018, the Federal Motor Carrier Safety Administration (FMCSA) issued new guidance on the use of commercial vehicles for personal conveyance.[(5)] The new guidance increases the flexibility of drivers to reach a suitable place to park. Among other provisions, it permits driving a laden truck to the nearest parking site. A fully functioning a system would aid a driver in locating that site.

1.3 COMPONENTS OF A SMARTPARK SYSTEM

A SmartPark system collects real-time parking information at a parking facility. This data is then sent to an information processing center to be converted into parking availability information, which is then disseminated via different media to drivers. There are three main components in a SmartPark system, each associated with a step in the process (see also Figure 1):

- Assessment of parking availability.
- Data processing.
- Data dissemination.

The first step is to assess the parking availability at a location. Various technologies have been developed to sense the presence of trucks or to count trucks entering or leaving a location. Other technologies are less sophisticated, using "crowd sourced" data from drivers who volunteer information when they park, or attendants manually counting the available spaces.

This parking information is transmitted to a central location for processing. The processor may be a State server handling other ITS information such as traffic conditions, construction notices, and road weather. Information may also be processed by a private firm providing the service.

The final step is to disseminate the processed data to drivers. A variety of means for doing so have been used. Some States post a DMS with Type A inserts to display the amount of available parking at a given location. Some display the data on a fully-functioned DMS. Many applications and websites are available, which can be accessed by mobile devices. An application may be provided by a truck stop chain, an industry group, or an independent application developer.

Some SmartPark systems exist in isolation from others and function with relatively simple processes, as shown in Figure 1. On the opposite extreme are complex nationwide systems still under development. These complex systems will gather information from many parking locations and allow drivers to specify a region of interest according to their current location or anticipated location at the end of a shift.

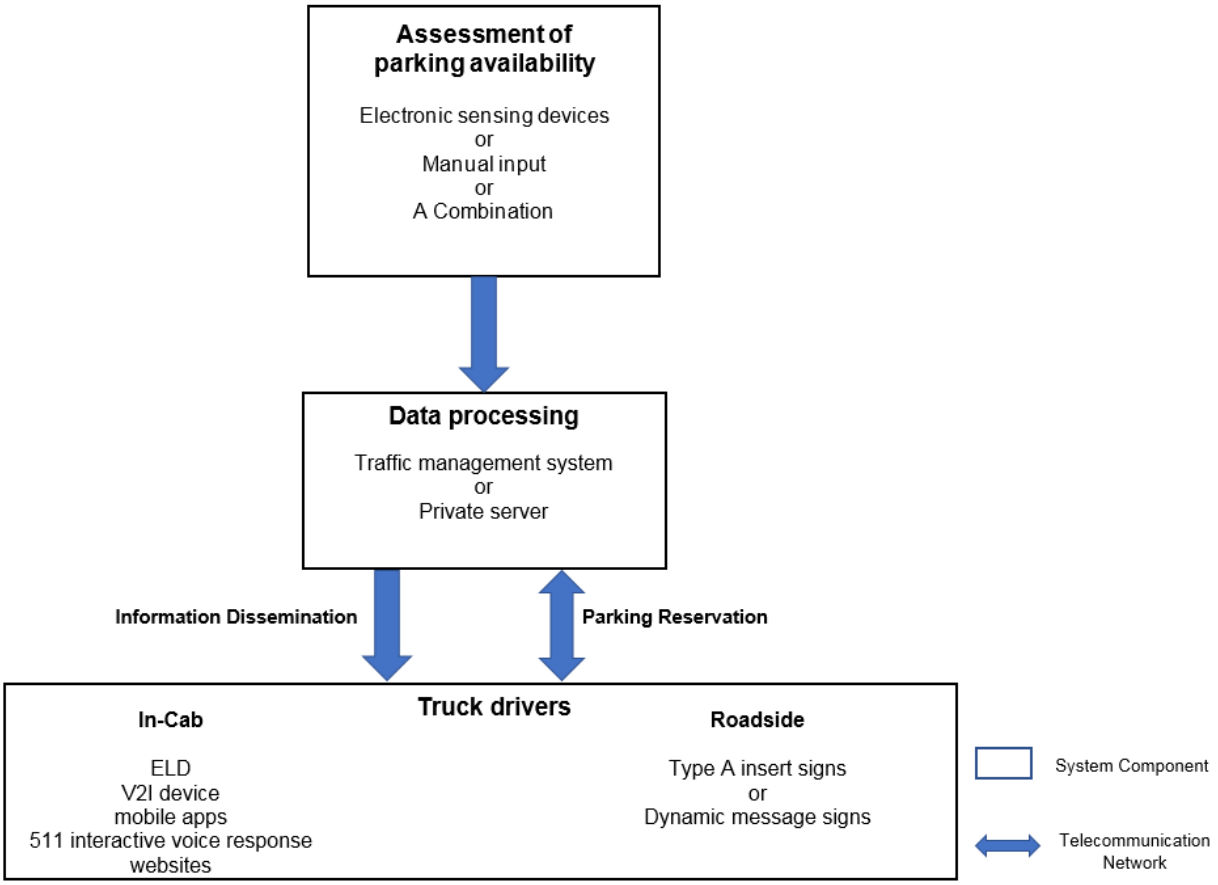

Figure 1. Diagram. The three main components of a SmartPark system.

1.4 SUMMARY OF SIGNIFICANT TRUCK PARKING PROJECTS

Several parking information systems are operating or are under installation. The most ambitious effort to date is the eight-State Mid America Association of State Transportation Officials (MAASTO) project funded through a Transportation Investment Generating Economic Recovery (TIGER) grant. As of this writing, it is on schedule to go live in early 2019. Table 1 lists some of the projects involving parking information systems. Some have been funded by FMCSA and some by the Federal Highway Administration (FHWA). An additional project on the Pennsylvania Turnpike is in the planning stage.[6]

Table 1. Summary of significant truck parking projects.

Project	Caltrans[7]	Minnesota DOT (MNDOT)[8]	Colorado DOT[9]	Florida[10]	Michigan DOT[11]	I-95 Corridor Coalition[12]	MAASTO[13]	Wisconsin DOT[14]	Tennessee[15]
Funding Agency	FHWA and Caltrans	Initially MNDOT and FHWA. Now part of the MAASTO TIGER grant.	Federal Funding and Colorado DOT	FHWA and FDOT	Initially funded by FHWA. Now part of the MAASTO TIGER grant.	FHWA, MSHA and VDOT	USDOT through TIGER grant.	Initially funded by FHWA. Now part of the MAASTO TIGER grant.	FMCSA
Partners	California DOT, University of California, Berkeley (UC Berkeley) Transportation Sustainability Research Center	MNDOT, University of Minnesota's Center for Transportation Studies, American Transportation Research Institute (ATRI)	Colorado DOT	Florida DOT, Florida Trucking Association, Florida Highway Patrol	Michigan DOT	I-95 Corridor Coalition is a partnership of transportation agencies, toll authorities, public safety, and related organizations from Maine to Florida.	Eight MAASTO states: Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Ohio, and Wisconsin.	Wisconsin DOT and Traffic and Parking Control Company, Inc. (TAPCO)	FMCSA, Tennessee DOT, Gannett Fleming
Location	Five privately owned sites on I-5	Three public rest areas along I-94. It will also integrate with the Wisconsin I-94 system.	Six locations during the first phase, with a final goal of deploying across the State on I-25, I-70 and I-76.	Seven rest areas and weigh stations along I-4 and I-95 are scheduled for phase 1. A total of 68 locations will be active by April 2019.	Seven private truck stops and five public rest areas	Testing was done at rest areas on I-95. Currently, the system is active at two rest areas in I-95 and two more on I-64 Virginia.	The system will be deployed in major corridors in member States.	Four rest areas along the I-94 corridor. It will integrate with the Minnesota I-94 system.	Two rest areas on I-75 northbound between Chattanooga and Knoxville

Project	Caltrans[7]	Minnesota DOT (MNDOT)[8]	Colorado DOT[9]	Florida[10]	Michigan DOT[11]	I-95 Corridor Coalition[12]	MAASTO[13]	Wisconsin DOT[14]	Tennessee[15]
Sensing Technology	Gate, Loops, Radio Frequency Identification (RFID), Video, Inventory	Multi-camera system	Combination of static cameras and sensors. Information is not available.	In-pavement sensors and closed circuit television (CCTV) cameras will be used for rest areas and welcome centers. Microwave systems will be used for weigh stations.	For public rest stops, a combination of CCTV and in-ground magnetometers. For private truck stops, elevated camera sensors.	In-ground sensors incorporating both radar and magnetometers in a single casing.	Each State will select the technology that best fits its needs.	Multi-camera system in one rest area and a count in/out microwave system, along with CCTV cameras for error correction in three rest areas.	Doppler radar and side laser scanner.
Information Dissemination	Website	DMS, website, in-cab geolocation application device integrated with existing ELD and extensible markup language (XML) feeds for third-party use.	DMS with type "A" inserts, website, mobile apps, and XML feeds for third-party use.	DMS, website, mobile apps, in-cab devices, and XML feeds for third-party use.	DMS with type "A" inserts, in-cab devices, website, and mobile apps.	Website, interactive voice response (IVR) and XML feeds for third-party use.	Website, DMS with type "A" inserts, mobile apps, and in-cab devices.	Website, DMS with type "A" inserts, in-cab devices, mobile apps, and XML feeds for third-party use.	DMS, website, IVR, and mobile apps.
Project cost	$5,135,373	$2,040,940	$9,000,000	$22,227,419	Estimated $115,000 per rest area and $65,000 per private site.	$10,251,688	$33,663,649	(not available)	$782,000
Project status	Project is ongoing. Website is up and running.	Project has ended. Website is not active.	(This grant was not funded, but two sites are operating in summer 2018.)	Project is ongoing.	Project ended in 2014. Website is still up and running. Incorporated with MAASTO.	Project ended. Website is still up and running.	The system is expected to be in operation by January 2019.	Incorporated with MAASTO.	Field test ended August 2016.

Figure 2 shows which States have pilot programs either in place or scheduled for deployment. Several States are involved in multiple projects, but no project maps an entire State's parking resources.

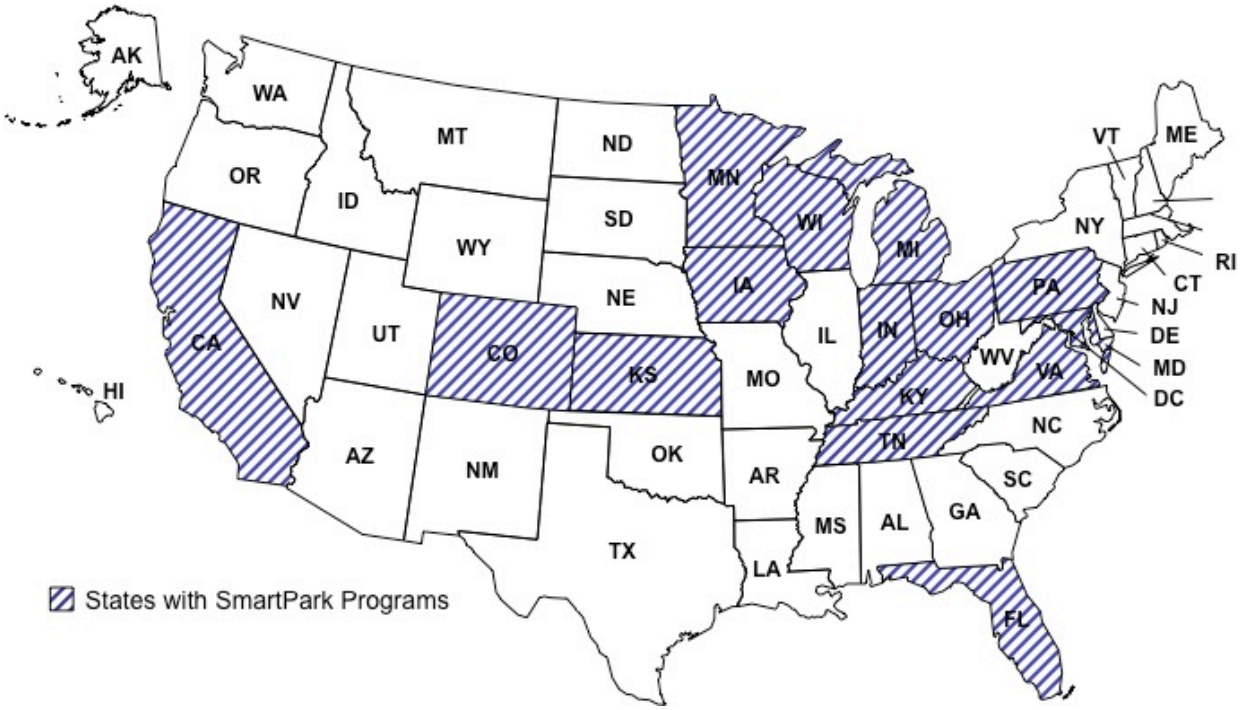

Figure 2. Map. States with SmartPark pilots, as of September 2018.

1.5 APPROACH

This plan was developed after information gathering and analysis.

The team researched and reviewed publications on truck parking ITS. Team members interviewed a variety of stakeholders, including State participants in SmartPark system grants and persons in various segments of the trucking industry. The team participated in online NCTP working group meetings and attended conference sessions on truck parking systems.

The team identified common themes and important ideas. Members noted the concerns of diverse viewpoints. The team then synthesized a plan with concrete steps that USDOT can follow to accelerate the deployment of SmartPark system. Finally, the team reviewed the proposed plan with relevant stakeholders. Review comments of the stakeholders have been addressed and incorporated in this document without attribution to the source.

2. BARRIERS

SmartPark projects are in the early stages of deployment in the United States. As organizations undertake SmartPark system and similar projects, they face new situations and several types of barriers to deployment. Ways of addressing some of these barriers are being found and implemented as the projects progress. Solutions include revisiting traditional means of conducting business, improving communication between agencies, and devising innovative ways to raise revenue.

As organizations take on the task of helping drivers find available parking, they are encountering new questions:

- Where can we find funding?
- What technology provides the best value for a SmartPark project?
- What is the best way to disseminate information?
- How do drivers want the information delivered to them?
- How do we attract private companies to our SmartPark projects?
- What contractors are qualified for our SmartPark project?

These questions, while not new to the ITS world, require answers tailored to each unique situation. Current projects, operating without the benefit of similar past experience, are serving as a proving ground. As such, ways of addressing these questions are being found and implemented as projects unfold.

Barriers addressed in this report include:

- **Financial:** paying for deployment and operation.
- **Institutional:** applying lessons from limited demonstrations to create successful ongoing deployments, and coordinating collaborative efforts among public and private entities with diverse interests.
- **Technology:** making the right technical choices to ensure cost-effectiveness and system scalability.
- **User acceptance:** winning system support from the necessary stakeholders while negotiating possible ramifications.

One major barrier lies outside the scope of this study: the existence of adequate parking for a SmartPark system to locate. A SmartPark system improves efficiency of existing parking, but it does not create new parking capacity. Discussion of this barrier (in Chapter 2.1) is therefore brief.

While s SmartPark system depends on several maturing technologies, the current state of technology is not a significant barrier to SmartPark system deployment. The technology questions discussed in this report have more to do with making the best choices about sensor

types and system design than the need for any major advancements. Technology is less a barrier than a site where other barriers (especially cost and institutional barriers) prevail.

2.1 CAPACITY BARRIER

A SmartPark system directs drivers to available parking, helping them park when they otherwise would be unaware of available parking. Along corridors where ample parking is always available and convenient to the highway, a SmartPark system is not necessary. At the opposite extreme, where all spaces within a driver's reasonable path are occupied, the system cannot fulfill its purpose. In these situations, a SmartPark system could support drivers only by advising a driver to stop early because all parking in the hours of service remaining is taken.

SmartPark demonstration projects currently underway report parking availability within limited areas, and they often include only public rest areas. These may help a driver decide when to stop, but to be more useful, systems must be able to inform drivers of parking they would not otherwise be able to find when obvious options are full to capacity. These alternative sites might not be readily visible from the highway or might include non-traditional parking, such as shopping centers that allow trucks at night.

These unconventional overflow sites will probably not be instrumented for counting nor available for reservation. Applications can alert drivers to the possibility of available space, but drivers would be required to go there to find confirmation. These sites would relieve some drivers from unauthorized parking, but recommendations to go there to search would likely frustrate drivers who found them full.

As these points illustrate, a SmartPark system is a valuable tool, but it is just part of a more complete set of solutions. Providing adequate capacity is an essential element of any truck parking plan. Indeed, truck parking should be part of any freight plan. USDOT has other initiatives directed at improving the supply of truck parking in regions where it is needed.

2.2 FINANCIAL BARRIERS

The cost of a SmartPark project is often one of the largest barriers to implementation. Given the number of States involved and the size of the undertaking, projects like MAASTO cost tens of millions of dollars.[13]

Within State budgets, truck parking competes with guardrails and bridge repair. Federal grants (e.g., the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users [SAFETEA-LU] Section 1305 and TIGER) have started several projects on truck parking capacity or information. Operations and maintenance (O&M) funding to sustain the projects after the grant period remains an open question.

Private truck stops fund their parking areas by selling food and fuel. Information about available spaces is a form of advertising for them and a possible selling point for a SmartPark system. Paid reservations can contribute to funding, but reservations are difficult to enforce when parking is tight and meaningless when space is ample. Drivers have shown a reluctance to pay for parking

spots, much less for reservations that unforeseen traffic conditions may prevent them from reaching.

Another barrier is the lack of a complete business case for State agencies. Many analyses have been published, but they tend to rely on assumptions rather than data, particularly when describing benefits. Current projects are small pilots with little more than anecdotal results. Several State projects are now in construction as part of the MAASTO grant, but their cost numbers have yet to be collected, and the best analysis is still the original grant application. Compounding the problem, a business case has yet to be published to show how private parking owners can make money from participating in SmartPark projects.

When making cost-benefit decisions, transportation agencies sometimes consider only the cost of installation and maintenance. Agencies should consider also the economic and social benefits, though some institutional cultures are hesitant to consider more qualitative advantages. Cultures and approaches vary widely, and people with an analytical background often prefer a quantitative assessment. Adequate information to support a complete, purely quantitative assessment is still forthcoming.

2.2.1 Current Projects and Cost Benchmarks

Of the projects in operation or under construction, none have published costs or benefits based on actual experience. MAASTO States have their contracts in place and construction is underway at the time of this writing, but the only financial data available are from the grant proposal.

As an example, the MAASTO financials from the TIGER grant application are summarized in Table 2, which shows the 2015 projected project costs of the MAASTO SmartPark project, by State.

Table 2. 2015 MAASTO deployment costs.

MAASTO Breakdown by State	Public Sites	Public Spaces	Private Sites	Private Spaces	DMS Signs	Deployment Total (2015 $)	Annual State O&M (2015 $)	Cost per Space (Public and Private)	O&M per Space
Indiana	20	1044	0	0	20	$6,085,800	$235,775	$5,829	$226
Iowa	14	263	10	2060	14	$4,980,864	$423,336	$2,144	$182
Kansas	16	160	0	0	16	$4,868,640	$188,620	$30,429	$1,179
Kentucky	9	375	14	1560	12	$4,077,383	$478,922	$2,107	$248
Michigan	8	194	22	942	8	$4,020,089	$662,556	$3,539	$583
Minnesota	5	130	0	0	8	$1,775,000	$68,289	$13,654	$525
Ohio	18	515	33	2592	18	$7,855,873	$1,064,566	$2,528	$343
Wisconsin	7	241	0	0	14	$3,000,000	$82,521	$12,448	$342
Total	**97**	**2922**	**79**	**7154**	**110**	**$36,663,649**	**$3,204,585**	**$3,639**	**$318**

Cost per space was not supplied in the MAASTO financials. It was calculated by dividing the "Deployment Total" by the sum of the public and private spaces. Cost per space gives context

and supports comparison between different States' solutions within the MAASTO framework. Through that lens, the wide range of costs becomes clear. The State of Kentucky achieved the lowest cost per space at approximately $2,107 per space. The most expensive State was Kansas at $30,429 per space. While the cost per space does not represent all factors, it does provide some insight into the cost dynamics at play within the early SmartPark projects. Factors influencing costs include technology, location, number of parties, incorporation of private entities, and deployment strategy.

It would be imprudent to offer speculation on the causes or ramifications of the large range of deployment costs at this time due to not having the latest financial information. Cost benchmarks will be hypothetical until more SmartPark projects reach completion. A larger sample size of projects and data is needed before accurate projections and calculations can be made. As these projects mature, new deploying organizations will learn from the successes and failures of current SmartPark projects. This larger sample size and information from subsequent projects will provide a more complete picture of cost-benefit effectiveness and performance.

2.2.2 State Matching Grants

Each State participating in the MAASTO SmartPark project provided a 10-percent funding match. With the conclusion of the project, the respective State DOTs are responsible for ongoing O&M, expansion, and removal costs. A summary of the MAASTO State matches and O&M figures is provided in Table 3.

Table 3. 2015 MAASTO State match and O&M costs.

MAASTO Breakdown by State	Deployment Total (2015 $)	90% TIGER Request (2015 $)	10% State Match (2015 $)	Annual State O&M (2015 $)
Indiana	$6,085,800	$5,477,220	$608,580	$235,775
Iowa	$4,980,864	$4,482,778	$498,086	$423,336
Kansas	$4,868,640	$4,381,776	$486,864	$188,620
Kentucky	$4,077,383	$3,669,645	$407,738	$478,922
Michigan	$4,020,089	$3,618,080	$402,009	$662,556
Minnesota	$1,775,000	$1,597,500	$177,500	$68,289
Ohio	$7,855,873	$7,070,286	$785,587	$1,064,566
Wisconsin	$3,000,000	$2,700,000	$300,000	$82,521
Total	**$36,663,649**	**$32,997,284**	**$3,666,365**	**$3,204,585**

Source: http://www.maasto.net/documents/TPIMS-Grant.pdf.

This information indicates that deployment of SmartPark projects is dependent on Federal funding and the availability of matching funds from States. Two States in the MAASTO organization were not able to take part due to a lack of matching funds.

Benefit-cost analyses are the primary way to find out whether the benefits justify the costs for projects. Without such an analysis, the justification for future projects is difficult to make. Due to the early development cycle of many SmartPark projects and the lack of completed projects, the

data needed to analyze the actual costs and realized benefits for most projects will be unavailable for some time.

Two projects of note—MAASTO and the Colorado Truck Parking Information System—have completed preliminary benefit-cost analyses, but neither has generated enough data to support conclusions.[9,13] Table 4 shows selected metrics from the two projects' grant applications. In the absence of concrete data, these analyses based projected benefits on assumed improvements. As such, no SmartPark project to date has generated enough performance metrics to support a complete benefit-cost analysis.

Table 4. The Colorado and MAASTO grant applications estimated benefit-cost ratios.

Measure	Colorado DOT[9]			MAASTO[13]		
	Undiscounted	Discounted at 3%	Discounted at 7%	Undiscounted	Discounted at 3%	Discounted at 7%
Travel Time Benefits[1]	$45,387,006	$35,327,827	$25,850,210	$206,344,580	$140,082,959	$86,550,788
Operating Cost Benefits[2]	$61,183,130	$47,623,037	$34,846,907	N/A	N/A	N/A
Safety Benefit[3]	$33,667,085	$26,205,407	$19,175,118	$107,139,265	$72,734,574	$45,677,214
Environmental Benefits[4]	$18,396,450	$14,293,152	$11,896,609	$89,574,770	$60,466,668	$46,927,508
Total Benefits	$158,633,671	$123,449,424	$91,768,844	$403,058,614	$273,264,201	$179,155,509
Deployment Costs	$9,000,000	$8,417,576	$7,727,168	$36,663,649	$33,063,805	$28,949,491
Maintenance Costs (10 years)	$9,450,000	$7,376,995	$5,418,001	$57,682,548	$39,159,458	$24,592,087
Total Cost	$18,450,000	$15,794,571	$13,145,169	$94,346,197	$72,223,263	$53,541,577
Net Present Value	$140,183,671	$107,654,853	$78,623,675	N/A	N/A	N/A
Benefit/Cost Ratio	8.60[5]	7.80	7.00	4.27	3.35	3.78

[1] Travel Time Benefit assumptions were similar for both MAASTO and Colorado. Both projects estimated 15 minutes of drive time was saved for the operator with 80-percent utilization of parking spaces.

The hourly rate of a driver was assumed to be $25.80 (MAASTO) vs. $26.68 (Colorado).

[2] Colorado operating cost benefits consist primarily of the fuel savings and vehicle non-fuel cost savings for the truck driver. The MAASTO estimate did not list these items.

[3] Safety Benefits estimates for both projects assumed a 10-percent crash reduction.

[4] Environmental benefits for both projects assumed 80-percent parking utilization, 2 gallons of fuel savings per parking space, 12 miles savings per parking space, 15 minutes time savings per parking space.

[5] The benefit/cost ratio for the undiscounted dollars was not presented in the original. The value here was calculated from other numbers in the table.

Colorado and MAASTO followed similar formats, but differences in their approaches prevent a direct comparison. The most significant difference is Colorado's inclusion of Operating Cost Benefit, providing more benefit value to the project than MAASTO's model. The Colorado project Operating Cost Benefit accounted for gains that accrue to the truck driver in terms of equipment and fuel costs. Unaccounted for in the Colorado project analysis are additional societal benefits such as job creation for the SmartPark system employees, work created to build SmartPark facilities, and the tax revenue from private SmartPark projects.

Removing the Operating Cost Benefit from the Colorado proposal gives a benefit-cost ratio of 5.3 (undiscounted), 4.8 (3-percent discounted), and 4.3 (7-percent discounted), bringing it closer to the MAASTO figure. (Higher ratios reflect better performance.) Regional dissimilarities, team calculations, and other small variations account for the remainder of the difference between the two projects.

These analyses project that for every $1 in investment, between $3.30 to $7.80 benefit will be returned, but the actual costs and realized benefits are yet to be corroborated. This difference between benefit-cost ratios highlights the lack of a defined methodology for comparing the benefit-cost analyses across SmartPark projects. A template or sample benefit-cost analysis, complete with defined terminology and criteria, would enable true one-for-one comparisons.

The absence of such tools is a barrier because State decision-makers are likely waiting to see solid data before making additional funding commitments.

2.2.3 Operation and Maintenance Costs

O&M costs, especially those which accrue to public agencies, need to be considered early in the project. The expectation is that after the initial testing and subsequent deployment, SmartPark systems will result in fewer crashes and reduced travel times, but the resultant monetary savings will directly benefit private enterprise rather than public agencies.

The financial benefits of a truck parking project are either unknown or rough estimates at this time. As a result, organizations are most likely choosing to invest in known activities that are less costly, carry less perceived risk, and with investors who have prior experience. As more projects are deployed and positive results become public, additional budget resources may be redirected to SmartPark projects.

The Virginia DOT created a budget that included O&M costs for the continuation of a SmartPark project. As a result, the I-95 Coalition selected the Virginia DOT to build the infrastructure for their SmartPark project. The inclusion of O&M costs in planning of SmartPark projects is crucial for two reasons. There are some States that considered only the capital costs, installed SmartPark technology and then later shut it down because they did not consider budgeting for O&M costs. Second, some Federal grants applicable for SmartPark systems are for capital expenses only, some for O&M costs only, and some for both.

2.2.4 Location Drives Cost

The location of SmartPark projects influences worker rates, available contractors, and other cost drivers.

Cost will vary from State to State. Each State has organizational standards and methods that will directly affect their costs. These variations manifest themselves in regional laws, standards, and practices. Within States, metropolitan areas can have additional requirements regarding zoning, aesthetic considerations, and technical challenges. Each of these factors can create costs not present in rural areas.

2.2.5 Unpopularity of Paid Spot Reservations

Diverse ways to obtain revenue for maintaining the system beyond initial funding are being explored. One method involves creating a system that will allow users to pay in advance for parking spots at public rest areas. Several surveys have shown that truck drivers consider the ability to reserve a parking location useful. Truck drivers generally agree that this is a benefit and a feature that increases operational efficiency and safety. But nearly half of the surveyed participants have shown a reluctance to pay for this service themselves.[17] The respondents agreed that carriers should cover this cost. It should be noted that some carriers have begun to reimburse their drivers for reservation costs,[17] but this is not feasible for all carriers. The seemingly minimal cost for a driver to pay for a daily parking reservation accumulates over a year, and this cost can be a large decision point in a competitive industry with compressed financial margins.

Anecdotal information from truck drivers suggests that reservation based systems are not gaining wide user acceptance. Spaces dedicated to pay-for-parking remain open throughout the day, while the free parking spots are filled. An unfavorable characteristic of pay-for-parking systems is that payment needs to be made when reserving the spot instead of on arrival. If a cancelation needs to be made, it must be done hours in advance to get a full refund. This has resulted in drivers arriving at their paid parking location and finding free parking locations available, but still being unable to claim a refund for an unnecessary reservation. This has decreased drivers' acceptance of pay-for-parking. From the driver's perspective, the money outlaid is more important than the security of knowing a parking spot is reserved for the night.

Reserved parking fees can be a revenue stream for truck stops, but enforcing reservations increases operational costs. FMCSA found the use of an honor system to enforce truck parking reservations is not viable, and manual or mechanical enforcement is necessary.[18] Additional costly tasks include taking phone calls, monitoring reserved parking locations, and removing unauthorized trucks from reserved locations.

State DOTs are restricted from charging fees for parking at rest areas on Interstate Highways. Federal law under 23 U.S.C. 111 prohibits most commercial activity at rest areas on Interstate Highways.

2.3 INSTITUTIONAL BARRIERS

Institutional barriers are policies, procedures, or situations that create systemic or organizational resistance to progress. For SmartPark systems, institutional barriers tend to complicate cooperation between organizations. One means of cooperation is a public-private partnership,

often called a P3. These partnerships are more easily established in some jurisdictions than others. Less formal and more flexible means of reaching a common goal are available.

Whatever the shape of the final partnership, public agencies and private entities both provide parking services, and both must cooperate to deliver a unified system to drivers. Many factors make this difficult. Public agencies are interested in improving safety and promoting freight flow while businesses exist to make a profit. Public agencies are constrained by laws and policies, while private firms may be more agile.

Owners of private parking facilities are reluctant to cooperate with public agencies on ventures that would harm their businesses. Though laws (e.g., 23 U.S.C. 111) limit the services that can be provided by public rest areas on Interstates, publicizing free parking could drive customers away from private facilities.

Laws vary from State to State, so a solution in one State may be unworkable in another. Cooperation among several States will be necessary to accelerate the deployment of a nationwide, unified SmartPark system.

2.3.1 Privately Held Parking Capacity

Including private truck stops is essential to a comprehensive system. Truck parking capacity is available under several forms of ownership:

- Public rest areas, current and re-purposed weigh stations, and occasional street parking.
- Private truck stops.
- Private courtesy parking, such as shopping centers.
- Private shipper, receiver, and warehouse sites.

Each of these classes has its own motivations and revenue model.

Most of the parking capacity is privately owned. The first Jason's Law study reported over 1,908 public rest areas in the Nation with a total of 36,622 spaces, while the 6,372 private truck stops offered over 272,298 spaces.[19] Figure 3 illustrates the ratio of spaces in truck stops to public rest areas. In the United States, there are more open parking spaces at truck stops than the total number of spaces at public rest areas.

Surveys have shown that truck drivers generally prefer truck stops over public rest areas for long-duration rests.[17] Truck stops provide several amenities that rest areas do not, such as food, fuel, showers, and bigger parking spaces.

A system able to direct trucks only to public parking ignores most parking spaces and falls short of its full potential. Current State-funded SmartPark systems focus on rest areas and other publicly owned spaces. It is easier for States to instrument areas under their control and supervision. Lack of legal authority and institutional unwillingness on the part of the State, private provider, or in some cases both, are the main reasons why States have not incorporated privately owned entities into SmartPark projects.

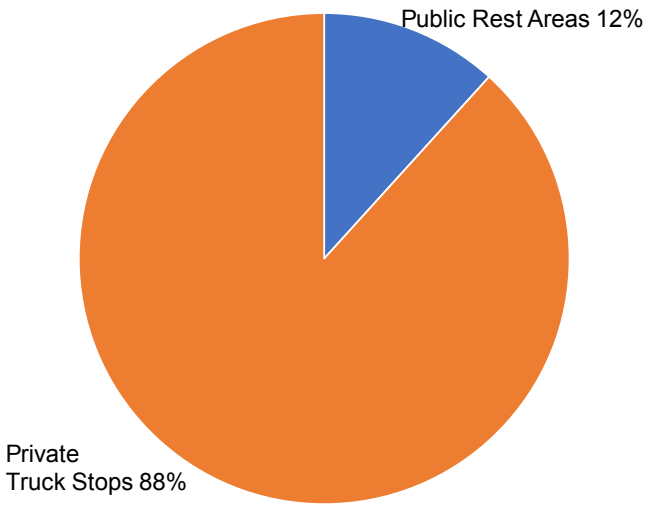

Figure 3. Pie chart. Parking distribution between public and private locations.

2.3.2 Policy Barriers to Public/Private Cooperation

Governments and private entities have different motivations and limits that can inhibit working together. For example, some States are prohibited from forming partnerships with private parking entities because those States may not directly advertise private businesses (displaying a sign showing truck parking availability at a private provider has been construed as advertising). Cooperation can be complex even when permitted by law. Private entities can generally use public data more readily than public agencies can use private data.

State budget decision-makers may be reluctant to instrument private areas with SmartPark technology, even if laws permit, due to concerns about private sector response to such actions. Some State agencies have the impression that working with private parking owners is too much trouble. Some State agencies also believe that promoting private businesses is not a proper use of public money, and some jurisdictions impose narrow limits on doing so.

In general, private organizations do not want programs forced on them by governments. They do not want outsiders installing equipment that could become a liability. Private business owners may fear that the government is intruding on their operations or that their business data will be made available to their competitors. A profit-making business does not want to direct potential customers away, a possible consequence of a system that only reports nominal capacity. Some private truck stops have the ability exceed their nominal capacity by allowing parking on unpaved land when weather permits, or by other means.

Even so, many owners of private truck parking have installed instruments so they can post their current availability. In other instances, States have sought and received permission to instrument a private site so that it can be included in a State SmartPark system. States have had to contractually agree that the equipment would not damage the site and would be removed when desired. Some owners have declined to install sensing equipment because of bad experiences with previous enterprises.

National chains have corporate legal departments to protect their interests. In contrast, smaller businesses might not have the legal representation to protect them if a problem does occur. Some States have managed to work through the barriers that impede the cooperation with private institutions, and independent stops have been successfully incorporated into SmartPark projects created by State DOTs.

Even successful incorporation can incur costs. Stakeholders have reported that many memoranda of understanding (MOUs) were needed to achieve a result, so motivation must be high to complete a partnership. Legal expenses for contracts and MOUs increase as the number of agreements and parties increase.

According to information published by the National Council for Public-Private Partnerships, 37 States have legislation that enables some sort of public-private partnership.[20] A report by FHWA shows that each State has unique statutes, some of which may reduce interest from the private sector.[21] These statutes can limit:

- The types of contracts that can be put in place.
- The number of P3 projects that can be undertaken at the same time.
- The scope of the projects set by a State.
- The size of P3 projects.

USDOT provides guidance and recommendations through the Build America Bureau for public organizations interested in establishing a P3.[23] The main goal of this bureau is to promote use of private funding for public infrastructure projects (e.g., toll roads or toll bridges), provide guidance, and encourage use of funds specially designed for these types of projects.

The Federal Transit Administration's (FTA's) new rule, which aims to remove barriers to private investment in U.S. public transportation projects, could be a model for partnership.[22] The rule allows grant recipients to identify any barriers that impede private involvement in a project and request waivers to overcome those barriers.

For SmartPark systems, there is precedent for both success and setbacks in public/private relations. Two currently operating public systems in Michigan and California have included privately owned sites. Three MAASTO States, Michigan, Iowa, and Kentucky, will include private sites. At least one public system had to drop plans to include private parking when the deployment schedule was compressed.

Addressing barriers to partnership will require skilled negotiating, careful listening to business owners, and knowledge of State and local laws.

2.3.3 Coordination Across Multiple States is Difficult

SmartPark projects are large and often depend on multiple public and private entities. Each State has a defined set of procedures and guidelines for operations. Each has its own identity and approach to a project. Success depends on creating a sense of system ownership for each organization.

Within each SmartPark project are multiple interfaces both within and without the State, some of them likely to be new. A State's freight office, for example, may not be accustomed to coordinating with the ITS office. A planner in a region in the early stages of implementing a SmartPark system observed that the freight office viewed the program as a freight issue while the ITS office saw it as an ITS issue. In reality, a SmartPark system spanned both offices, so it was a shared issue.

As these regional systems grow and reach one another's boundaries, they will have to interact. A State with a welcome center near a border will need to put a sign in an adjacent State (as Minnesota did for I-94) to inform inbound traffic. Drivers will desire a seamless system, which will require information sharing across State lines. Common practices for disseminating information and technical standards for interchange will become essential. USDOT has a role in anticipating what these common needs will be, learning best practices from pilot programs, and developing a consensus for common standards. When the number of parties involved increases, the number of administrative and technical interfaces grows, and the resulting complexity can become unwieldy if not managed well.

Strong leadership is therefore essential. Leaders will relay information to each constituent and be able to describe how project funding will flow to each State. Allowing States to create their own ways to collect parking availability information within set formatting guidelines has been proven to help solve most interface issues and give States a voice in the process. All members must understand that they are a part of a larger system and that system-wide success depends on the success of their individual efforts.

The experience of multi-State organizations that have overcome this barrier can be a guideline for newer consortiums. As more projects are implemented, these experiences and tested methodologies will help overcome barriers to interstate cooperation.

2.3.4 Fragmentation of Current Parking Information

Drivers report frustration at the number of sources they must consult to determine parking availability. A full, integrated "system" needs to be deployed to realize the potential of SmartPark system. Individual pilot projects dotting the Nation do not make a system, so a concerted effort is needed to create a scalable, ubiquitous system that incorporates rest areas, other public parking, private truck stops, and courtesy parking.

Interstate 94 in Michigan offers an example of the multiplicity of sources a driver must consult to locate parking. Table 5 compiles parking locations on the eastern portion of the interstate, beginning at the Indiana-Michigan border and proceeding east almost to Ann Arbor. The first two columns of Table 5 list the location, description, and ownership of the parking locations. The next four columns indicate by a check mark whether the location is listed on four common truck parking information systems accessible via smartphone.

Table 5. Parking locations on I-94 in Michigan.

Location	Description and Ownership	Mi Drive	American Truck Parking	Park My Truck	Trucker Path
MP 0 EB	New Buffalo Welcome Center (S)	✓	--	--	--
Exit 1	Plaza 1 Truck Stop (I)	✓	--	--	--
MP 2	New Buffalo Weigh Station (S)	--	--	--	✓
Exit 12	TA Sawyer (N)	--	--	✓	✓
Exit 12	Dune's Truck Plaza	--	--	--	✓
Exit 16	McDonald's (C)	--	--	--	✓
Exit 29	Pri-Mart Fuel Center (I)	✓	--	--	✓
Exit 30	Pilot Travel Center (N)	--	--	--	✓
Exit 39	McDonald's (C)	--	--	--	✓
MP 42	Watervliet Rest Area (S)	✓	✓	--	✓
Exit 56	Road Hawk Travel Center (I)	--	--	--	✓
Exit 66	Speedway Gas Station (N)	--	--	--	✓
MP 85	Galesburg Rest Area (S)	✓	✓	--	✓
Exit 92	Arlene's Truck Stop (I)	✓	--	--	✓
MP 96	Battle Creek Rest Area (S)	✓	✓	--	✓
Exit 104	TA Battle Creek (N)	--	--	✓	✓
Exit 104	Pilot (11 Mile Road) (N)	--	--	--	✓
Exit 110	Pioneer Auto Truck Plaza (I)	✓	--	--	--
Exit 110	Brewer Park Food Mart (I)	--	--	--	✓
Exit 110	Pacific Pride (I)	--	--	--	✓
Exit 112	Love's (N)	✓	--	--	✓
MP 113	Marshall Rest Area (S)	✓	✓	--	✓
Exit 115	PTP Stop (N)	✓	--	--	✓
Exit 128	Parma Travel Center	✓	--	--	✓
Exit 130	Sunoco Truck Stop (N)	--	--	--	✓
Exit 136	Sandstone Rest Area (I)	--	✓	--	✓
Exit 145	145 Auto Truck Plaza (I)	--	--	--	✓
MP 161	Chelsea Rest Area (S)	--	✓	--	✓

Notes: Site ownership is indicated by State (S), Private nationwide chain (N), Private independent (I), or Private courtesy (C). None of these four sources include all of the parking locations on a segment of I-94 in Michigan.

A driver in Michigan might consult four separate sources to find parking:

- Mi Drive (https://mdotjboss.state.mi.us/MiDrive/map) is the official Michigan Department of Transportation website, which lists traffic conditions, road weather, and other information. It reports the total number of spaces and the number of open spaces at each location. The locations checked in the table were instrumented through an earlier grant and are currently operating. The MAASTO grant will extend coverage eastward toward Detroit.

- American Truck Parking (http://www.americantruckparking.com) is a website maintained by the University of California. In the western part of the country, it reports static information on capacity. (It has real-time information on sites in other regions.)
- Park My Truck is a mobile application operated by the National Association of Truck Stop Operators (NATSO), the trade group of travel plaza and truck stop owners and operators. It has real-time updates in the form of unoccupied/total spaces. For example, 44/155 indicates that a site has a total of 155 spaces and that 44 were available at the most recent update.
- Trucker Path, another mobile app, has a map of the country with different icons to indicate the various types of parking (rest area, truck stop by brand, courtesy, etc.). Availability information is provided by truckers. The application indicates the time of the most recent update.

But even after consulting these four sources, a driver will not have a complete, up-to-date picture of parking availability on the corridor. In addition to the four examples in this table, other applications are produced by truck stop chains and independent developers. Some of them are reviewed in Table 8. The point of this illustration is that there is no single source a driver can consult for a complete, current assessment of parking availability. Assembling this table required not only the four sources listed but also an online map to confirm milepost numbers and to determine the order in which trucks would encounter the locations. Doing so at a desk with a full-size computer screen and a high-speed Internet connection was inconvenient; finding a spot with a small smartphone screen and metered connection would be even more difficult and time-consuming.

These issues affect developers as well as drivers. A firm creating a new application would have to gather information from many places and transmit it in many manners. State-owned information is generally posted for any interested party to download and retransmit, but privately-owned information is intellectual property, and an application developer would need to negotiate to license it.

2.4 TECHNOLOGY BARRIERS

Research efforts exploring the use and creation of a Truck Parking Management System date back to 2004.[4] Technology will have a role in future truck parking installations, but there are several challenges that need to be overcome.

Devices for assessing availability have performed well in tests but need further research. Different devices have trade-offs in capital cost, operating cost, accuracy in unfavorable conditions, and suitability for different sites.

The databases currently being created that catalog SmartPark projects are difficult to integrate. Current incarnations of databases are not designed to scale with other projects, and the lack of a vision for future growth is harming the industry. The absence of a system orchestrator has left the industry chipping away at the problem piecemeal, deploying applications that draw from disparate sources and that do not adhere to any single standard. The presence of standards for

data sharing would ease database integration across different truck parking projects and accelerate solution deployment.

2.4.1 Comparing Parking Instrumentation Methods

There are two broad approaches to assessing the availability of parking. One is to count the available or occupied spaces directly, which can be done by sensors or by visually estimating available capacity. The other approach is to count the number of commercial vehicles entering and exiting a parking location. Various technologies are available for both approaches, and each has trade-offs in accuracy, installation cost, and operating cost.

Occupancy can be counted by sensors installed in each space or by machine vision systems that recognize trucks. Occupancy counting methods are more accurate at locations with a fixed, small number of spaces. FMCSA found that they are less accurate where drivers can park in spaces that are not individually instrumented, such as unpaved gravel areas or paved but unmarked spaces. Occupancy counters are also less accurate when spaces are marked and instrumented but drivers use more than one parking space.[16]

Entry-and-exit systems, which use magnetometers or cameras to count incoming and outgoing trucks, have lower equipment costs because only the entrance and exit need sensors. They can be immediately adjusted when capacity changes, whether temporarily or permanently. More than one operator of a current system said that entry and exit systems are less costly. But errors can accumulate in these systems, due to sensor misreads or tailgating trucks. Manual error correction is required once or twice daily. Entry-and-exit systems require well-defined entrance and exit points, and they may not function as well at truck stops with parking that has multiple ingress and egress locations.

Video detection technology is less expensive than magnetometers for counting truck parking availability by monitoring numbers of entries and exits. Both provide similar levels of performance, but there are tradeoffs in terms of installation needs and customization. On the other hand, for counting truck parking availability by monitoring individual space occupancy, magnetometers are less expensive to implement than video detection systems, but their accuracy is lower. Additionally, multi-camera systems require the installation of a camera pole, power lines, and below-grade conduit. Magnetometers are battery operated and wireless. Installation, though it requires boring the pavement, is easier than with video systems.

Table 6 and Table 7 summarize the advantages and disadvantages of the detection systems.

Table 6. Sensors for counting trucks as they enter and exit a parking location.

Item	Magnetometer	Light (Laser)	Microwave (Radar)	Video Detection
Cost	$$	$$$	$$	$
Accuracy	++	+++	+	++
Pros	Wireless technology	Accurate in all speeds and weather conditions	Low power	Classification in non-ideal settings
Cons	Installation needs to be in pavement	Expensive, unique software	Reflections and low speed affect accuracy	Affected by visibility

Table 7. Sensors for counting truck parking space occupancy.

Sensor	Magnetometer	Magnetometer and Microwave	Magnetometer with Infrared	Video Detection	Crowd-sourced	Manual Input
Cost	$$	$$$	$$$	$$$$	$	$
Accuracy	+	++	++	+++	+	+
Pros	Low cost per-space technology	Dual technology more accurate	Dual technology more accurate	Most accurate technology	No capital cost, no need for technology installation	No capital cost, no need for technology installation
Cons	Low accuracy, requires digging pavement, multiple sensors needed	Needs to be installed in paved space, multiple sensors needed	Needs to be installed in paved space, multiple sensors needed	High cost, not reliable in low light, high need of calibration	Accuracy relies on the number of users	Accuracy relies on update rate by the operator

Project constraints will dictate the measuring system. In the case of entrance and exit ramps and overflow parking locations, implementation of space occupancy systems would be ineffective because these locations contain non-painted spaces and unpaved grounds. For locations like these, entry and exit counting systems would be the best choice.

Each site will require a different approach. Some detection mechanisms that would be ideal for one site would be ineffective or cost-prohibitive in another. Diverse ways for connecting these locations to the system are available and should be considered in light of budget constraints. The technology cost for including all parking locations in a region could render the system non-viable depending on available funding.

2.4.2 Standards for Sharing Data are Immature

As an organization takes on the task of providing real-time parking information to truck drivers, it collects data from the parking location and formats it for dissemination to drivers. The presentation to the public is usually in the form of a digital sign, website, or mobile application. Projects are currently implemented according to individual project guidelines and without

uniform standards. This lack of standardized data formatting results in parking information that is only available regionally and cannot be shared with other organizations.

With a standard or set of standards in place, cost and schedule efficiencies could be realized instead of re-inventing the wheel for each new project. The reasons for this lack of reuse need to be researched and fully understood to offer solutions.

The benefits of having a data standard include:

- **Readiness for future growth.** Standards facilitate future growth by creating portable processes that are easy to learn. This translates into greater scalability and wider deployment.
- **Increased performance management.** Standards allow performance management across multiple projects. Similar processes and modules become comparable across projects, organizations, and entities. This allows analysis of which approaches are most effective.
- **Improved quality and consistency.** Quality at the Federal, State, and local levels of these projects would improve. Commonality within the region and across the Nation would offer a more consistent, refined experience to the end-user.
- **Protection and portability of knowledge.** Written standards help maintain knowledge and enable members to understand advanced concepts.
- **Reduced cost and shortened schedules.** Standardization allows projects to be recreated based on past efforts, saving time and money.
- **Stronger basis for future study and improvement.** Standards allow consistent performance metrics across multiple regions. With fewer variables, the system can be analyzed and improved more quickly.

For all these reasons, the creation and use of standards is preferable to the current approach of piecemeal development.

2.4.3 Truck Parking Applications and Fragmentation

Phone applications have become an important business tool in the trucking industry. Applications offer convenient access to information at any time and any location, and this capability has fueled development of many trucking-related applications. According to a survey by the American Transportation Research Institute (ATRI), 55.5 percent of surveyed truck drivers use mostly websites or phone applications to select parking locations.[17] The simpler parking applications provide the parking location and number of spaces. The more complex applications provide real-time parking availability, and some include the ability to reserve a spot.

The organizations that developed the truck parking mobile applications listed in Table 8 are diverse and have different objectives. For example, TravelCenters of America (TA) and Pilot Travel Centers are private companies that generate revenue by selling fuel, amenities, and merchandise. Their applications provide parking availability, advanced parking reservation, amenities information, and navigation capabilities. The use of sensing technology to calculate

available parking is being explored by the Pilot/Flying J mobile application, while TA relies on its employees to review and update the parking availability through manual effort.

In addition to helping truck drivers find company locations for food, fuel, and amenities, these companies use their applications to better understand their customers through data analytics and other information gathered from third-party applications running on mobile devices. The TA and Pilot mobile applications are limited to their respective stores and do not include public rest areas or other parking locations not under company control.

A few mobile applications attempt to include both private and public parking locations. Some update parking availability by crowdsourcing information while others retrieve parking availability data electronically from other sites. Trucker Path and Road Hunter are among the applications that allow a driver to enter information on parking availability at both public and private locations. This information is made available to other drivers, who navigate to the website and update the data if needed. The drawback to relying on driver input is that parking information depends on user input. Applications relying on driver input can display outdated data.

NATSO, the American Trucking Associations (ATA), and ATRI created the Park My Truck application, which allows any parking provider (public or private) to register on a parking site and update parking availability information. Virginia DOT is pushing information to the application, and the application's developers are in the process of adding more States. While Park My Truck offers both public and private data, the data accuracy depends on the participating parking locations periodically updating the information. Participating SmartPark projects update their data automatically.

The application fragmentation issue is a result of multiple companies attempting to find a solution without cooperation. While competition and independent innovation is good, having a smaller number of superior solutions would improve drivers' experiences.

Table 8. Truck parking mobile applications.

Name of Application	Hosting Organization	Coverage	Source of Information	Count Display Precision	Extra Features
TruckSmart	TA	Parking availability only for TA and Petro truck stops.	Manually entered by truck stop personnel.	Provides an exact count of available spaces.	Parking reservations, amenities, fuel prices, navigation to the truck stop.
Love's Connect	Love's Travel Stop and Country Store	Provides total number of parking spaces at Love's truck stops.	Does not provide real-time parking availability.	Does not provide real-time parking availability.	Amenities, fuel prices, navigation to the truck stop.

Name of Application	Hosting Organization	Coverage	Source of Information	Count Display Precision	Extra Features
myPilot	Pilot FlyingJ	Parking availability only for Pilot FlyingJ truck stops.	30 locations equipped with in-ground sensors. Other locations manually entered by truck stop personnel.	Provides an exact count of available spaces.	Parking reservations, amenities, fuel prices, navigation to the truck stop.
Park My Truck	NATSO, ATA, ATRI	Parking availability, total number of parking spaces for both participating public and private parking locations.	It offers the capability to manually enter parking availability or by means of an application programming interface (API).	Provides an exact count of available spaces. Data times out if not updated at least every 2 hours.	Brief description of the parking location, phone number when available, navigation to the truck stop.
Trucker Path	Trucker Path Inc.	Parking availability of truck stops, rest areas and other parking locations.	Relies on crowdsourcing for parking availability.	Parking availability is displayed as "Lots of Spots," "Some Spots," and "Lot is Full."	Parking location amenities, user reviews, parking forecasting, navigation to the truck stop, ELD side application.
Road Hunter	Road Hunter Team	Parking availability of truck stops, rest areas and other parking locations.	Relies on crowdsourcing for parking availability.	Parking availability is displayed as "Empty," "More than 10," "Less than 10," and "Full."	Parking location amenities, navigation.

2.4.4 Protecting Security Across Interfaces

Information security professionals consider any system interface with multiple contributors to be a potential security vulnerability. Many participants, public and private, would contribute data to a SmartPark system. Many parties would use the system: individual drivers seeking a place to park, services intending to further process and disseminate data, and transportation planners analyzing trends. As a start, SmartPark system designers should consider the extent to which existing ITS security measures are adequate. Any new vulnerabilities need to be assessed and addressed.

2.5 ACCEPTANCE BARRIERS

A driver unable to find an available safe parking location is faced with two bad choices: continue driving or park in an unauthorized location. Both options lead to an unsafe situation.

The importance of finding a solution to the truck parking issue needs to be appreciated by State decision-makers at the highest levels. Unfortunately, States have difficulties making a case for

assigning higher priority to truck parking funding. This is because of the lack of solid data on cost benefits of providing truck parking, as truck parking projects compete with other highway infrastructure projects.

2.5.1 Funding Competition with Capacity or Other Safety Initiatives

State decision-makers balance competing budget priorities. Some decision-makers need evidence that a SmartPark system will have a safety benefit comparable to cable barriers, rumble strips, or other measures. Even within the domain of parking solutions, they will compare the benefit-cost ratio of a SmartPark system against the benefit-cost ratios of repurposed weigh stations or paving State-owned land near highways to add capacity.

The performance measurements of current projects will not be available until those projects reach completion. Operational, safety, and economic data will eventually become available.

2.5.2 The Difficult of Quantifying Performance Data

Only a handful of projects are currently underway, and their performance measurements will not be available until the projects are evaluated and analyzed, which will take years.

These measurements will try to quantify the performance of the system based on parking utilization, safety and security, and system reliability. Baseline data will be gathered that will reflect crash rates related to fatigued truck drivers. The expectation is that the number of crashes will be reduced by implementation of the system.

Accurate and efficient measurement of each SmartPark project is needed to further the discussion and validation of these projects. While statistics like parking utilization are relatively easy to gather for these projects, other indicators like safety, perception, and overall effectiveness at utilizing available parking are harder to quantify. These additional indicators require larger amounts of manual effort in the form of surveys, calls, collating reports, and conversations.

2.5.3 ELD Vendors are Waiting for a Product and a Market

Most commercial vehicle drivers are now required to use an ELD. With an electronic device already in the cab, providing real-time parking information seems like a natural extension to the product offering that could be implemented as a software addition. Indeed, ELD vendors have shown interest in the possibility. One major vendor participated in the Minnesota study, and another has a relevant patent.[24] Trucker Path, an application that provides crowd-sourced parking information among other functions, recently added an ELD feature. Applications like this that run on a driver's phone are used by drivers without enterprise-scale ELDs with dedicated hardware.

A barrier that might prevent an ELD vendor from adding the SmartPark feature is the lack of information across regions (i.e., information exists only in a small number of regions). An integrated SmartPark feature would have minimal functionality in the near-term and would not generate enough sales to justify the investment. When a sufficient amount of real-time data is online and customers begin demanding the service, ELD vendors will provide it.

3. SOLUTIONS

This section presents solutions to overcome the various barriers to SmartPark system deployment. Solutions include approaches to finances and funding, ways to reduce institutional barriers within and between public agencies, uses of existing technology, and improving existing perceptions of SmartPark systems.

The information presented in this section is a result of a comprehensive analysis of previous and current SmartPark pilot projects and research papers. Information from interviews with current SmartPark project managers, private company representatives, commercial vendors, and others in the industry was also collected. These solutions were gathered mostly from success stories provided by project managers and suggestions from industry experts.

Some barriers, notably State and Federal legislation, current levels of technology, and organizational budgets, can be influenced by USDOT but not necessarily directly changed.

3.1 FINANCIAL

3.1.1 Expedite Cost Benchmarks

As mentioned earlier in this report, cost-effectiveness information will be available as existing SmartPark projects are completed. At this time, such data are not available. However, cost benchmarks are needed to plan future sites. Measuring the community impact of deployments is difficult without a way to measure costs. Final numbers on costs and benefits are still years away. When this information becomes available, quantitative judgments regarding success and failure can be made.

Providing this information to researchers, designers, and planners sooner would free additional time to develop parking solutions iteratively. As current projects mature, new organizations will have the ability to evaluate the successes and failures of current SmartPark projects. This information will allow final judgments on cost-effectiveness.

3.1.2 Anticipate Costs to Decrease with Scale, Efficiency, and Reusability

Scale, reusability, and efficiency drive costs down. These concepts should be applied to SmartPark system deployments. As pilot and on-off deployments resolve issues, deployment should scale up to the State level to access cost efficiencies. Designing installations to be reusable across a variety of situations will reduce design labor and time. Real-world experience will drive down management and operational costs.

3.1.3 Provide Funding Sources for Operation and Maintenance Costs

States' assumption of the continuing O&M costs is one factor limiting the number of SmartPark projects. Grants are for a specific period of time, and States need to assume recurring costs afterwards. States have existing ITS programs with associated staff, infrastructure, and budget. A well-planned SmartPark system will employ existing resources so that budget effects will be minimized.

Federal grants that can be used specifically for O&M activities are available for deploying organizations. FMCSA's High-Priority Innovative Technology Deployment (HP-ITD) grant allows for ongoing expenses. USDOT can entice more organizations to develop their own systems by publicizing grants for O&M.

3.1.4 Consider a Reservation System Where Feasible

The main purpose of considering a reservation system where feasible is to serve as a fair and reasonable rationing system for truck parking when the demand exceeds supply for a particular truck parking location.

Reservations could provide an additional revenue source for SmartPark projects. A reservation-based revenue system could provide an additional incentive for private site investment and development and improve financial stability for public sites. Reservation systems are in use today, but their acceptance is low for several reasons.

Where real estate costs are high, the revenue from truck parking is insufficient to justify dedicated parking lots from both public and private perspectives. In such areas, mixed-use development would generate more tax revenue than a parking lot. From the private perspective, the revenue from selling diesel fuel and meals does not justify the opportunity costs implied by other uses of the real estate. Truck parking lots in such areas do not generate economic profit.

From drivers' perspectives, demand for paid parking depends on circumstance and location. Some drivers will pay for a parking place if that payment enables them to rest at a location that fits their route, or to stage for the next day's appointment.

These considerations must be part of the larger picture of regional planning and business development.

Without driver, carrier, or site operator acceptance, reservation models will not gain traction. Better understanding of why drivers or carriers will not pay for reservations, especially when it can reduce the cost of searching, needs to be a priority. Site operator concerns need to be better explored. If a financial incentive for this group can be found to compensate for the additional labor, time, and effort, the resulting funds could support new SmartPark projects.

Parking reservation is a service that has been explored by a few SmartPark projects. One way of enforcing proper use of the system is only admitting vehicles that have a reservation. Electronic devices such as radio frequency identification (RFID) tag readers and automated entrance and exit gates could control lot access by reading reservation status information from an RFID tag on each vehicle. This system, though useful, entails its own start-up and O&M costs. Some States have cooperated in multi-State tolling agreements (e.g., E-ZPass). These could serve as a model for interoperability of parking RFID tags across State lines.

Under current Federal law, parking reservations for a fee could not be offered at interstate rest areas. But they could be offered at public facilities off the interstate and private facilities.

3.2 INSTITUTIONAL

Skilled managers can overcome many institutional barriers. Heeding the concerns of all parties can build consensus. A SmartPark system needs to appear to truck drivers as a single, integrated source of information, but there may be more than one method of presenting information to drivers, depending on their preferences or business. Multiple perspectives, coordinated by skilled managers, are vital to success. Behind the scenes, each public or private entity can fulfill its mission and contribute what it does best.

Deployment should also account for different State actors. While one nationwide system is an ideal, a set of separate, smaller systems is viable if it makes these systems more cost-effective. Organizers of multi-State projects have realized that member States need the freedom to create their own systems. States must follow their own laws with respect to cooperation with private entities. States have established differing ITS infrastructures and their own procedures in traffic management centers. SmartPark system deployment should take advantage of existing data infrastructure. Finally, States are more productive when they can take ownership of a project.

3.2.1 Employ Strong Champions

SmartPark systems are in their infancy. Procedures are being developed, and agreements with multiple agencies and organizations are being set in place. This is not a simple task, because there is no guideline to follow and methods are not yet fully defined. These efforts require the involvement of people familiar with the truck parking problem who understand key players and are committed to finding a solution.

SmartPark system success depends on the conviction and drive of the project manager. Strong champions need to reach out to the different key players and convey the message that their efforts will benefit everyone. This will lead these entities to work together towards a common goal and foster deeper involvement in the project, ultimately creating a sense of system ownership.

The project manager needs to understand that private industry plays a key role in developing solutions. The manager must be able to communicate the benefits of a SmartPark system to the private sector, presenting the advantages for both public and private organizations.

As an organization takes on the effort of implementing a SmartPark solution, it needs to identify these champions early. It may find them both inside and outside the organization. Champions will help guide the project towards a successful design and implementation. For example, a champion would put a SmartPark system in the State's freight plan to give it visibility for funding purposes.

3.2.2 Bring in Private Providers

Private truck stops are an essential element of a SmartPark system. Private businesses account for the majority of parking capacity, and drivers prefer truck stops to rest areas for 10-hour breaks, notably for the availability of a shower and hot meal. Public agencies have brought private truck stops into SmartPark projects, and their initial accomplishments can be a model for the future.

Several organizations have brought private truck stops into their SmartPark project by demonstrating a commitment from the deploying organization to create an effective solution. Commitment is established through constant interaction with private members, assuring them that the investments in the project are for a long-term solution that will benefit both public and private sectors.

In a nationwide effort to solve these issues, Federal agencies should:

- Reach out to the private sector with information on successful partnerships with private truck stops and how they were achieved.
- Demonstrate that SmartPark system efforts are no longer pilot or research projects but full long-term proven solutions that will help both the private and public sectors.
- Present the idea that, as more organizations get involved, the system will expand throughout the Nation.

Federal and State agencies alike should communicate that participating truck stops will see economic benefits by publicizing real-time parking availability to truck drivers. This will be possible when current and future SmartPark projects collect, analyze, and publish the benefit-cost analyses of their projects.

Agencies deploying a SmartPark project must include private entities from the beginning, working hard to understand and address concerns and adapting the project to fit private entities' needs. Agencies need to demonstrate to private organizations that private parking providers are an integral part of the project and share public goals.

Independent truck stops, with a smaller advertising budget than the chains, have at times been more willing to participate in SmartPark projects. Publicizing their availability through SmartPark systems—which is free to them, unlike advertising—improves business.

Discussions with private location operators take time and effort. The time needed to go through their concerns, build relationships, and offer a solution tailored to their operating needs can be considerable, but the investment is necessary to bring these members onto projects. Private companies have had many concerns about joining SmartPark projects. They mentioned other failed projects and technologies that required relationship building to generate trust and confidence. "Confidence" signifies the confidence of private companies in the State, that whatever truck parking project on which it would cooperate with the State, would benefit and not harm their business, in contrast to other State projects on which they had cooperated.

Some States noted that an intermediary member was beneficial in communicating with private entities. For example, Michigan DOT contracted a third party to represent their needs and to help enlist private organizations. To build trust with private members, Michigan DOT allowed private organizations the ability to exit the project more easily than is usual. Specifically, removal of the hardware was covered by the State, and there was no length of contract dictating the duration of the project.

Michigan has had successful experience with recruiting private companies to SmartPark projects. Since 2014, 7 of the 10 original private facilities recruited to their SmartPark projects are still participating.

The NCTP is exploring additional ways to fund truck parking projects. For example, agreements with private truck stops for joint O&M activities at State-funded parking locations have been achieved in several States. In Utah, a parking location adjacent to a private truck stop was constructed by the State. Nevada put gravel on a lot next to a truck stop, adding capacity to an established private resource.

3.2.3 Make Public and Private Arrangements on Smaller Scales

Local governments sometimes have more flexibility to enter agreements with private entities than do State governments. Historically, projects with a budget of less than $200 million have had a small chance of involving private and public partnership.[26] There is a stronger record of multiple smaller projects on a local level. Locally owned truck stops have more flexibility than corporately owned sites and may appreciate the publicity SmartPark systems could provide. One project manager found that truck stop owners were more receptive to a SmartPark system when approached by a private firm proposing a business-to-business transaction.

Solutions to small-scale deployment barriers are to develop trust and work on common goals. Using an agreed-upon format for data can also ease cooperation. With data technically available to all, public and private dissemination channels can use one another's data without directly working together.

3.2.4 Continue Compiling National Inventories of Parking Capacity

The problem illustrated by the data fragmentation in Table 5 will not be solved until a complete inventory of national parking capacity is established and made available to SmartPark system providers. The Jason's Law survey currently underway will produce a snapshot of capacity. It will compile detailed data on truck parking at State rest areas and also include information on private truck stops, and ports. It will not include unofficial private sites, such as shopping centers that allow trucks to park overnight as a courtesy.

Organizers of SmartPark systems have a role in creating an inventory of parking locations. They can encourage owners of the locations to have their spaces instrumented or at least listed. This job could be done by State DOTs, metropolitan planning organizations, carrier organizations, or information service providers. Market forces will encourage application providers to maintain broader lists because customers will prefer providers with more alternatives.

Sensing technology works only at the catalogued locations. The inventory needs to be kept up to date as sites are added, remodeled, or temporarily closed. The frequency of the Jason's Law survey cannot keep pace with continuous construction. FMCSA should explore ways to maintain the inventory, but how to do so involves many considerations. The first question is whether FMCSA or States have a duty to maintain an "official" list or if maintenance should be in private hands. Access to information is also an issue; States know about changes at public sites on their rights of way, but most parking inventory is privately owned.

Attempts at nationwide data dissemination channels have begun. The website http://www.americantruckparking.com/ has a map of the United States. Users can zoom to areas to find parking services or search by various attributes, though the map is not yet populated. The Park My Truck application is functional, and other applications are reviewed in Table 8. Efforts like these are practical if timely information is available in a standardized electronic format.

Inventories should also include all truck parking, conventional and unconventional (unconventional locations are those not on official applications or maps but publicized through word of mouth). Cataloging these locations would improve the efficiency of SmartPark projects.

There are technical and institutional hurdles, too. The technical hurdles are comparatively small; the data are available in a manageable number of formats and can be obtained from electronic inquiries to a manageable number of websites. The institutional hurdles are potentially more challenging because licensed, private data are involved.

3.3 TECHNOLOGY

The technologies for operating a SmartPark system already exist. Sensing technologies need to mature through use, and further research is in order. Communication standards ought to be established before protocols proliferate and approaches that might not be adequate or expandable become established. The adage that security should not be an afterthought applies. But overall, technical capability is not a significant barrier to deploying a SmartPark system.

3.3.1 Employ Low-Cost Parking Availability Detection Systems

An ideal system would disseminate available truck parking information for all parking locations in a region. But the cost of having every parking space equipped with an occupancy detector is high. Manual and partly manual systems can be less expensive and still provide adequate accuracy.

One purely manual approach calls for truck stop personnel to periodically estimate the available space. This takes time from other duties but requires minimal capital cost. At attended or unattended sites, drivers can be asked to report availability when they arrive, but such reporting is not always reliable or accurate. The main shortcoming is that sporadically reported data can become stale.

A partly manual approach is to install sensors that count trucks entering and leaving a site. These sensors are not perfectly accurate, so once or twice daily, parking availability is manually counted and the system updated. This approach is less expensive than instrumenting every single space, more accurate than a purely electronic entry and exit counter, and updates more often than a purely manual method.

Several SmartPark system deploying projects have chosen to go with the counting of truck parking availability by monitoring entries and exits. This is because they are sufficiently accurate and it is a less expensive approach than counting truck parking availability by monitoring occupancy of individual parking spaces. Their focus is to provide usable and reliable parking information for the most locations possible.

3.3.2 Promote the Use of Established Truck Parking Availability Solutions

Within the MAASTO project, Iowa has created a research opportunity. While other participants are erecting signs on the highway, Iowa will disseminate the information only via its 511 traveler information system and through data feeds. Providing information through established channels and third-party vendors eliminates the costs of installing and maintaining roadside equipment. The reactions of drivers and effects on parking, compared with the other States, may yield insights into the value of signs.

One stakeholder offered the argument that providing parking information is a duty of the State, similar to providing traveler information through ITS. Treating a SmartPark system as an ITS project not only addresses the attitudinal barrier; it also reduces the costs of implementation. Treating parking information as an extension of ITS functionality takes advantage of the existing capital investment in ITS. The marginal cost of adding information about truck parking availability to an existing 511 website is minimal.

Digital information channels already exist, such as NATSO's Park My Truck mobile application and Caltrans's American Truck Parking website (americantruckparking.com). Building on these systems would reduce design costs and, by employing channels drivers already use, reduce drivers' need to download multiple applications and consult multiple websites.

3.3.3 Develop Guidelines and Standards

A barrier identified in this study was the lack of national consensus standards for information dissemination. This causes problems because each deploying organization has a different data format, and the differences impede information sharing across organizations.

USDOT can encourage stakeholders to set standards for electronically communicating information on availability. An analysis of the different methods for formatting and distributing parking availability should be performed. Based on the information gathered, a set of guidelines to be used by deployment organizations should be created. These guidelines will show new deployment organizations how their information should be formatted and deployed, enabling interconnectivity of systems across the Nation. Examples of different organizations setting up their own ad hoc standards for data are given below.

The MAASTO organization has already created a standardized data feed for member States to follow. This standard provides a uniform way of distributing the data across the region, simplifying the sharing of information with other users and allowing for a reliable sole source of valid information. This information can be used by third-party developers in their mobile applications or ELDs. This provides truck drivers with available parking information quickly and efficiently by using established information channels.

The I-95 Coalition and MAASTO are using different standards and formats for posting their data for electronic retrieval. Both methods use long established and well accepted internet communication protocols.

The regional Truck Parking Information Management System (TPIMS) Data Exchange for MAASTO provides an application programming interface (API) document that explains all of the data. A trusted partner can request a key to access the data stored in the exchange. This key

enables the trusted partner to request data through an HTTP RESTful (hypertext transfer protocol representational state transfer) convention. The exchange will return data in JSON (JavaScript Object Notation) format that is easily parsed by most high-level programming languages. The data in JSON format is text-based and readable by humans. Figure 4 is an example of the data for the dynamic public data feed in the State of Wisconsin. The data are available at https://transportal.cee.wisc.edu/TPIMS/dynamic; documentation is expected to be published by MAASTO.


```
[{"siteId":"WI00039IS0011300SRSTARE11","timeStamp":"2018-06-18T13:52:33Z",
"timeStampStatic":"2016-12-02T16:23:22Z","reportedAvailable":"50",
"trend":"STEADY","open":null,"trustData":null,"capacity":68},{"siteId":"WI0
0090IS0007400ERSTARE09", "timeStamp":"2018-06-20T19:23:05Z",
"timeStampStatic":"2016-11-07T02:04:08Z","reportedAvailable":"15",
"trend":"CLEARING","open":null,"trustData":null,"capacity":23},{"siteId":"W
I00094IS000430OE0000RA61","timeStamp":"2018-06-20T19:22:14Z",
"timeStampStatic":"2017-03-28T18:34:50Z","reportedAvailable":"7",
"trend":"STEADY","open":"true","trustData":"true","capacity":24},{"siteId":
"WI00094IS0012400ERSTARE53","timeStamp":"2018-06-20T19:23:05Z",
"timeStampStatic":"2016-12-01T17:22:15Z", "reportedAvailable":"32",
"trend":"FILLING","open":null,"trustData":null,"capacity":41}]
```


Figure 4. Text string. The TPIMS data feed.

Source: MAASTO

The Truck ‘n Park data feed provides real-time truck parking along the I-95 corridor. A user can register for access to the data through their website. The interface uses HTTP POST or GET, or SOAP (simple object access protocol). The data is returned when a request is made and is formatted in XML (extensible markup language). Like JSON, XML is a text-based format that can easily be parsed by most high-level languages and is human readable. All information to parse the data received can be found in the documentation for the data feed.

The Freight-Specific Dynamic Travel Planning service package in the National ITS Reference Architecture provides many pre-trip and en-route travel planning services for commercial vehicles. Services include truck parking locations and current statuses.[25] A high-level description of a SmartPark system is included.

An organization seeking ways to reduce implementation and O&M costs should consider reaching out to mobile application developers and device manufacturers to disseminate parking availability. Dissemination can be simplified and expanded to national scales if organizations standardize formatting and sharing. As more organizations decide to follow one data standard, effort and cost of implementation will decrease.

USDOT has a role in promoting freedom within limits. Through the Manual on Uniform Traffic Control Devices (MUTCD), it has already established a format for roadside signs. The Department should support stakeholders to generate analogous standards for electronically communicating information on parking availability.

Standards are essential for communicating information from one entity to another. They enable one contractor to install sensing equipment at a site and supply information to another contractor’s equipment at a traffic management center. Standards can also facilitate the

cooperation of two entities that cannot formally enter a joint agreement, as when private organizations access publicly available data.

3.4 ACCEPTANCE

Widespread deployment of SmartPark systems depends on deployment organizations and the trucking industry accepting it as an effective (if partial) solution to the truck parking problem. These entities need to be aware of current efforts, the benefits of SmartPark systems, and upcoming deployments.

3.4.1 Promote SmartPark Solutions Among State Organizations

The general lack of knowledge regarding the costs, benefits, and capabilities that SmartPark projects provide impedes wide deployment. Making sure that organizations fully understand how a SmartPark project works, and promoting nationwide use, is necessary to full deployment.

To this end, key information should be compiled and made available to State organizations as a way of encouraging State-level deployment of SmartPark solutions. Key information includes:

- Distinctions between different implementations.
- Different technology options.
- Different data dissemination methods.
- Total costs.
- Total benefits.

Access to this information would help deployment organizations choose an implementation that meets their needs. Upfront possession of this knowledge would also provide assurances that there are qualified people who can be contacted for guidance throughout the process. Clear understanding of SmartPark system's methods and benefits will help change the perception that funding is better spent on other safety initiatives.

USDOT should find ways to share relevant information with each State's department of transportation. Efforts should focus on demonstrating the importance of the truck parking issue, the viability of SmartPark systems as a vital part of the nationwide solution, and the availability of different types of funding.

USDOT also should find ways to distribute the information collected from all the previous SmartPark-related research, pilot projects, and deployment efforts to every State department of transportation in the Nation. Methods need to be created to make these organizations aware of the different funding sources available for this type of project and to ensure that every State recognizes that the truck parking problem is a nationwide issue that needs to be addressed.

3.4.2 Develop Market Pull

Market pull for SmartPark systems should come from the trucking industry, which includes truck drivers and fleets. Vendors of fleet management systems will include parking information in

their ELD and navigation systems if their carrier customers ask for it. Mobile application developers will also respond to customer demand. FMCSA can promote the benefits of SmartPark systems to fleets, and the regular course of customer-vendor relationships will encourage vendors to deploy solutions.

Promoting SmartPark systems to fleets involves explaining current efforts, upcoming deployments, and means of accessing SmartPark data. As drivers begin to interact with the system, they will come to understand the advantages of SmartPark systems and adopt it as an everyday tool. This day-to-day use of effective SmartPark systems will lead to acceptance and increased demand.

NCTP meetings, for all of their accomplishments, are attended mostly by Federal, State, and metropolitan planning organization representatives. FMCSA can play a role in increasing the involvement of other entities, like carriers and drivers, that need to engage with SmartPark systems and find ways to communicate.

Several surveys show that drivers are interested in SmartPark systems. These surveys have also collected information about how drivers understand their parking needs. ATRI's Research Advisory Committee surveyed truck drivers on their daily issues with truck parking.[17] A subsequent survey was performed as part of a Minnesota DOT project.[8] The Utah DOT surveyed truck drivers about their experiences with long-term truck parking and the possibility of a SmartPark system.[27] Following the Michigan DOT SmartPark system deployment project, the University of Michigan Transportation Research Institute surveyed drivers that had been in the Michigan DOT project and other drivers on the SmartPark system-equipped route.[11]

A common finding of the surveys was that locating parking is a problem truck drivers face every day. All surveys found that information on the location of parking facilities along with the number of available spaces would be valuable and increase productivity. Of the ATRI respondents, 36.5 percent reported that they parked in unauthorized locations three to four times per week. In the Utah survey, 82 percent of the drivers reported using ramps and shoulders at some time. Respondents to a survey in the Pacific Northwest reported that knowing the number of parking spaces available at upcoming locations would reduce their anxiety about finding parking.[29]

While 38 percent of surveyed drivers still relied on books and maps to locate parking, around 55 percent preferred websites or smartphones. Some drivers used their previous experience to locate parking, but when driving an unfamiliar route, they would often drive around looking for a vacant parking location or rely on other drivers' tips and suggestions. Some drove to the nearest industrial area and hoped to find a vacant lot.

The surveys indicate that drivers prefer to obtain parking availability information through a DMS. DMSs provide parking availability information, but only for locations located a few miles downstream of each sign. A DMS is therefore useful when the driver is nearing the end of a shift. Drivers reported that they found DMSs both clear and useful, more so than other sources. Drivers preferred that the DMS, or other interface, give an exact count of available spaces. Adjectives ("low" or "medium") and colors were less meaningful, and drivers wondered if the inexact indicators carried the same information in different states or different phone applications.

An ideal phone application would be able to identify the driver's location and provide directions and parking availability for nearby parking lots through a hands-free interface.

For short regional trips, selection of a potential parking locations is often made prior to the trip. This is not possible for long-haul trips, because factors like traffic, work zones, and other unexpected events prevent precise route timing. Instead, drivers start to look for a parking location a few hours before reaching HOS limits.

The surveys indicate that drivers would be willing to pay for a reserved spot only as a last resort.

Discontinuing an extant SmartPark system can harm drivers' perceptions of SmartPark systems. Confidence in a mobile app is lost if the driver realizes the information is not accurate. As a SmartPark project expires, services shut down, removing a source of information on which drivers have come to rely. This creates a sense of distrust. Truck drivers want reliability, accurate information, and consistency.

All this information indicates that in-cab consumption of data and drivers' needs are still not fully understood. Additional engagement, polling, surveying, and communication with carriers and drivers is needed. Outreach sessions in the form of webinars, coalition meetings, forums, and workshops will clarify how drivers want parking information and will promote buy-in for solutions.

3.4.3 Establish a Repository for Performance Data, Lessons Learned, and Results

As organizations implement a SmartPark solution in their region, access to lessons learned from past projects, methods, and results will be beneficial. This information will serve as a guideline for future projects. It will demonstrate the benefits of a SmartPark solution and mark a path for more successful implementations.

A knowledge database containing a comprehensive collection of reports, standards, lessons learned, and any measures of effectiveness of previous SmartPark projects should be established. Because interviews with key players in SmartPark projects have been valuable sources of information, current and past projects managers should be identified and contacted to contribute to this database. High priorities include measures of overall project performance, technological performance, and the efficacy of whichever means of data dissemination each project used. Methods for engaging the private corporations should also be documented, including any barriers and means of overcoming them. This knowledge database would share information among projects and connect current project managers to key players in current and past efforts. It would accelerate the deployment of SmartPark projects by creating a common source of information and promoting the effectiveness of the solution.

Data collection for the knowledge database must be robust and systematic. Some data will be difficult to obtain, but its collection is still necessary. Research topics include:

- How drivers most effectively receive data in their cabs.
- How well drivers accept these systems and what suggestions they have for improvement.
- Formal analysis of performance metrics of SmartPark systems, including reductions in unauthorized parking and congestion.
- Extent of economic benefits from improved freight flow.

The collected data would support project development from concept of operation and requirements through implementation. Because access to more information is a prerequisite for so many other elements of SmartPark system deployment, capturing data is one of the most important early goals. Decision making and performance evaluation both depend on data, and projects should be designed with data collection and performance metrics in mind.

4. PATH FORWARD

This section contains actionable recommendations that FMCSA and other entities can follow to accelerate the deployment of future SmartPark projects.

Decision-makers will likely come on board when they see that a SmartPark system is feasible and cost-effective. Checklists, how-to guides, and tutorials that come out of early projects will address fears that a SmartPark system is too complicated. Testimonials and performance metrics from these early projects will demonstrate that a SmartPark system is worth the effort.

Table 9 lists recommended actions and the barrier that each action addresses. Most actions are Federal. FHWA or FMCSA can carry out the work directly or organize responsible groups. Other actions will be carried out by States, perhaps with Federal guidance. The possible action durations are "short-term" (within 1 or 2 years), "intermediate" (between 2 and 4 years), "long-term" (beyond 4 years), and "ongoing" (currently underway). The right-hand column describes when each action should be initiated: "immediately" (within a year), "soon" (within 2 years), or "when possible" (within 3 years). Note that all State actions are marked as "when possible." This is because there is no Federal statute that mandates State actions regarding truck parking.

4.1 PUBLICIZE EARLY SUCCESSES

Enthusiasm for SmartPark systems will develop when benefits are known. The MAASTO project will collect performance data and deliver a formal benefit-cost analysis. But waiting years for the results of this project is not necessary. Most implementations already in place have been beneficial on a small scale. For example, State police have provided anecdotal reports of decreases in unauthorized shoulder parking where a SmartPark system has been implemented. By publicizing the success of these early efforts, USDOT can bring more decision-makers on board with SmartPark systems.

Awareness that SmartPark systems can be cost-effective will lead to buy-in. USDOT can publicize the information through venues like the Transportation Research Board (TRB), the Intelligent Transportation Systems Professional Capacity Building Program (ITS PCB), Talking Freight, and other forums.

Table 9. Recommended actions and associated barriers.

Action	Financial Barrier	Institutional Barrier	Technology Barrier	Acceptance Barrier	Responsibility	Duration	Start
4.1 Publicize Early Successes	--	--	--	P	Federal	Short-term	Soon
4.2 Start Projects Where the Potential Cost Benefit is Greatest	P	--	--	S	State	Intermediate	When possible
4.3 Start Small when Necessary and Grow	P	S	--	S	State	Intermediate	When possible
4.4 Promote Available Federal Grants	P	--	--	--	Federal	Ongoing	Immediately
4.5 Distribute How-To Guides	S	S	S	P	Federal	Short-term	Soon
4.6 Involve Private Parking Providers	--	P	--	--	State	Ongoing	When possible
4.7 Design a Modular System	--	S	P	--	Federal	Long-term	Soon
4.8 Establish Consensus on Data Formats	--	S	P	--	Federal	Intermediate	Immediately
4.9 Continue Researching the Needs of Truck Parking	--	--	P	--	Federal	Long-term	When possible

Notes:

P means the action primarily addresses this barrier.
S means the barrier is addressed as a secondary benefit of the action.
-- means the action does not apply to this barrier.

4.2 START PROJECTS WHERE THE POTENTIAL COST BENEFIT IS GREATEST

Successful implementations of SmartPark systems will win State attention. USDOT should identify locations where a SmartPark system would clearly be cost-beneficial and work to have systems installed there to create positive examples. Enthusiasm among decision-makers will increase when they recognize the potential of a SmartPark project. On the private industry side, when truck drivers experience tangible improvements, they will ask that truck stop operators and application developers expand the service.

4.2.1 Publicize Cost-Benefit and Other Performance Data from Early Adopters

Projects under current grants will produce performance measures and data that can inform the budgets of State transportation departments. The projections in the grant applications can be replaced with results, which are more persuasive to decision-makers. Program managers at FHWA and FMCSA who oversee grants should encourage States to present their analyses in ways that are comparable across States and in a format that supports budgetary analysis by any interested State.

Documented benefits should include all benefits realized by society, both directly financial and intangible. Public organizations operating with grant money will not be positioned to document financial benefits to private businesses, but they should endeavor to make any data available to truck stop owners so that owners can assess projects from their own perspectives. Within the constraints of the grants, organizations should also analyze how improvements in freight flow will affect the economy of their region.

States vary widely in freight flow, geography, and internal budget structure. Their ITS implementations may be vastly different. A benefit-cost analysis in one State is unlikely to be directly applicable to another, and transferring lessons from one region to another depends on accounting for these differences. Therefore, the analyses of current projects must be presented with enough detail to support analyses in other regions. This includes documenting the sources of all numbers, explaining every step in calculations, and clearly stating all assumptions.

Objective data will allow a SmartPark system's inclusion in State freight plans, where its costs and benefits can be compared with other needs and with programs intended to improve freight flow.

4.2.2 Seek Locations where the Opportunity is Good

Deployment should prioritize locations where a SmartPark system will be most effective, especially in the near-term. The Jason's Law survey currently underway will provide the data needed to identify corridors that could most benefit from a SmartPark system. Using these data will eliminate the need to wait for completion of current SmartPark projects.

The ongoing survey asks which locations are instrumented to assess availability. The results may show that a SmartPark project already in progress could be enhanced by adding SmartPark system support to nearby locations with unusually high or low availability. These small-effort, high-value improvements to existing projects are near-term opportunities which could quickly produce results for program promotion.

The survey results may also show a corridor that could benefit from a SmartPark system where no project is currently planned. USDOT should work with local transportation agencies and parking owners to implement SmartPark systems suitable to those locations. Such a project would take years from identification through planning to commissioning and would therefore not provide immediate results.

4.3 START SMALL WHEN NECESSARY AND GROW

A SmartPark project requires multiple parties to come together to create a customized solution based on cost, schedule, and technology. The MAASTO project is demonstrating how several adjacent States can work together to establish a system spanning hundreds of miles. But a SmartPark system does not need to be this large to be useful, and even modest or local benefits can provide valuable selling points.

A smaller project with lower capital cost (one that uses video entry and exit monitors with periodic manual updates) would get a system running quickly and inexpensively. Purely manual systems (information from a site attendant or crowd sourced by drivers themselves) would cost even less, but their timeliness and reliability have yet to be proven.

Some capacity additions are simple, such as pouring gravel adjacent to an existing truck stop. The same approach of adding capacity can be taken for a SmartPark system. Entry-exit and crowd-sourced counting are more appropriate for unpaved lots than in-ground occupancy detectors.

Some stakeholders have informally reported tangible benefits systems spanning only part of a route across a State. The intention has been to start with a project of manageable size and to grow it as budget and experience allow. Relieving congestion at one or two locations by diverting traffic to adjacent locations is a tangible improvement, one that will be appreciated by drivers and noticed by higher-level decision-makers.

4.4 PROMOTE AVAILABLE FEDERAL GRANTS

FHWA and FMCSA can publicize current grant programs that provide capital funding. Deploying organizations may not be fully aware of the available funding programs or how to apply. When a deploying organization has a complete picture of the funding options available, it can design a SmartPark system that complies with grant requirements. The designing process also helps to identify other funding needs.

The FHWA has several funding programs that State DOTs can apply to SmartPark projects:

- Highway Safety Improvement Program.
- National Highway Freight Improvement Program.
- National Highway Performance Program.
- Surface Transportation Block Grant Program.

In addition, there are grant programs such as Better Utilizing Investments to Leverage Development (BUILD) and Infrastructure for Building America (INFRA).

FMSCA also has the HP-ITD grant program that can be used for the O&M piece of SmartPark projects, in addition to the design and implementation stages.

4.5 DISTRIBUTE HOW-TO GUIDES

Over the years, SmartPark systems have seen research and pilot and functional implementation projects. New deployment organizations would benefit from a how-to guide based on these experiences. Advantages to capturing lessons from previous project lifecycles include reduced delays and costs, increased productivity, and clearer visions of both technological and organizational aspects of the project.

Variations between regions are to be expected, but they do not diminish the usefulness of a well done how-to guide. Each project has diverse needs according to its budget and organizational structure, and sensing technology that performs effectively in one location may not suit others. Effective ways of disseminating truck parking information in one region might be cost-prohibitive in others. Some organizations might have methods to minimize organizational and political obstacles where others have not been able to identify solutions. The variety of circumstances, though, does not eliminate the value of a how-to guide, especially if, as described in Chapter 4.2.1, the how-to guide and supporting database account for regional differences. Accounts of past experience, along with cost and performance metrics, would allow an organization to simplify its processes and minimize costs.

Information is currently dispersed across the various reports and websites provided by different organizations. Some of this information is outdated and does not represent the actual state of the project. Other information is not publicly available. An effort should be made to create a general repository of SmartPark project information that presents costs (capital and O&M), economic benefits, safety benefits, and implementation information such as:

- Budget creation.
- Project management.
- Project organizational structure.
- Methods to facilitate public-private partnerships.
- SmartPark project site selection.
- Sensing technology performance, characteristics and limitations.
- Dissemination technology performance, characteristics and limitations.
- Lessons learned.

Forums and workshops will also be critical to educating potential projects leaders about common obstacles and ways to overcome them. Written workshop materials can take the form of guides, presentations, webinars, reports, and other media. In addition, contracts, MOUs, legal

documentation, and organizational structures can be shared with other participants. With this information, the next project will have more information and be better prepared than its predecessor.

Pilots are valuable for the first implementation of new ideas. Communities of regional or corridor State DOTs deploying SmartPark systems could be established to share practical knowledge gained during pilots.

4.6 INVOLVE PRIVATE PARKING PROVIDERS

Because most of the Nation's parking is privately owned, a comprehensive and functional system must include directions to private parking areas. The private sector can profit directly from truck traffic. Private entities can make a viable business case more readily than can public agencies, whose benefits of improved safety and better freight flow are desirable but difficult to tie quantitatively to parking systems. Federal engagement with NATSO and with the major truck stop chains will make it easier for States to invite private owners to participate in SmartPark systems.

However, buy-in by private entities is not assured. Some private truck stop owners consider their parking availability data to be part of their proprietary business records. Applications with crowd sourced data regard their data as their intellectual property. Even so, some private property owners have agreed to have their availability data disseminated by outside parties and some have agreed to let their property be instrumented. Developing trust at the personal level as well as the institutional scale has been vital in reaching agreements for private involvement. Details pertaining to these early (successful) agreements and how they have led to improvement in truck stop business should be publicized to assuage the concerns of other owners. Where they fail, parties should take the time to record the lessons learned.

There are several steps that can be taken to encourage private participation:

- Work with private truck stop owners to inform them of drivers' inability to find parking in their vicinity.
- Provide private entities with the business case for participation.
- Encourage local governments through outreach and training to incorporate truck parking and planning into strategies.
- Convene in-person meetings of government and private parties, perhaps through an independent entity, to establish relationships and understanding.

4.7 DESIGN A MODULAR SYSTEM

A viable SmartPark system should use modular components. If a system uses well-defined interfaces to connect its components, then the individual components can be replaced without disrupting the overall system. Modularity enables installations to begin small and then grow. A State might begin with a system that includes only one or two parking locations. As its budget

allows and its needs grow, the system can be expanded. New parking facilities can be brought online as SmartPark systems mature. Existing sites may be reconfigured or removed temporarily or permanently.

The concept of modularity applies to several aspects of a SmartPark system:

- **Technology:** States or private parking operators will have their own criteria for selecting sensor instrumentation. Considerations will include climate, expected hardware lifetime, and the mix of truck and non-truck vehicles using the location. Data from multiple sensors may be aggregated on-site and transmitted as a count through a communication channel. At the other end of the system, applications designed by diverse providers need to collect processed data through a query of a State 511 website or a truck stop provider website. In other words, a set of common standards is necessary to allow communication between the different sensors, communication channels, and means of driver access. A modular design will let equipment suit local needs and business practices. It will also allow technology upgrades without disruption of service. Clear standards for communicating between parking locations and data processing centers, and between and processing centers and dissemination channels, provide modularity and enable interoperability throughout a nationwide system.
- **State laws, culture, and existing ITS infrastructure:** Each State has its own laws and ways of organizing its transportation or highway department. Each has developed a system of traffic management centers using different contractors with their own designs. States vary in their means and sophistication of disseminating traffic information. The scheme for implementing SmartPark systems nationwide must be flexible enough to allow new States to adapt it to their unique practices without compromising the whole system.
- **Dissemination channels:** Many methods for disseminating information to drivers are in use, and more are sure to be developed. Data must be served in a manner that follows common technical standards so that it is readily available to all. Too many different formats will slow innovation.
- **Varying reservation rules:** Some sites will accept reservations. There will be many differences in how reservations are handled and paid. For example, some will be paid for individually by the driver, some will be paid for by the carrier on a per-use basis, and some will be paid for through a blanket contract with the carrier. All communication systems that impact reservation need the flexibility to accommodate these and other differences.

4.8 ESTABLISH CONSENSUS ON DATA FORMATS

SmartPark systems are about getting information from one point to another. The sender and receiver of the information need to agree on a format. The need for agreement grows with the number of senders or receivers.

Ongoing SmartPark projects have differing approaches for transmitting data. Two prominent data sources are Park My Truck and American Truck Parking. In the short term, a reference guide would help mitigate the fragmentation issue that forces drivers to consult many sources.

Parking availability data is being shared electronically today, so *de facto* standards exist. States are posting the data electronically for anyone to collect and disseminate. All MAASTO States post data using the same format, and Colorado also uses the MAASTO format. The I-95 Coalition is pushing data to Park My Truck and uses the accompanying format. Given the existence of experience with these formats, FMCSA can support collaboration between providers and users of the data to determine whether the standards need to be revised for workability or enhanced for future capability. The development of a formal standard will ensure that minor details are addressed and that new participants have an authoritative reference.

Standards for delivering data to drivers must consider human factors. These factors may impact different communication channels differently. Signs, for example, should be uniform. The MUTCD governs some sign characteristics but does not standardize how parking information is conveyed. Drivers who have passed several signs with an exact count of available spaces do not know how to interpret a sign with a word (e.g., "available," "limited," or "none") instead. Consistency across State lines is the best way to provide unambiguous information. In the case of smartphone applications, however, drivers might try several alternatives and choose a favorite. In this case, ensuring common formats for outgoing data rather than uniform displays across all applications is the key consideration. As long as applications have access to nationwide information, the market can solve for diverse tastes in display styles.

4.9 CONTINUE RESEARCHING THE NEEDS OF TRUCK PARKING

More research related to truck parking needs to be conducted. Several topics that need to be understood are listed below:

- **Forecasting when a parking lot will fill up.** Tennessee considered a model for this but did not have the opportunity to create one. Florida has begun to collect data to develop a forecasting model, and a model of the daily fluctuations in occupancy has been applied to forecasting on I-5 in California.[28] Data from existing truck parking areas will enable models to be developed and tested.
- **Improving sensing technology.** Video can be less expensive to install if mounting posts are favorably located, but it has yet to prove itself in all conditions.
- **Public monitoring of how capacity is used.** Public agencies will have an ongoing role in monitoring the fraction of capacity that is used. Hard data confirming that parking is regularly filled to capacity would help justify decisions to open more parking. As SmartPark systems mature, they will become a means of quantifying parking needs.
- **Understanding the ways drivers use the data and their preferences for receiving data.** The MAASTO States are presenting availability data to drivers in slightly different formats. This creates a research opportunity to ask the drivers which format they find most useful.

REFERENCES

1. Federal Motor Carrier Safety Administration. “Interstate Truck Driver’s Guide to Hours of Service.” (October 2016)
2. Shirk, Alexandra; Murray, Dan. “Kansas Truck Parking Survey Analysis.” Kansas Department of Transportation. (September 2016)
3. J.B. Hunt. “660 Minutes: How Improving Driver Efficiency Increases Capacity.” (2015)
4. Garber, Nicholas J; Teng, Hualiang; Lu, Yuan. “A Proposed Methodology for Implementing and Evaluating a Truck Parking Information System.” U.S. Department of Transportation. (2004)
5. Federal Motor Carrier Safety Administration. “Hours of Service of Drivers of Commercial Motor Vehicles: Regulatory Guidance Concerning the Use of a Commercial Motor Vehicle for Personal Conveyance.” 83 FR 26377. (June 7, 2018)
6. Pennsylvania Turnpike. “Truck Parking Management System: Concept of Operations.” (May 30, 2018)
7. UC Regents and ITS/TSRC. “American Truck Parking” (2018). Available from: http://www.americantruckparking.com/about-us
8. Morris, T., Vassilios, M., Nikolaos., P., Doug, C., Dan, M., Katie, F., & Weber, A. “A Comprehensive System for Assessing Truck Parking Availability.” (2017) http://www.dot.state.mn.us/ofrw/PDF/assessing-truck-parking.pdf
9. Colorado Department of Transportation. “Colorado Truck Parking Information Management System.” (2016)
10. Tucker, M., Frost, J. and Toth, C. “FDOT Launches Truck Parking Availability System (TPAS)” (2016)
11. Woodrooffe, J., Blower, D., and Sullivan J. “Evaluation of MDOT Truck Parking Information and Management System.” University of Michigan Transportation Research Institute. (2016)
12. I-95 Corridor Coalition. “Truck’npark: The I-95 Commercial Truck Parking System” (2017). Available from: http://www.i95truckparking.com/tnp/Home.aspx.
13. Mid America Association of State Transportation Officials “Project Details.” (2017) Available from: http://trucksparkhere.com/projectdetails/
14. Randall, H., “Wisconsin Truck Parking Project.” Wisconsin Department of Transportation: ITS Wisconsin. (2015)
15. Kwan, Q. “FMCSA’s SmartPark – Phase 2.” FMCSA: ITS America 25th Annual Meeting. (June 2, 2015)
16. Fallon, J., Howard, K. “SmartPark Truck Parking Availability System: Magnetometer Technology Field Operational Test Results” RRT-10-041. Federal Motor Carrier Association (January 2011). Available from: https://rosap.ntl.bts.gov/view/dot/103

17. Boris, C., Brewster, R.M. “Managing Critical Truck Parking Case Study- Real World Insights from Truck Parking Diaries” American Transportation Research Institute, (December 2016)

18. López-Jacobs, V. “SmartPark Technology Demonstration Project, Phase II: Final Report.” RRT-16-024. Federal Motor Carrier Safety Administration (May 2018). Available from: https://rosap.ntl.bts.gov/view/dot/35959

19. Federal Highway Administration. “Jason's Law Truck Parking Survey Results and Comparative Analysis.” (2015)

20. The National Council for Public-Private Partnerships. “State Legislation.” Available from: https://www.ncppp.org/resources/research-information/state-legislation/

21. U.S. Department of Transportation. “Early Involvement of Private Developers in the Consideration of Long-Term Public-Private Partnership Concession Options: A Discussion Paper” FHWA-HIN-007 (February 2017)

22. Federal Transit Administration. “Private Investment Project Procedures.” 2018-11385 (June 6, 2018)

23. U.S. Department of Transportation. “Public-Private Partnerships.” Available from: https://www.transportation.gov/buildamerica/programs-services/p3

24. Mays, Wesley M., and Glasmann, Richard. “Vehicle Parking System.” U.S. Patent 9,810,542. November 7, 2017.

25. United States Department of Transportation. “ARC-IT Version 8.1- The National ITS Reference Architecture” CVO09: Freight-Specific Dynamic Travel Planning. Available from: https://local.iteris.com/arc-it/html/servicepackages/sp32.html#tab-3

26. CityLabs, Capps, Kriston. “How local governments came to embrace business partnerships.” Available from: https://www.citylab.com/solutions/2017/11/local-governments-partner-with-business/542487/

27. Utah Department of Transportation. “Utah Interstate 15 Truck Parking Study. Draft.” (August 7, 2012)

28. Sadek, Bassel., Martin, Elliot., and Shaheen, Susan. “Truck Parking Forecasting and Error Correction Using a Fourier Method: A Case Study of the I-5 in California.” Paper Number 18-06736. TRB Annual Meeting, Washington, January 8, 2018.

29. Anderson, Jason C., Hernandez, Salvador., Jessup, Eric L. and North, Eric. “Perceived safe and adequate truck parking: A random parameters binary logit analysis of truck driver opinions in the Pacific Northwest” International Journal of Transportation Science and Technology, *7*(1), 89-102. (March 2018) Retrieved from https://www.sciencedirect.com/science/article/pii/S204604301730076X