Nationwide Electronic Toll Collection Interoperability

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U.S. Department of Transportation
Federal Highway Administration

FOREWORD

The Federal Highway Administration (FHWA) authorized a research and synthesis study to document the progress and direction toward achieving nationwide toll interoperability. This report employs the results of that study, and identifies current efforts toward nationwide interoperability, challenges to overcome, near-term trajectory of achieving nationwide toll interoperability, and the potential for emerging technologies and business models to influence achieving the goal.

The report is intended to inform U.S. Department of Transportation (USDOT) and FHWA leadership and staff, as well as Congressional staff, about the status and potential future direction of nationwide toll interoperability. It is also intended to serve as a resource to public- and private-sector toll agencies, State and local transportation agencies, technology providers, vendors, and other stakeholders in the tolling industry.

Martin Knopp
Associate Administrator, Office of Operations

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16. Abstract In 2019, the Federal Highway Administration (FHWA) authorized a research and synthesis study to document the progress and direction toward achieving nationwide electronic toll collection (ETC) interoperability. This report discusses the results of that study and identifies current efforts toward nationwide interoperability, challenges to overcome, near-term trajectory of achieving nationwide toll interoperability, and the potential for emerging technologies and business models to influence achieving national ETC interoperability.		
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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 yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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LIST OF ACRONYMS

3G	third generation
4G	fourth generation
5G	fifth generation
AET	all-electronic tolling
ALPR	automatic license plate recognition
ANTT	Brazilian National Agency for Terrestrial Transportation
ATI	Alliance for Tolling Interoperability
AVC	automatic vehicle classification
AVI	automatic vehicle identification
CFX	Central Florida Expressway Authority
CSC	customer service center
CTOC	California Toll agencies Council
CUSIOP	Central United States Interoperability
CV	connected vehicle
C–V2X	cellular vehicle-to-everything
DMV	department of motor vehicles
DOT	department of transportation
DSRC	dedicated short-range communication
EETS	European Electronic Toll Service
ETC	electronic toll collection
EU	European Union
FAST	Fixing America's Surface Transportation Act
FHWA	Federal Highway Administration
GPS	global positioning system
HGS	Fast Passing System
HOT	high-occupancy toll
IAG	Interagency Group
IBTTA	International Bridge, Tunnel and Turnpike Association
ICD	interface control document
ISO	International Standards Organization
ITM	integrated toll module
km	kilometer
LTE	long term evolution
MaaS	mobility-as-a-service
MAP–21	Moving Ahead for Progress in the 21st Century Act
MHz	megahertz
MOU	memorandum of understanding
NCTA	North Carolina Turnpike Authority
OBE	onboard equipment
OBU	onboard unit
ORT	open road tolling
REETS	Regional EETS
RFID	radio frequency identification
SAE	Society of Automotive Engineers

SHC	Street and Highway Code
SINIAV	Sistema Nacional de Identificação Automática de Veículos
SRTA	State Road and Tollway Authority
TBP	toll-by-plate
TCA	Transportation Corridor Agencies
TDM	time domain multiplexing
TVL	tag validation list
USDOT	U.S. Department of Transportation
V2X	vehicle-to-everything
VES	violation enforcement system
WSDOT	Washington State Department of Transportation

EXECUTIVE SUMMARY

In the United States, toll facilities are located in about 35 States and generate more than $18 billion in revenue each year. There are more than 180 different toll agencies, State departments of transportation (DOTs), turnpike authorities, and private entities that operate toll facilities in the Nation. Before 1989, customers paid their tolls with cash at toll booths. Since 1989, advances in electronic toll collection (ETC) have enabled customers to pay tolls electronically using an account linked to a vehicle transponder or vehicle license plate, or both. Currently, more than 86 million devices that enable ETC transactions are in operation on U.S. roads.[1] As ETC technology improves and becomes more widely deployed, the percentage of tolls collected in cash has decreased. Cash collections declined from 29 percent of all tolls collected in 2010 to 18 percent of all tolls collected in 2015.[2] With wider deployment of ETC as the primary collection mechanism, interoperability of systems among jurisdictions comes into sharp focus.

ELECTRONIC TOLL COLLECTION INTEROPERABILITY ISSUES

An ETC system comprises two main elements: the roadside system and the back-office system. Managing these two ETC elements is the central challenge of interoperability. Table 1 summarizes the primary functions and key issues associated with each component.

Table 1. Primary functions and key interoperability issues associated with electronic toll collection (ETC) systems.

	Primary Function	Key Interoperability Issue
Roadside System	• Identify vehicles to match to toll accounts: vehicles are identified through vehicle-mounted transponders communicating with roadside readers or with automatic license plate recognition (ALPR) cameras that capture license plates. • Identify ETC customer accounts and create toll transactions for their trips using transponder or license plate information.	• Different single protocol technologies[3] used to communicate between transponders and roadside readers: when ETC was first deployed, toll facilities procured ETC systems from different technology vendors because there was no pre-existing national technology standard or protocols governing transponder technology. • No means to capture license plates: without violation enforcement cameras, some toll agencies cannot capture license plates of ETC customers who do not use transponders, or those whose transponders use different protocols.

[1] See chapter 4, section titled *The Search for A Single National Protocol* of this report for back-up calculation.

[2] International Bridge, Tunnel and Turnpike Association. (2016). Toll Technology Transforms Mobility for Customers: 2016 National Toll Technology Survey.

[3] A single-protocol technology is defined as an electronic toll system designed to recognize and operate with transponder devices using a single specific data transfer protocol. By definition, such a technology is not interoperable with a system using a different data transfer protocol.

Table 1. Primary functions and key interoperability issues associated with electronic toll collection systems. (continuation)

	Primary Function	Key Interoperability Issue
Back-Office System	• Process customer transactions and payments and interface with toll customers. • Communicate with other systems if a customer's account is held by a different agency: back offices exchange transaction information with the interoperable agency's back office and settles payments. • Process violations: if there is no account associated with a vehicle, the back-office initiates violation processing to identify the registered owner, via the license plate, and send a bill or violation notice.	• Inability to exchange information: toll agencies' back-office systems are not connected, effectively preventing account holders from electronically paying tolls in neighboring jurisdictions. For example, toll agencies in Texas or the southeastern United States cannot identify toll road accounts from the northeastern United States. • Inability to exchange payments: accounting and payment processes and systems are not interconnected to enable agencies to exchange payments.

Legislation related to ETC interoperability in Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA–LU),[4] and the subsequent Moving Ahead for Progress in the 21st Century Act (MAP–21)[5] with regard to ETC interoperability, prompted action by the U.S. tolling industry. Through groups like the International Bridge, Tunnel and Turnpike Association (IBTTA), the industry has devoted considerable effort to formulating a conceptual framework for achieving nationwide toll interoperability. The toll industry and its agencies sought to solve the challenge of interoperability, and worked to deliver solutions that enable:

- Toll agencies and customers to use common technologies to cross tolling boundaries nationwide and within a region
- Customers to use their toll accounts seamlessly
- Cost-effective financial reconciliation among toll agencies

This study outlines the current state of interoperability in the toll industry; challenges of achieving interoperability; steps taken to expand interoperability; and potential implications of future technologies, business models, and systems on tolling interoperability. This study**, which was researched and reflects developments as of February 2021,** outlines the state of interoperability in the toll industry; challenges of achieving interoperability; steps taken to expand interoperability; and potential implications of future technologies, business models, and systems on tolling interoperability.

[4] Pub L. No. 109-59
[5] Pub. L. No. 112-141

INTEROPERABILITY APPROACHES

The U.S. toll industry has used the following approaches to address technology, financial, institutional, and communications challenges of achieving nationwide toll interoperability:

- **Approach 1: regional hub-based interoperability** – The tolling industry's dominant approach to nationwide interoperability. It leverages the existing networks of tolling interoperability among toll agencies and uses transponders and license plate technologies to exchange information through regional clearinghouses (i.e., regional hubs) to connect toll agencies in different regions.

- **Approach 2: third-party payment providers** – Private-sector alternative to providing nationwide interoperability. Private firms have accounts and business arrangements with multiple toll agencies to issue transponders or register license plates to offer consolidated tolling services to their customers. Their customers have one account while these third-party payment providers handle transaction and payments with multiple toll agencies.

- **Approach 3: national interoperability clearinghouse** – Led by the Alliance for Tolling Interoperability (ATI), this approach focused on creating a centralized clearinghouse to exchange toll information among toll agencies, starting with license plates and eventually transponders. ATI was formerly a private organization formed by toll operators to promote and implement interstate interoperability for the benefit of member agencies and their customers. Since 2020, it has been rebranded as Alliance for Tolling Innovations. After achieving initial success through pilots, this approach was discontinued in 2019, with toll agencies gravitating to approach 1.

> The path forward involves four regional hubs that will provide the backbone to store and transmit the data needed to support interoperability.... [this path builds on] existing governance models and establishes new ones more related to customer patterns and minimizing transaction flows across regions through an exception process model.
>
> ~ Samuel Johnson, Chief Executive Director, Transportation Corridor Agencies (TCA); 2020 IBTTA President

CURRENT INDUSTRY APPROACH: REGIONAL HUBS

By 2017, the U.S. toll industry had implemented a hub-to-hub approach to nationwide toll interoperability. The industry selected this approach based on developments in technologies and processes to overcome roadside and back-office challenges associated with interoperability.

Roadside Systems. Much of the initial efforts in achieving nationwide toll interoperability focused on identifying a single national ETC protocol. After extensive testing and opening of proprietary protocols, this effort was abandoned, as it did not result in identifying a single superior protocol. Instead of a single national transponder protocol, three protocols emerged that met the necessary technical standards supported by agencies in the toll industry: time domain multiplexing (TDM), Super eGo® (SeGo), and the International Organization for Standardization (ISO) 18000-63 (commonly known as 6C). A key aspect of toll agencies accepting the three protocols

is that a combination of tolling technologies has significantly improved in recent years to provide toll agencies cost-effective, accurate, and reliable methods for identifying ETC customers.

Some of these trends in roadside system technologies are described below:

- **Multiprotocol readers –** Wider implementation of readers that can read two protocols, and recent introduction of readers that can read three protocols. Multiprotocol readers can simultaneously and accurately read the major protocols in use. This allows agencies to read transponders that use any of the three leading national protocols in use in the future. Several toll agencies in the Nation have indicated plans to have multiprotocol readers installed over the next 1–3 years.[6]

- **Automatic license plate recognition (ALPR) –** Wider implementation of ALPR, as more agencies convert from gated toll plazas to open road tolling (ORT) and all-electronic tolling (AET) toll facilities, gives agencies the option to identify vehicles using license plate images instead of transponder reading. Thus, the problem of identifying vehicles from outside a local interoperable region can be solved without installing multiprotocol readers.

- **Multiprotocol transponders –** Development of transponders with the ability to communicate using multiple protocols. Over the past few years, some agencies have offered customers enrolled in ETC tolling programs multiprotocol transponders as an option.

- **A single de facto protocol –** Rise in adoption of a protocol that provides comparable performance to existing protocols at a lower cost. This is being witnessed in the rise in adoption of the 6C protocol. Although it has a smaller installed base of distributed transponders nationally, it is fast becoming the cost-effective choice.[7] The 6C sticker transponders cost less than $1 dollar, enabling toll agencies to make the business case that the cost of transitioning to 6C will be quickly recouped and reap millions in savings over the long term.[8] Although toll agencies still have a large installed base of their respective protocols, in the long term, 6C's cost competitiveness and proven technology could become the de facto protocol of choice nationwide, due to market forces.

- **Back Office Systems –** Hub-to-hub interoperability structure creates a new national peer-to-peer network among regional back-office clearinghouses (hubs). This enables exchanging data and transactions, while allowing regions to continue using their current interoperable networks in their regions. In 2019, a regional hub working group published a set of business rules and interface control document (ICD) specifications for regional

[6] According to input received from the toll agencies' peer exchange/listening session, April 1–2, 2020.

[7] The 6C coalition Annual Meeting in April 2020 included a presentation on 6C statistics noting a 116 percent increase in number of active 6C tags between 2016 and 2019 and expansion from 10 to 22 operators during the same period.

[8] IBTTA, North American Toll Interoperability. Available at: https://www.ibtta.org/sites/default/files/Interoperabiity%20Background-1.pdf.

hub use.[9] These documents describe how regional hubs will exchange toll transactions, customer transponder and license plate information, and settlement payments among interoperable toll agencies.

Regional hub interoperability is established by four major toll interoperability regions (or hubs) in the United States coming together, as shown in figure 1:

- E-ZPass® region (northeast United States and the Midwest)
- Southeast region (Florida, Georgia, South Carolina, and Alabama)
- Central United States Interoperability (CUSIOP) region (Texas, Oklahoma, Kansas, Colorado, and Louisiana)
- Western region (California, Oregon, Washington, and Utah)

Both the southeast and western regions are working with CUSIOP to connect their respective hubs in 2021, while E-ZPass® will develop and connect its regional hub in 2023. As more toll agencies decide to become nationally interoperable, they will connect to one of these regional hubs as a member of an interoperability region.

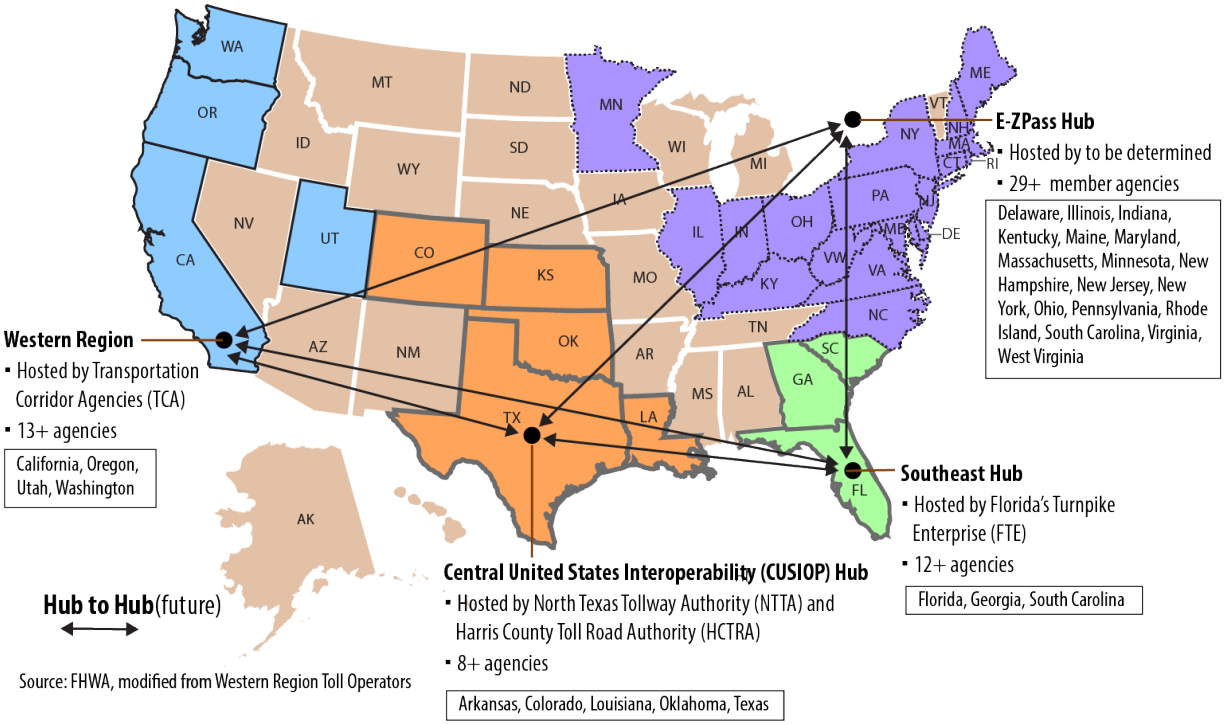


Figure 1. Illustration. Four regional interoperability hubs.

Challenges to Interoperability through Regional Hubs

The current trajectory suggests that nationwide toll interoperability will likely be achieved within the next 2–3 years. This period would include the time needed for agencies to acquire

[9] Business Rules for National Interoperability Version 1.01 (2019). Available at: https://www.ibtta.org/ibtta-interoperability-committee-iop.

technology, reconcile remaining business rules, establish four regional hubs, and eventually initiate hub-to-hub transaction and revenue exchange. However, the following challenges would need to be resolved:

- **Business rules** – Agencies have different policies and processes, such as time limits on processing, rules for handling disputes, and limitations on types of information that can be included in interagency transactions. The interoperability regions have made progress on harmonizing some of these differences; however, these changes in business rules would need to be ratified with interagency agreements to support interoperability.

- **Adapting to a hub model** – Expanding interoperability to every agency involves adapting and connecting hubs to the existing interoperable methods tolling regions use. Should the tolling industry move towards a national hub-based model, the tolling regions with peer-to-peer connections would need to develop new hubs.

- **Business case** – Per discussions with toll authorities, there remains some question as to whether every individual toll agency in the United States will participate in the hub-based system. The key question is if there is a sufficient business case for nationwide interoperability, especially as it relates to small toll agencies in more isolated areas. While there is considerable interregional travel between the E-ZPass® region and southeast region, less frequent interregional travel occurs between, for instance, the E-ZPass® region and the western region. Some smaller agencies may not be able to make a business case to justify the costs associated with establishing interregional, hub-to-hub transfers of data and revenue.

- **Legal implications** – The combination of new technologies to identify customers on toll facilities and new payment methods raises new legal hurdles for nationwide interoperability. Privacy laws and regulations at the Federal, State, and local levels could preclude using certain technologies and the exchange of information for interoperability. This could create a patchwork of adoption and unravel universal acceptance. For instance, exemptions on exchanging personal identifiable information, typically extended to public toll agencies, may not apply to third-party payment services. Consumer protection laws and data retention regulations are other legal issues current interoperability schemes address that may need to be reevaluated in the future. Beyond laws and regulations, several existing tolling agreements and their terms, such as revenue bond covenants, may not have been structured to anticipate new tolling technologies and payment methods.

- **Customer communications** – As more payment channels are developed and incorporated for toll payments, the ability of toll agencies to communicate with interoperable customers becomes even more challenging. For example, express lane toll agencies have varying business rules for occupancy levels for free or discounted toll trips. Conveying tolling rules and notices to customers in a timely fashion becomes a challenge if the responsibility and methods for informing the ultimate toll customer on the roadway are not clearly defined. Signage and customer agreements are being developed to simplify communications for near-term interoperability.

THIRD-PARTY PAYMENT SERVICE INTEROPERABILITY

Several new third-party payment services have emerged, which provide parallel alternative methods of achieving nationwide toll interoperability. These services offer their clients (toll customers) alternative payment and account management mechanisms and provide payment guarantees to tolling agencies. The most prominent customers are commercial fleet owners and rental car companies—toll customers with a high volume of toll transactions or significant travel across jurisdictions. The cornerstone of third-party payment services is the guarantee of payment to toll agencies that accept the tolling services. When a vehicle enrolled in a particular tolling service passes through a tolling point, the toll charge is electronically billed to the service provider, which guarantees payment to the toll agency. The toll charge is then applied to the individual customer account. Interoperability is, thus, effectively achieved through third-party payment services as they are accepted at many toll agencies. This approach reduces agency-to-agency transfer of transaction data and payment reconciliation. The guarantee of payment also helps address the challenges of out-of-state billing and violations processing. Because tolling agencies are guaranteed payment, they can reduce revenue leakage and improve efficiency of collections for toll agencies. Some key trends among third-party payment service providers are described below:

- In addition to tolling-related services, third-party payment services also provide specialized account data and accelerated release of transaction to their customers.
- In recent years, third-party payment services have emerged that target less frequent drivers, or other niche customer categories.
- Many third-party payment services provide vehicle identification technology—either transponder devices or global positioning system (GPS)-based applications—and offer enhanced account management services or other benefits, such as route guidance services.
- Several new in-vehicle technologies rely on third-party payment services. For example, the three open protocols (TDM, SeGo, 6C) largely in use across the U.S., have enabled development of multiprotocol transponders that incorporate all three technologies. These transponders are beginning to be built into select vehicles at the assembly line (typically within the rearview mirror). Referred to as integrated transponder modules (ITM), the built-in transponders rely on third-party account management, because the transponders are not issued by an individual toll agency.

However, third-party payment services are likely to remain a niche service in the tolling ecosystem for the foreseeable future. Today, even with several third-party payment services, electronic tolls are largely collected using agency-issued transponders. Future emerging changes in mobility services and payment mechanisms may gradually alter the toll collection business model from customers largely being served by agencies to exclusively being served by third-party providers.

ALTERNATIVE TECHNOLOGIES AND BUSINESS MODELS THAT MAY IMPACT THE HUB-BASED INTEROPERABILITY MODEL

In the future, several changes in electronic payment systems, vehicle and account identification technologies, and approaches to assess and collect transportation revenues could alter the toll

collection approaches of today. Based on research, interviews, and peer exchanges conducted as part of this study, three potential alternative scenarios have implications for tolling interoperability in the United States over the long term:

- **Alternative scenario 1:** Built-in vehicle technology supersedes radio frequency identification (RFID) technology that is currently implemented through agency-provided transponder tags. Connected vehicle (CV) technology, or another approach employing onboard telematics, is a candidate for this alternative scenario.

- **Alternative scenario 2:** Smartphone applications that support toll payments could supersede RFID technology because of the high availability and customer-friendly interfaces of smartphones.

- **Alternative scenario 3:** Comprehensive road usage charging policy that subsumes tolling, congestion charging, and other roadway pricing policies and programs could render tolling, as a separate and distinct pricing mechanism, obsolete.

While these scenarios may not have an imminent impact on the current trajectory of ETC interoperability, they may have potentially serious implications in the medium to long term for how tolls are collected across the country, and thus, how nationwide interoperability is eventually achieved. Toll industry stakeholders have already begun to contend with some of these developments.

Challenges Associated with Alternative Technologies and Business Models

Technical Interoperability

As vehicle and customer identification technologies broaden beyond transponders and license plate readers, toll agencies must decide whether to invest in these new technologies to maintain interoperability. Just as toll agencies today may wrestle with adopting a new transponder protocol, toll agencies in the future may be balancing the cost, timing, and return on investment of adopting new vehicle and customer identification technologies. As toll agencies decide whether to accommodate new toll collection methods, nationwide toll interoperability achieved with transponders and license plate readers will evolve, and may provide opportunities that expand ETC.

Exchanging Payments

With the rise of new transportation payment mechanisms, toll agencies benefit from potentially less expensive methods for identifying and collecting payments from customers. These new transportation payment methods shift ownership and responsibility of customer accounts from local toll agencies to third-party payment services. Therefore, to maintain interoperability, toll agencies will need to establish new system interfaces for these new payment sources. Ideally, open data exchange standards would be more cost-effective than developing customized and proprietary methods for accommodating new payment sources. Agencies may also develop new business rules for including new payment sources. Additionally, tolling interoperability is currently based on the premise that toll payments are guaranteed, since toll accounts are tied to

toll agencies. However, future customer accounts may not necessarily be backed by traditional toll agencies. As such, toll agencies and interoperability regions may wish to develop new ways to make themselves financially secure, such as requiring bonding or certain levels of toll prepayments from new non-tolling account owners.

SUMMARY

The tolling industry expects the regional hub-based model to deliver effective nationwide toll interoperability in the short term, after the industry overcomes the remaining business rules, policy, and legal challenges. In the longer term, however, this current model may become increasingly influenced by market and technology forces leading away from agency ownership of accounts. As the tolling industry addresses near-term challenges of nationwide interoperability through public-sector-led regional hubs and private-vendor toll account aggregators, the tolling industry views nationwide interoperability as an evolving concept and investigates alternative technologies that will continue or expand ETC interoperability.

CHAPTER 1. INTRODUCTION

Toll facilities are located in about 35 States in the United States and generate more than $18 billion in revenue each year. More than 130 different toll agencies, State departments of transportation (DOT), turnpike authorities, and private entities operate toll facilities in the Nation (referred to as toll agency or operator throughout this report). Before 1989, customers paid tolls with cash at toll booths. Since 1989, advances in electronic toll collection (ETC) have enabled customers to pay tolls electronically using an account linked to a vehicle transponder or vehicle license plate. More recently, with the advent of express lanes, some facilities require transponders for facility use and assessment of tolls. Currently, more than 86 million devices that enable ETC transactions are in operation on U.S. roads.[10] When ETC was first deployed, no pre-existing national technology standard or protocols governed the technology. As toll agencies across the Nation began to procure ETC systems from multiple technology vendors, different—and often incompatible—technologies emerged in different parts of the country. ETC account holders were effectively prevented from electronically paying tolls in neighboring jurisdictions because the facilities' back-office systems were not connected. At one point in the past, more than seven incompatible ETC transponder protocols were in use across the industry.

STUDY BACKGROUND

The toll industry has gradually introduced ETC interoperability among facilities within a State or region. However, achieving nationwide ETC interoperability (referred to as nationwide toll interoperability or nationwide interoperability throughout this report), in which a transponder or an account from one agency is accepted at all other facilities in the Nation, has been a challenge. In 2019, the Federal Highway Administration (FHWA) authorized a research and synthesis study to document the progress and direction toward achieving nationwide toll interoperability. This report discusses the results of that study, and identifies current efforts toward nationwide interoperability, challenges to overcome, near-term trajectory of achieving nationwide toll interoperability, and the potential for emerging technologies and business models to influence achieving the goal.

PROJECT OBJECTIVES

The objective of the research and synthesis study was to identify, research, and synthesize current and emerging technologies and operational and organizational solutions for achieving nationwide toll interoperability. The synthesis included:

- Reviewing progress to date, including toll industry initiatives and testing and formation of interoperable ETC regions and hubs.
- Identifying challenges to overcome to achieve nationwide toll interoperability.
- Collecting feedback and insights from toll agencies and stakeholders through listening sessions and interviews.

[10] See the section in chapter 4: *The Search for A Single National Transponder Protocol* of this report for back-up calculation.

- Identifying emerging technologies and new third-party payment services that may influence how nationwide toll interoperability is achieved.

After addressing the project objectives, the study describes the most likely path to full ETC interoperability, potential limitations or exceptions, and potential variations resulting from new technology solutions and emerging mobility or payment options.

BACKGROUND AND MOTIVATION FOR THE PROJECT

Regional toll interoperability has been well established in some parts of the country, but the notion of nationwide interoperability arose, in large part, from Federal rulemaking initiatives between 2007 and 2009. The U.S. toll industry recognized these emerging requirements, and established through the International Bridge, Tunnel and Turnpike Association (IBTTA) committees and working groups in 2010. While the need for this research project relates to a Federal need to understand the current state and challenges associated with ETC interoperability, there has been growing acknowledgment within the tolling industry about the need for nationwide interoperability that serves the traveling public and the strategic goals of tolling agencies alike. This acknowledgement has been evidenced in IBTTA's continuing efforts over the past decade to find appropriate solutions for achieving complete, or effective, nationwide toll interoperability. This section describes key milestones leading up to and underscoring the motivation of the current project.

Federal Activities

The earliest Federal actions on nationwide toll interoperability can be traced to a final rule published by the Federal Highway Administration in the Federal Register on October 8, 2009.(1) As described in the rule description in the *Federal Register*:

> Although a nationwide interoperability standard has not yet been established, this rule seeks to accelerate progress toward achieving nationwide interoperability by requiring these facilities to upgrade their ETC systems to the national standards whenever adopted.[11]

The 2009 rule recognized that FHWA could not yet establish a national standard at that time, but stated that:

> The FHWA believes that requiring toll agencies to take interoperability issues into consideration in developing their toll collections systems addresses the objective of the statute to accelerate progress toward the goal of nationwide interoperability."[12]

Even though the 2009 rule stopped short of defining the exact nature or pathway to nationwide interoperability, in its Notice of Proposed Rulemaking, FHWA solicited comments and inputs with respect to six important questions:

- How should a national electronic toll collection standard be pursued?

[11] The final rule was published on October 8, 2009, 74 FR 51762.
[12] 74 FR 51762.

- What aspects of electronic toll collection should be standardized?
- How critical is the timing for establishing a national electronic toll collection standard?
- How should the national standard incorporate current technologies and functions?
- How should the national standard allow for changes in technology over time?
- What are the personal privacy aspects of a national electronic toll collection standard and the technologies that may be used to achieve it?[13]

In response to these questions, FHWA received feedback from all segments of the toll industry, representatives of the auto industry, and industry associations and standards organizations. This was fully documented in the *Federal Register*.[14] As will be discussed further throughout this report, many of the issues raised in the questions in 2009 are still pertinent as the industry moves toward nationwide toll interoperability.

The rule applied to facilities tolled under the Value Pricing Pilot Program, the Express Lanes Demonstration Program, and the Interstate System Reconstruction Pilot Program included in Section 1604[15] of the 2005 Transportation Reauthorization Bill, known as the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA–LU). Section 1604 of SAFETEA–LU[16] also directed the Secretary of the U.S. Department of Transportation (USDOT) to the maximum extent possible, to:

- Accelerate progress toward the national goal of achieving nationwide interoperability in ETC system(s).
- Take into account the use of noncash electronic technology currently deployed within an appropriated geographical area of travel and the noncash electronic technology likely to be in use within the next 5 years.
- Minimize additional costs and maximize convenience to users of toll facilities and to the toll facility owner or operator.[17]

In July 2012, the Congressional Transportation Reauthorization Bill, known as the Moving Ahead for Progress in the 21st Century Act (MAP-21),[(3)] was signed into law. It included a deadline for achieving nationwide toll interoperability on Federal-aid highways (Section 129. (MAP-21 § 1512) for achieving nationwide toll interoperability till date:

> *Not later than 4 years after the date of the enactment of this Act, all toll facilities on the Federal-aid highways shall implement technologies or business practices that provide for the interoperability of electronic toll collection programs*.[18]

While MAP-21 did not provide specific direction for achieving this goal, it established a 2016 target for full ETC interoperability for all U.S. toll facilities on the Federal-aid highway system. Some toll facilities are not located on Federal-aid highways, but most are. In 2015, another

[13] 72 FR 53736 .
[14] Ibid.
[15] Section 1604(a) of Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) (Pub.L.109-59; Stat.1252).
[16] Ibid.
[17] Ibid.
[18] Section 1512(b) of Moving Ahead for Progress in the 21st Century Act (MAP-21) (Pub.L.112-141; Stat.572).

reauthorization bill, known as the Fixing America's Surface Transportation (FAST) Act, was passed, although it did not alter the goal of nationwide interoperability.

Toll Industry Activities through the International Bridge, Tunnel and Turnpike Association

IBTTA is the primary trade association for the United States and worldwide toll industry. Its members are toll agencies, facility operators, consultants, technology providers, and toll service providers, including international members across 26 countries. It also provides a connection between tolling developments in the United States and those in other nations.

As ETC emerged in the United States around 1989, and toll facilities increasingly adopted the approach, the technology protocol standards were driven by the technology supplier in different regions or jurisdictions. By 2010, some interoperability had been deployed at the State level in several States, and along Interstate 95 in the northeast United States. An organization called the Interagency Group (IAG) was formed in 1990 by seven toll operators in New York, New Jersey, and Pennsylvania, which used transponders of a common protocol, known as E-ZPass®. IAG established interagency agreements for payment guarantees and information exchange and remains the largest interagency toll network today. Interoperability had also been established within certain States, including Florida, Texas, and California. Although each State encompassed multiple toll agencies and facilities, they used common ETC protocols and established statewide processing and revenue transfer agreements.

As Federal initiatives concerning national interoperability emerged, IBTTA recognized the need to begin planning for nationwide interoperability. An Interoperability Committee was formed to begin the planning process. The committee, which included consultants and toll authority agency representation, began identifying challenges, issues, and potential solutions. In 2011, IBTTA shared the initial committee report with the House Committee on Transportation and Infrastructure and offered to lead the effort toward nationwide interoperability, targeted for 2016. Efforts to achieve nationwide interoperability since 2011 have largely been undertaken by the tolling industry under the leadership of IBTTA.

Definition of the Goal of Interoperability

The March 19, 2013, *Progress Report of the Interoperability Committee of the IBTTA*,[(8)] defined the goal of nationwide interoperability as:

> ...a system in which customers have the choice of opting in and are able to pay tolls on any participating toll facility in the country using a single account. The immediate goal is to achieve nationwide interoperability for valid prepaid toll customers – in essence, registered toll customers. The plan does not include un-registered toll customers.

The *Progress Report* further expanded upon this goal in the definition of nationwide toll interoperability as follows:

> We envision that a driver who has a valid registered account with any electronic toll collection (ETC) system (i.e., E-ZPass®, SunPass, TxTag, FasTrak, etc.) can have their vehicle identified seamlessly in the electronic toll lanes of any other ETC system using a

required National TollTag (which would also be associated with their existing account) and have the appropriate fees deducted from their account.

This definition of interoperability remained consistent throughout IBTTA's efforts. However, the means of achieving this desired end state evolved through the work of the Interoperability Committee's effort. These industry efforts, other associated developments, and the implications for the path toward nationwide interoperability will be discussed throughout the remainder of this report.

INTENDED AUDIENCE FOR THE REPORT

This report is intended to inform USDOT leadership and staff about the status and potential future direction of nationwide toll interoperability. It is also intended to serve as a resource to public- and private-sector toll agencies, State and local transportation agencies, technology providers, vendors, and other stakeholders in the tolling industry with interest in this topic.

OVERVIEW OF STUDY APPROACH

The study was initiated in August 2019 and was completed after an 18-month period. The key research, investigation, and information collection tasks are described below. The overall study included the following six primary work tasks:

- **Task 1: Project Management** – Included refinement of the study approach and a kickoff meeting between the consultant team and the FHWA technical team in which project deliverables and schedules were refined and lines of communication and review established. This task also included periodic updating and reporting, with regular monthly project calls scheduled with FHWA throughout the project.

- **Task 2: ETC Literature Search, Research, Analysis, and Synthesis** – Included assembly and review of several reports, articles, and documentation of activities related to tolling and the pursuit of electronic toll interoperability. Task 2 culminated in a detailed letter report that summarized the literature review and provided a broad introduction to tolling, an overview of technologies and processes, and a discussion of the recent shifts toward four regional geographic interoperability regions and the planned shift to a hub-and-spoke system of information exchange. The document also examined toll interoperability efforts outside the United States as well as emerging technology trends with implications for tolling interoperability. Much of the important information included in the literature review report has also been included in this report.

- **Task 3: Peer Exchange Listening Sessions** – Included peer listening sessions with almost two dozen toll agencies, which provided feedback on several issues such as the unique challenges agencies have been facing as the industry moves to cashless all-electronic tolling (AET) in pursuit of nationwide interoperability. The first listening session had been planned for early April at the 2020 IBTTA Annual Technology Conference in San Diego, California. However, due to State and local restrictions on large in-person gatherings, and organizational restrictions on travel, the conference was postponed. The listening sessions were eventually held as virtual sessions. More

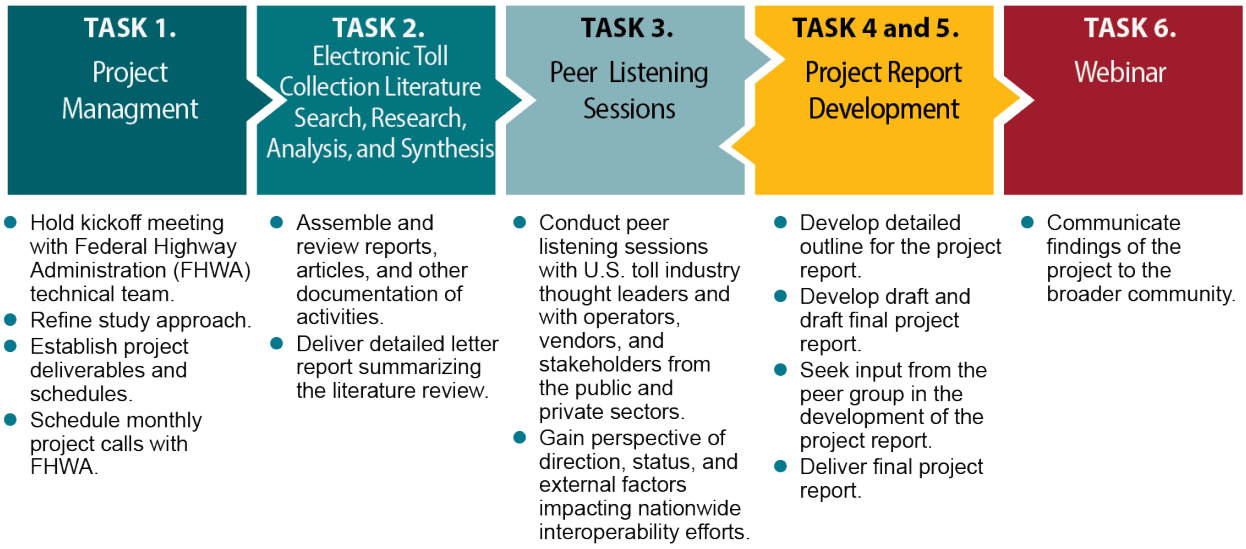
information on the sessions is provided below, and feedback and peer inputs to the study are featured by topic area in several later chapters.

- **Task 4: Annotated Outline of Project Report** – Involved a detailed annotated outline of the project report, which was reviewed and approved by the FHWA team. The outline covered the basics of tolling, challenges to nationwide toll interoperability such as issues with transponder technology, interagency payment guarantees and revenue clearing, current trajectory toward nationwide interoperability, coming technology changes, and the most probable pathway to achievement.

- **Task 5: Project Report** – Included a project report with case studies on how interoperability is being achieved in the United States and abroad.

- **Task 6: Webinar** – Will include a webinar (that took place in November 2021) in which the study and project report are presented and discussed.

Figure 2 presents a chronological progression of the tasks associated with the report.



Source: FHWA.

Figure 2. Illustration. Tasks associated with the technical study approach.

Literature Search, Research, Analysis, and Synthesis

The research team assembled, cataloged, and reviewed relevant literature on nationwide toll interoperability. The literature review documented three areas:

- **Ongoing efforts toward national interoperability (primarily led by IBTTA).** This search included IBTTA conference proceedings, IBTTA Interoperability Committee notes, IBTTA Annual Big Issues Updates and IBTTA testimonies and report to Congress regarding its progress to meet the requirements of MAP-21. It also included review of

prior FHWA reports, industry journals, technical papers, presentations by industry stakeholders including toll agencies, and industry interest groups and coalitions.

- **Emerging technology and transportation policy with implications for tolling interoperability.** This search included documenting the implications of road usage charging, congestion pricing, connected vehicle (CV) technology, mobility on demand, and integrated electronic toll payment systems for tolling interoperability.

- **Examples of tolling interoperability around the world and in other industries.** This search included in-depth analysis of the European ETC business model, a review of tolling interoperability in Brazil and Turkey, and a review of key considerations around payment systems interoperability.

Peer Exchange Listening Sessions

Listening Session with Toll agencies in April 2020

The research team held two virtual listening sessions with U.S. toll agencies and agencies, each two hours in length, on April 1 and 2, 2020. In addition to FHWA and the consultant project team, representatives of 23 toll and transportation agencies, private toll agencies, and industry associations participated in the listening sessions. Table 2 presents a list of participants.

Table 2. Toll agency participants in the first peer listening session held in April 2020.

State	Agency/Organization
California	Transportation Corridor Agencies
California	Golden Gate Bridge District
California	Bay Area Toll Authority
Florida	Tampa-Hillsborough Expressway Authority
Florida	Florida Turnpike Enterprise
Georgia	State Road and Tollway Authority
Illinois	Illinois State Toll Highway Authority
New Jersey	Burlington County Bridge Commission
New Jersey	New Jersey Turnpike Authority
New York	MTA Bridges and Tunnels
North Carolina	North Carolina Turnpike Authority
Ohio	Ohio Turnpike and Infrastructure Commission
Oklahoma	Oklahoma Turnpike Authority
Oregon	Oregon Department of Transportation
Pennsylvania	Pennsylvania Turnpike Commission
Texas	North Texas Tollway Authority
Texas	Cintra (express lanes/toll road operator)
Utah	Utah Department of Transportation
Virginia	Transurban (express lanes toll operator)
Washington	Washington State Department of Transportation
Various	I–95 Corridor Coalition
Various	Interagency Group – E-ZPass® Group
Various	International Bridge, Tunnel and Turnpike Association

The listening session opened with introductory comments and opening remarks by Samuel Johnson, chief executive officer of California's Transportation Corridor Agencies (TCA) and 2020 IBTTA president. Each event was broken into three sessions, as shown in table 3.

Table 3. Focus areas in the first peer listening session held in April 2020.

Task 3. Peer Listening Sessions		
Focus Area 1: Current State of Tolling Interoperability	**Focus Area 2: Moving Forward from Here – the Current Trajectory**	**Focus Area 3: Future Changes in Toll Collection and Beyond**
Focused on how agencies are handling interoperability today and where they think things stand. It showed a high degree of awareness of the shift to regional networks and planned regional hubs. Participants also shared many challenges they are experiencing, and how they are beginning to deal with the lack of a single national protocol.	Covered a range of issues, including privacy concerns, business rules, interstate collection and enforcement challenges, and customer education.	Discussed new business models, new mobile tolling applications, shifts in urban mobility, and how it all may influence the pathway to nationwide toll interoperability. Perhaps most significantly, it became clear that the toll industry is becoming more aware of, and accepting of, the future role of third-party service providers in toll collection.

Important information obtained during the peer listening session will be presented in later chapters, depending on topic area.

Interviews with Toll Industry Stakeholders and Vendors

In addition to collecting input from the toll agencies, the research team also sought input from industry stakeholders, vendors, and representatives on emerging trends and approaches relevant to nationwide toll interoperability. The objective was to capture the range of experiences, current operations, and future plans of the wider tolling community, along with perspectives on business, operation, technological, and financial aspects of the interoperability adoption process. Seven interviews were conducted in July and August 2020 with representatives from the following short list of industry stakeholders:

- MaaS America, a nonprofit advocating a mobility-as-a-service (MaaS) ecosystem in the United States.
- Egis®, global concessionaire and facility provider involved with operating and maintaining toll road and rail assets.
- Bestpass®, a third-party payment services provider primarily serving trucking companies and fleet owners with tolling needs.
- PlusPass, a third-party payment services provider offering both smartphone and transponder account options.

- Kapsch, a radio frequency identification (RFID)-based toll solutions vendor and E-ZPass® supplier.
- A member of Society of Automotive Engineers (SAE) International committee J3217 focused on developing standards to enable vehicle-to-everything (V2X) tolls and other financial transactions.
- GeoToll, a mobile payment solutions provider.

The interviews covered the following key discussion questions:

- Describe your role in the toll design, delivery, and operation value chain.
- Does the work you perform impact nationwide toll interoperability?
- Do you envision new business approaches and new technologies that will enhance the user experience with respect to achieving nationwide toll interoperability?
  - Describe these potential approaches.
- Do you envision new business approaches and new technologies that will assist toll agencies in their effort to deliver nationwide toll interoperability?
  - Describe these approaches.
- Describe how these approaches could improve efficiency of the toll road, reduce cost of design/delivery and operations, and increase throughput with respect to nationwide toll interoperability.
- Is there anything else to consider as we describe the path toward nationwide toll interoperability?

Relevant findings from these interviews are presented in later chapters, depending upon topic area.

OVERVIEW OF THE REPORT

Chapter 1 presents an overview of electronic tolling, the motivation for this project, and the study objectives and approach.

Chapter 2 provides an overview of electronic tolling, including a history and the current state of tolling in the United States.

Chapter 3 introduces two main challenges of achieving nationwide toll interoperability: technology (ETC protocols) and the business side of interoperability. This chapter also presents existing data and projections related to demand for nationwide toll interoperability.

Chapter 4 addresses technology issues with achieving nationwide toll interoperability.

Chapter 5 addresses the business side of ETC interoperability, such as back-office operations, interagency information exchange, and financial clearing.

Chapter 6 addresses the alternatives and trends that support the current trajectory of the hub-based alternatives that may alter the business model of tolling operations in the future.

Chapter 7 looks at future tolling technology and business model changes that may influence interoperability as it is currently envisioned by the tolling industry.

Chapter 8 provides concluding comments and near-term developments as progress toward achieving nationwide toll interoperability continues.

CHAPTER 2. OVERVIEW OF TOLLING IN THE UNITED STATES

Nationwide toll interoperability is a system in which a single electronic toll account is accepted and used to pay tolls at all toll facilities in the United States, regardless of where the account is issued and maintained.[19] In practice, achieving nationwide toll interoperability faces several technological, operational, and institutional challenges. This chapter begins with the historical evolution of tolling and milestones relevant to the emergence and current status of nationwide toll interoperability in the United States. It also provides a primer on tolling payment methods, state of the practice in tolling technology, back-office operations, accounting, enforcement, and electronic tolling logistics.

TOLLING PHILOSOPHY AND PRACTICES

Tolling is used as a tool for managing traffic, financing the construction and maintenance of roads and bridges, reducing congestion, improving the environment, and promoting travel modes such as public transportation and carpooling. Tolling in a corridor or in a regional system can provide benefits to the traveling public and highway system as a whole. In large metropolitan areas, demand for highway travel outpaces supply, leading to traffic congestion. Tolling a portion of the roadway network, or tolling certain lanes, can provide more reliable travel choices for those willing to pay for travel-time savings. Travelers may also place a value on their travel when they pay to use this service. In cases where the tolled facility serves the same travel patterns as adjacent transit lines, tolls allow travelers to compare direct costs when they make mode choices. Even when the purpose of a toll is to primarily reduce congestion or change travel patterns, tolls may produce a revenue stream that exceeds the operating costs of the toll facility. These revenues can fund roadway and transit improvements to further enhance mobility in the corridor.

There are direct costs associated with toll collection, such as technology, infrastructure, and back-office costs, as well as indirect costs resulting from interruptions to traffic flow and localized congestion. Tolling agencies address these considerations with appropriate tolling approaches guided by local laws, bond covenants, or concession agreement terms. As such, hard infrastructure cost considerations are a key factor in the move toward nationwide toll interoperability.

Over the past several decades, tolling has been implemented in a variety of ways to address a range of policies. Concepts such as variable tolling (e.g., by time of day, day of week, vehicle class), tolling exemptions and credits to advance preferred mobility policies (e.g., to promote increased transit or electric vehicle use), and operational approaches to address policy considerations (e.g., congestion mitigation, travel demand management, equity) have been implemented to varying degrees. While a detailed discussion of tolling approaches is not a focus of this study, it is helpful to acknowledge that, in addition to hard infrastructure, operational

[19] Adapted from the definition for nationwide interoperability provided in the International Bridge, Tunnel and Turnpike AssociationProgress Report of the Interoperability Committee of the International Bridge, Tunnel and Turnpike Association (IBTTA): *Migrating to U.S. Nationwide Electronic Tolling Interoperability*. March 19, 2013.

policy variations may also be a significant consideration in achieving nationwide interoperability.

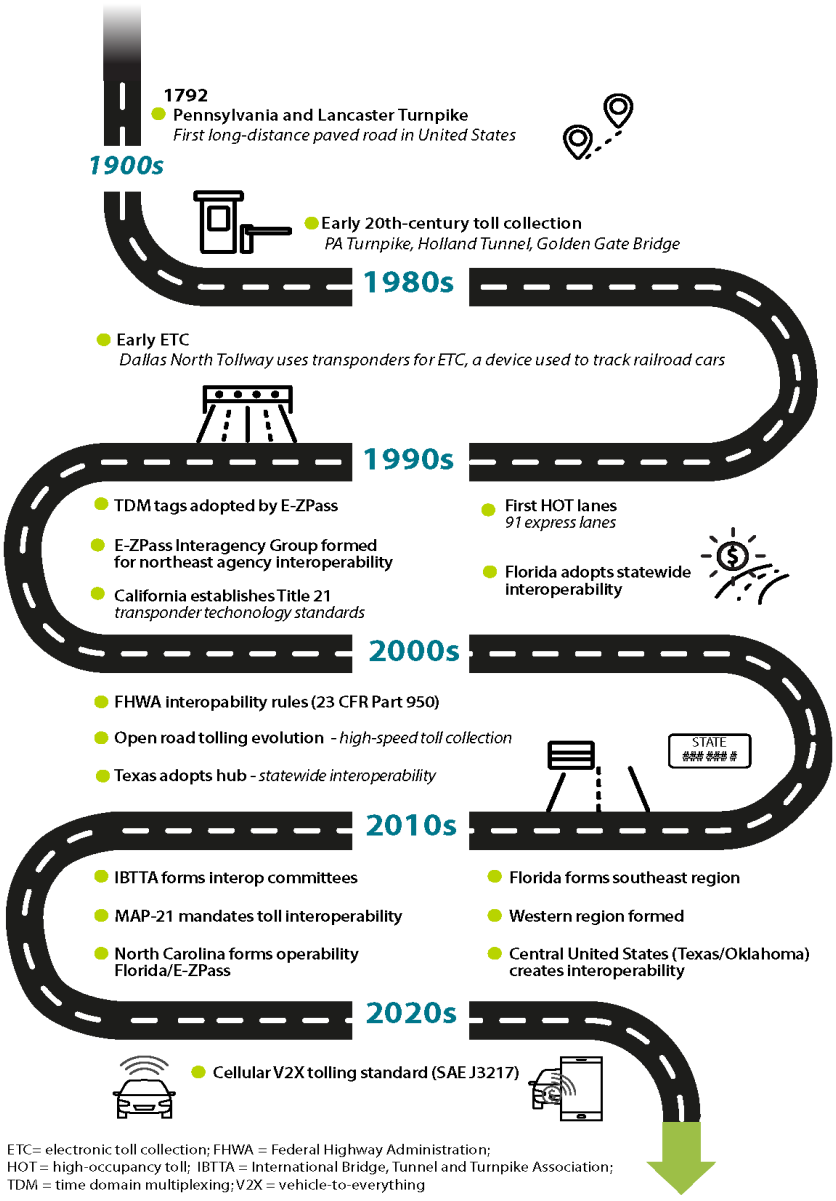
Historical Tolling Approaches

Although the history of tolled roads goes back hundreds of years, modern era toll roads, bridges, and tunnels have been in operation in the United States for more than 80 years—the first 50 of which primarily involved collection of cash. Individual toll booths evolved into multilane toll plazas constructed across a roadway that required drivers to stop at staffed toll booths to pay the toll. This fast-dwindling practice continues to this day at facilities across the country. Several major intercity turnpikes were constructed in the 1940s and 1950s for longer-distance travel; these often used a ticket system of toll collection in which toll points were placed at all points of entry and exit, and a single toll was collected for each trip, nominally based on distance traveled. Many urban toll facilities introduced automatic coin machines in the 1960s and 1970s. These machines were designed to collect exact change when the toll price was relatively low at most locations. Over the years, several facilities established discount programs, where customers used tokens or time-limited discount ticket books in lieu of cash. In some locations, regular customers purchased annual toll plates that mounted on vehicle bumpers, permitting nonstop passage around toll barriers using an honor system.

ETC emerged in the late 1980s with the first major deployment on a few urban toll facilities in Dallas, Texas, operated by the North Texas Tollway Authority (previously Texas Turnpike Authority). In 1990, the tolling agencies of New York, New Jersey, and Pennsylvania formed the IAG Group to create compatible electronic tolling technology. The first ETC system, which had become branded as TollTag, adapted an early form of small RFID technology initially developed for animal herd management.(7) At the outset, ETC was viewed as an automated technique that could replace commuter discount programs. The toll industry later recognized it could be attractive to customers who wanted to avoid cash payments at toll plazas.

The concept expanded throughout the industry, and over the next 10 or more years, most toll agencies in the Nation had invested in ETC technology.(9) In early applications, ETC readers were installed in designated gated toll lanes, and drivers had to come to a rolling stop. As low-speed, nonstop dedicated ETC lanes became more common, more and more customers shifted away from cash, as ETC usage reduced delays at toll plazas.(8) Over time, the share of traffic using toll transponders exceeded the share using cash, and toll agencies further adapted typical toll plaza configurations.(10)

Over the past 25 years, advancements in tolling technology and approaches have emerged. These advancements include AET, express lanes, and automatic license plate recognition (ALPR) technology that are described in detail later in this chapter. Many of these advancements enable toll assessment without the vehicle coming to a stop and even at highway speed. More recently, alternatives to RFID-based technology are being widely explored. Figure 3 shows key milestones in the evolution of toll collection in the United States.



Source: FHWA.

Figure 3. Illustration. Milestones in the evolution of electronic toll collection in the United States.

TOLL COLLECTION METHODS AND APPROACHES

This section describes the current primary methods of toll collection in the United States.

Cash Collection

As noted above, cash has long been the primary method of toll payment. In some cases, particularly at lower-volume ramp toll locations, unattended exact change payment is, to this day, the only available method for toll payment. A limited number of facilities include an option for credit card payments, especially for commercial vehicle charge accounts; however, most have now been replaced by electronic toll transponders.

Electronic Toll Collection

Drivers electing to enroll in ETC open prepaid accounts with a local agency. Most of these accounts are linked to credit cards or bank accounts that automatically replenish when account balances drop below predefined levels. Drivers are then issued an ETC transponder device, which is typically mounted on the inside of the vehicle's windshield. Most early transponders were designed as removable devices that could be shifted between vehicles, although in recent years lower-cost sticker tags have become more common, which are permanently affixed to a single vehicle.

An account can have more than one transponder associated with it, each of which has a unique identification number, referred to as the tag ID code. Different vendors developed proprietary and non-proprietary standards for transponders, including transponder ID, toll agency codes, identification codes, and in some cases, vehicle classification. The majority of ETC accounts also include the license plate registration numbers of vehicles associated with the transponder or account. This is important to properly identify an ETC customer's vehicle in case the transponder is not properly read in the lane and a license plate image is captured instead.

From the outset of electronic tolling, ETC accounts have typically been managed by a local toll agency. Even as statewide and regional interoperability agreements later emerged, the single agency account management practice continues today, reflecting a form of customer ownership structure within the U.S. toll industry. Some agencies assess small fees for account maintenance, or other similar charges, while others do not. Some agencies charge for transponders (either an initial purchase or a monthly rental fee) while others do not. Over the past decade, retail purchase options have become common in some States, but they still require linking the device to a prepaid toll account managed by one agency or another.[20]

Toll-by-Plate or Pay-by-Mail

Toll-by-plate (TBP), also known as pay-by-mail, identifies vehicle license plates through ALPR cameras. If the license plate is already associated with a customer ETC account, then payment is

[20] In some States, such as Florida, transponder purchases are offered through retail outlets such as supermarkets, drug stores, and others. The device may be purchased at a store, but an ETC account is established separately online or via telephone with the selected toll agency. The unique transponder "tag ID" number is then linked to the account via customer action.

automatically deducted. Otherwise, license plates are used to track down registered vehicles owners, so toll agencies can send either toll invoices or toll violation notices.

All-Electronic Tolling

AET is a general term used to categorize facilities where all transactions are electronic, requiring no human intervention. Several new toll facilities have been designed as AET at the outset, while other legacy facilities have been converted to AET and previous toll plazas removed. Figure 4 shows an example of an AET toll gantry in Florida.

AET is achieved in the following two ways:

- **Transponder only:** AET relies on typical ETC collection for most users. In a few cases, such as several facilities in the Houston region and most express toll lane projects, only vehicles equipped with ETC transponders are legally permitted to use the automated toll roads.
- **Transponder and TBP:** In most cases, vehicles that do not have a transponder can use AET facilities. Tolls from non-equipped vehicles are collected though TBP.

Some AET facilities may still require vehicles to pass through a toll plaza at slightly reduced speeds, whereas other facilities allow transponder-equipped vehicles to pass nonstop through plaza areas at higher speeds.

Open Road Tolling

Open road tolling (ORT) is a form of AET in which fully automated toll gantries are constructed over highway travel lanes that are physically separated from adjacent cash lanes. ORT enables vehicles equipped with a transponder to pass under a toll gantry at highway speeds.

Third-Party Payment Services

In recent years, third-party account management has gradually emerged. Examples of this growing trend are discussed below and described in greater detail in chapter 6.

Several legacy toll agencies offered volume discount programs for trucking but did not provide a seamless solution to address the interoperability needs of vehicles that typically cross several jurisdictions. Truck tolling service providers support the high volume of toll road use by trucking companies—a previously underserved market—by offering integrated account management.[(11)] They provide lists of customer license plates and guarantee payment to toll agencies. Before sending out a TBP invoice, if the toll agency identifies the plate as a participating vehicle, it simply bills the third-party service provider.

Figure 4. Photo. Florida SunPass® all-electronic toll gantry.

In recent years, several third-party payment services have begun allowing customers to pay tolls using smartphone applications. There is considerable change occurring in third-party markets, including emerging technologies that may well influence the final pathway to nationwide toll interoperability.

ELECTRONIC TOLL COLLECTION SYSTEM COMPONENTS

Collecting tolls electronically is accomplished through two major components: roadside technology and the customer service center (CSC) or back office. These are introduced below and further described in chapters 4 and 5.

Vehicle Detection and Identification

Roadside technology for vehicle detection and identification is implemented through pairing with in-vehicle system components. To electronically toll a vehicle, a toll agency must detect the passage of the vehicle at the tolling point, collect information that can be used to identify the vehicle owner or driver, and provide a means to collect payment. If the vehicle is associated with an account at the toll agency, different technologies exist to identity the vehicle and connect it to the account. These technologies include:

- **RFID-based technology –** Toll transponders are RFID-based devices internally mounted on windshields or externally mounted on bumper mounts or headlights; usually called a transponder, tag, or sticker.

- **License plates capture technologies –** ALPR video cameras at tolling points visually capture license plates and use computing logic to automatically decipher license numbers. More sophisticated ALPR systems can also recognize characteristics of vehicles, such as shapes and bumper stickers, to uniquely identify them.
- **Global positioning system (GPS) –** Technology in smartphone applications that indicates when a vehicle passes a tolling point.
- **CV technology –** Limited number of transponder protocol technologies directly integrated into vehicles, typically associated with connected vehicles.

As a vehicle passes a tolling point, roadside tolling equipment uses these technologies to detect the device associated with an account. The toll system matches the device to the account and triggers payment of the toll.

A key aspect for toll point vehicle detection and identification, and reconciling transaction data, is that the toll agency must account for all vehicles passing. Toll agencies currently rely on the in-vehicle identification mechanism (such as a transponder or an app) and the license plate at the time the vehicle passes through the toll point. This is key regarding some emerging third-party payment services that rely on GPS tracking and geographic information system geofencing techniques to identify when a participating vehicle passes a tolling point. While the third-party payment services may guarantee payment, agency accounting requirements may need a link between the GPS-created transaction and the actual transaction recording by the toll gantry. In most cases, this is handled through license plate imaging comparisons.

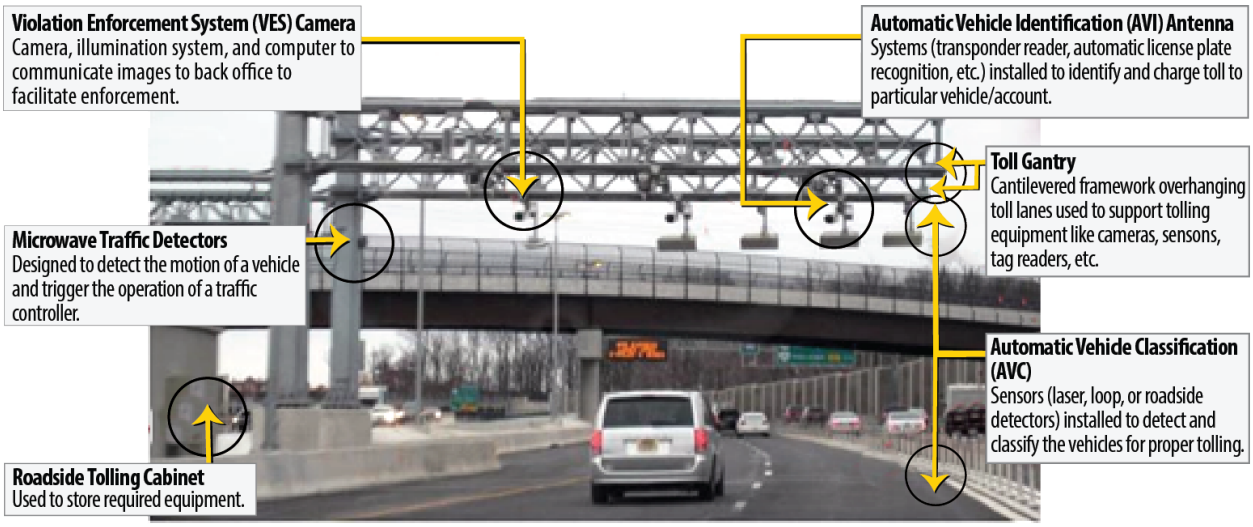
Roadside Technology Components

Figure 5 shows an example of a typical multilane AET gantry, which passes above the travel lanes. It includes all components necessary to identify and automatically classify each vehicle that passes under it, including:

- **Automatic vehicle identification (AVI) –** RFID technologies where antennas from readers wirelessly communicate with transponders in passing vehicles using an established protocol language developed for tolling. Protocols in the United States operate in the 900–928-megahertz (MHz) spectrum and are licensed for use by the Federal Communications Commission under Part 90.

- **Violation enforcement system (VES) –** System of cameras and illuminators that capture images of vehicle license plates, and ALPR software that identifies vehicles for which the system did not read a transponder. In the case of gantries which are restricted to vehicles with ETC transponders, the video technology is used to identify violators, while in AET operations the same camera technologies are used for TBP billing purposes.

- **Automatic vehicle classification (AVC) –** Two types of equipment associate vehicles to identification information and classify the size/type of vehicle (e.g., two-axle passenger car versus five-axle truck). The two types of AVC equipment are loops cut into the pavement below the gantry or overhead lasers hanged from the gantry. Sometimes these are used in combination for redundancy.



Source: FHWA, modified from © 2018 STC.

Figure 5. Photo. Multilane electronic toll gantry.

Customer Service Centers and Back-Office Systems

The emergence of ETC resulted in significant changes in the overall toll collection process—not the least of which was a major shift from in-lane collections and accounting to major investments in back-office systems and staffing to handle electronic toll account creations and management. The process became much more virtual, but also created the need for in-person and online CSCs.

CSCs provide a point of contact (either in person, by phone, or online) with toll customers. The CSC's function is to manage customers, process transactions and payments, and interface with toll customers. Responsibilities of the CSC operations include:

- **Opening and managing toll accounts.** This entails enabling customers to open/close accounts, select payments methods, manage vehicles linked to accounts, and update contact information. Customers can typically manage their accounts through websites, call centers, interactive voice recognition, mobile apps, and walk-in centers and kiosks.
- **Processing transactions and violations.** CSCs process toll transactions collected by roadside systems and post toll charges to customer accounts using transponder and license plate information. If transactions are not matched to accounts, those transactions are sent to violation processing. Violation processing involves identifying vehicle-registered owners through license plates in order to send those owners bills or violation notices.
- **Distributing toll transponders.** This entails handling transponder distribution to customers and managing transponder inventory.
- **Marketing and communications to customers and the general public.** This entails handling general inquiries from the public and explaining to customers how ETC works, various account and payment choices, and information on toll facilities.
- **Settling financial transactions.** This involves properly tracking transactions, payments received, and support auditing requirements.

Roadside equipment at various tolling points across a toll system communicates with a central back-office system at the agency level, which processes account and individual transaction data. The back-office system is the backbone of the typical electronic toll system and supports the CSC responsibilities, where all account management and transaction settlement take place. Some functions served by the back office include:

- **Processing transaction.** Record vehicle trips on toll facilities to charge proper accounts.
- **Setting toll rates.** Set different rate schedules, assess tolls based on vehicle types, manage dynamic pricing, and/or assign tolls based on location.
- **Managing accounts and customer interaction.** Help manage customer accounts, call center phone service, and public websites for customers to access their accounts.
- **Conducting image review and violation processing.** Support issuance of violations and manual review of license plate images.
- **Performing accounting and finance functions.** Allow for proper financial audits, interfacing with a toll agency's ledger and credit card clearinghouses and settling funds with other interoperable toll agencies.
- **Reporting.** Report transactions, revenues, system performance, traffic information, and other queries based on information stored in the toll system.
- **Administering the system.** Control access, security, and configuration of the toll system.
- **Maintaining online management system.** Maintain the toll system and monitor system health; also used for asset management.
- **Enabling network communications.** Enable the roadside to communicate with back-office systems, support external interfaces to other systems, and provide online access to customers using high-speed communications.

Some toll agencies have a separate roadside back office from their CSC back office, where the roadside back office is only responsible for creating transactions and setting toll rates. In certain areas, multiple agencies may be served by the same CSC back office. For example, five toll agencies in the Bay Area in California have their own roadside back office but use a single regional CSC and CSC back office so customers only need to go to one place. Figure 6 shows the various functions performed by toll back-office systems.

Source: STC and TollPlus.

Figure 6. Diagram. A typical toll back-office system.

CHAPTER 3. APPROACHES TO ACHIEVING NATIONWIDE TOLL INTEROPERABILITY

This chapter presents the basic elements of ETC interoperability, the challenges in achieving the goal on a nationwide level, and an overview of current industry approaches to achieving effective nationwide interoperability. It discusses the emergence of statewide and regional interagency toll interoperability, and typical procedures and processes used for information exchange, revenue settlement, and interagency payment guarantees. It further elaborates on the unique challenges of extending regional interoperability nationwide.

BASIC ELEMENTS OF ELECTRONIC TOLL COLLECTION INTEROPERABILITY

All ETC accounts are managed by individual agency/toll agencies. The agency that manages and maintains customer ETC accounts posts transactions, processes payments, and handles customer inquiries. An agency that issues transponders is usually referred to as the *home agency*. When a transponder is used on a toll facility operated by an agency other than the home agency, that agency is referred to as the *away agency*.

To support ETC interoperability, toll agencies would need to address how their back-office systems interact through agreements, policies, business rules, and interface control documents (ICD). In general, this process includes three primary functions:

- **Identify each other's ETC customers.** Toll agencies' roadway and back-office systems need to distinguish between vehicles that are home customers (local registered ETC customers) and away customers (customers with ETC accounts from other interoperable toll agencies). This is addressed by establishing methods and standards for agency back-office systems to exchange lists of ETC customers' transponders and license plates. Roadside systems have to be equipped to correctly read transponder protocols and accurately scan license plates.

- **Exchange ETC transaction information.** When an agency records toll transactions from away customers, the away agency sends those transactions to the home agency to collect toll payments. ICDs document back-office procedures, data standards, and system-to-system communications are used to send and acknowledge transactions between agencies.

- **Conduct financial settlements.** Interoperable agencies must settle funds owed for away agency transactions. Toll agencies execute agreements that lay out processes and timing of payments. In some cases, home agencies apply transaction fees for processing away transactions to recover credit card processing and handling costs. Depending on remittance amounts, agencies pay manually with checks or use direct wire transfers. Agencies also create data retention and reporting requirements for auditing purposes.

Typical Interoperability Provisions

To facilitate the interoperability process and protect participating agencies, certain procedures and terms can be defined among integrated parties. These can be detailed and varied within

different interoperable networks. The key elements of interoperability processes and agreements are described below:

- **Toll payment guarantees:** A cornerstone of the interoperability process is the existence of interagency toll payment guarantees. The home agency, which maintains and manages the ETC account, guarantees payment of a valid transaction at the away agency, provided the ETC account is valid and in good standing. Each agency typically guarantees the toll will be paid if the transaction is transferred to the home agency within a certain predefined time period.

- **Exchange of updated account information (transponder tag validation list [TVL]):** Toll payment guarantees rely on all potential away agencies being aware of the current validity of all accounts from each home agency. It is key that each agency provide, and frequently update, a full list of valid accounts and transponder ID numbers to all other agencies. This involves considerable daily data transfers. The valid account lists from all agencies are typically distributed to all tolling locations, such that the ETC system can verify an account is valid at the time the vehicle passes the tolling point. If a transponder is read but not listed as a valid account, the vehicle license plate image is taken, and the transaction may be treated as a violation.
    - In some cases, if the prepaid balance on an account goes negative, the account may be considered invalid. Most accounts are linked to credit cards or bank accounts, such that the account balance is automatically replenished. But where toll rates are high, an account can go negative on a single trip in progress, and it may take one or two days for automatic replenishment. Agencies define when an account becomes invalid differently. However, in most cases, unless the home agency notifies all away agencies of the change in status, it will still honor the toll charge.
    - Agencies may also exchange blacklists or lists of transponders that are not to be accepted. This is used if a transponder has been stolen or lost, or if an entire ETC account has been closed. If a transponder is on this list, it is immediately rejected at the toll site.

- **Exchange of license plate information associated with valid accounts (license plate validation list):** The majority of ETC accounts list the license plate of the vehicle on which the transponder is used. If a vehicle uses a toll facility without the transponder, or if the transponder was not read correctly, the transaction is initially treated as a video event—either a violation or a TBP in the case of AET systems. Before an agency sends a bill or a violation notice to a driver, they check observed license plates against the license plates listed on ETC accounts. The toll can then be processed as an ETC transaction as a courtesy to the customer.

- **Exchange of toll amount between home and away agency:** Each transponder has a unique tag ID number. Industry standards (or regional standards) define the specific format of the tag ID. Each tag includes an agency code that identifies the home agency associated with the transponder. This tells the away agency where to send the transaction information to request payment. The typical transaction record will include the full tag ID, time and date of transaction, toll amount, vehicle class, and other relevant information. There are some inconsistencies in record content and format between

interoperable regions. If all information is present and the account is valid, the home agency transfers the toll amount to the away agency. In most cases, there is no charge for the interoperable toll transfer, and in most cases, agencies typically handle about the same magnitude of transfers to and from other agencies. In some cases, such as Texas, a nominal processing charge is deducted by the home agency from each transfer processed.

Each interoperable State or region needs to have formally adopted business rules covering information exchange, payment guarantees, security procedures, and various institutional and interagency agreements.

CHALLENGES IN THE CURRENT STATE OF TOLLING

Transponder Protocols

By 2010, more than 70 percent of toll revenues had been collected using cashless toll transactions.(10) However, the toll industry had not defined technical standards for electronic toll devices. Instead, de facto standards emerged in different areas of the nation, depending on which vendors supplied systems. Several types of toll transponders are currently used in the United States. The transponders serve the same basic function and operate within the same overall frequency ranges but use a variety of disparate protocols. For the most part, these disparate protocols are incompatible. Historically, one protocol cannot be read by a reader of another protocol, although solutions to this problem are emerging. By 2014, six different ETC protocols were being successfully used by various toll agencies daily.[21] Figure 7 shows the geographical use and adoption of the different protocols across the United States.

[21] International Bridge, Tunnel and Turnpike Association. (2019). *U.S Tolling Industry Interoperability Efforts.* Federal Highway Administration (unpublished).

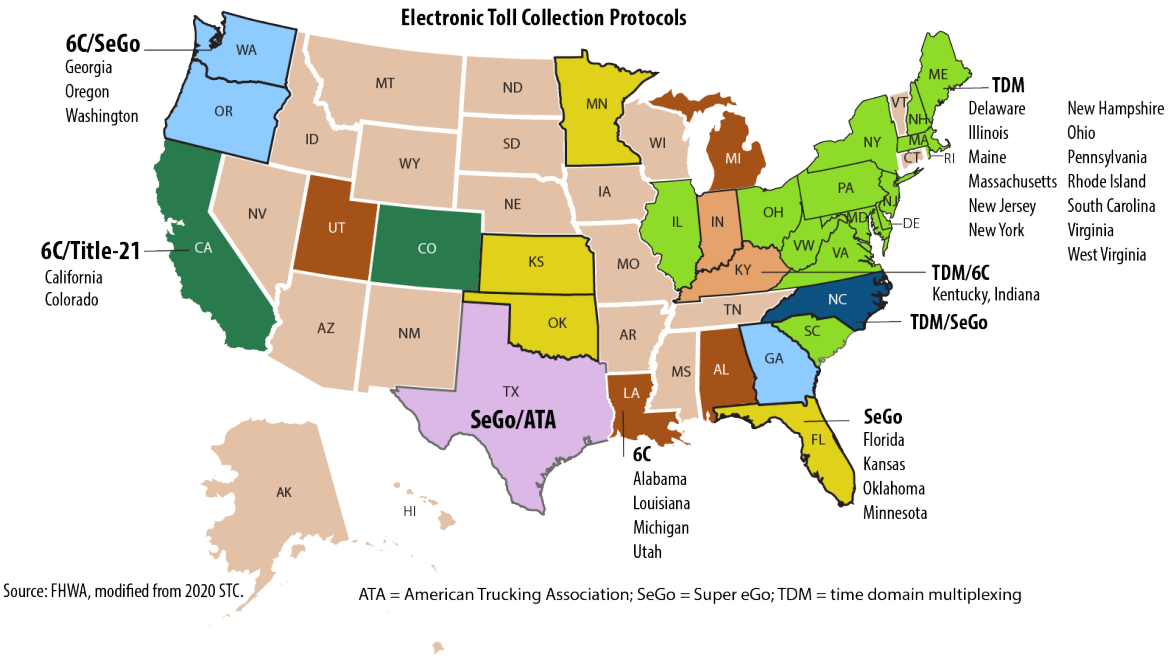


Figure 7. Illustration. Electronic toll collection transponder protocols currently used in the United States.

Toll Pricing

Almost all toll facilities have established a differential toll based on vehicle class. Historically, most classification structures in the United States have been based on the number of vehicle axles, although a few early systems based commercial vehicle classes on gross weight. While many systems simply based toll rates on a fixed amount per axle, today it is more common to assess higher rates per axle on vehicles larger than passenger cars, given the greater pavement and structural wear imposed by heavy trucks. A common pricing approach currently in use is referred to as N–1, in which the toll rate for any given axle class is equal to the number of vehicle axles, minus 1, multiplied by the passenger car rate. Hence, a two-axle vehicle would be charged the car rate, while a five-axle truck would be charged four times the car rate.

Agencies have different definitions of vehicle classes, and in some cases institutional and legal guidelines limit the ability to transfer class data between agencies.[22] With the emergence of high-speed multilane electronic tolling, some agencies are looking to simplify classification systems. Systems are shifting to structures such as car, single-unit trucks, and multi-unit trucks, which can be better identified through high-speed vehicle profiling rather than axle counting. Some agencies are incorporating measures of vehicle height or other characteristics into classification systems. However, the need for multiple classifications does require inclusion of automatic vehicle classification (AVC) technology into high-speed electronic tolling points.

[22] According to input received from the toll agencies' peer exchange/listening session, April 1–2, 2020. An employee of Oklahoma Turnpike mentioned different vehicle classification across the United States among other challenges in achieving interoperability. Oklahoma is looking into shape-based classification system (Trucks versus everything else) to make AET simpler.

Several facilities use other operational priorities to vary tolls, such as:

- Toll discounts for high-occupancy vehicles to improve person throughput and manage congestion in a corridor.
- Time-of-day and day-of-week variable toll policies to manage peak period congestion; area-based pricing and managed lane networks are new concepts being evaluated in some regions.
- Policies that provide toll discounts for electric and hybrid vehicles to encourage adoption of these vehicles.

These varied pricing policies and vehicle classification systems across States and jurisdictions also present a challenge with nationwide interoperability, since in many instances, variable policies are affected through agency-provided transponders. As such, the relevant discounts and other price variations are only available to home agency account holders and not to out-of-jurisdiction drivers.

All-Electronic Tolling

Over the past decade, the U.S. toll industry has significantly shifted to cashless AET. The International Bridge, Tunnel and Turnpike Association's (IBTTA) 2016 Toll Technology Survey found that just between 2010 and 2015 there was a 76 percent increase in cashless toll transactions in the United States.[10] With the advent of AET, many agencies that had been using traditional tolling have become cashless. Most of the earlier conversions to AET occurred on urban toll roads, which generally serve a predominately in-State customer market. However, more recently, larger intercity toll roads and turnpikes have begun the shift, which increases the proportion of out-of-State drivers.

In an AET operation, tolls are collected through fully automated toll gantries with no option to collect tolls by cash. Vehicles equipped with ETC transponders are handled using transponder readers. Vehicles without transponders are handled through video imaging of license plates, and toll charges are ultimately billed to vehicle owners.

License Plate Imaging

Most license plate images captured by VES cameras are machine readable using ALPR, although between 15 and 25 percent of images will typically require humans to intervene and manually review and enter license plates. Using the combination of automated and manual techniques, up to 90 percent of vehicle plates can be read.[9] The remaining license plate images are typically unusable due to weather conditions, plates obscured by mud or other debris, or plates obscured by trailer hitches or vehicles following too close.

There are also challenges associated with imaging license plates of freight vehicles. Since some States do not require passenger cars to have front license plates, video images for cars are focused on the rear plate. Although the image itself may contain more than just the plate itself—for example, it may include portions of the rear of the vehicle—it attempts to avoid portions inside the vehicle such as occupant photos.

Many trucks are combination vehicles that include a tractor (or cab) and one or two trailers. Both the cab and the trailers have unique license plates. The license plate number of the cab, not the trailers, is captured for toll billing purposes, because the trailers may be used by multiple agencies. Imaging is taken of the cab's front license plate, since the presence of a trailer typically obscures the rear license plate, and because all States require trucks to have front plates. Most AET tolling installations include both front and rear license plate imaging systems to ensure accurate recognition of both car and truck readable plates.

Further, most States have multiple license plate formats, with special plates for university alumni, social causes, and themes. Special plates may use a combination of differently sized characters, which further complicates matching to vehicle registration databases.(19) Toll system vendors can train optical character recognition software used by their ALPR systems for the most common State plates seen by their toll agency clients, but performance and accuracy decreases as less frequently observed State plates are added to support interoperability. With manual image review increasing operational costs and unreadable license plates reducing revenues, AET systems can result in greater revenue leakage than cash tolling.

Toll-by-Plate and Violation Processing

Once a license plate is recognized, it is either matched back to the associated ETC account or sent to TBP or violations processing. Unknown license plates are submitted to State departments of motor vehicles (DMV) or to commercial data sources to get the vehicle owner's name and address. Some registration files may have incorrect current address information—for instance, if the owner changes address between registration renewals.

Some agencies will send invoices for TBP transactions to the vehicle owner. If not paid within a certain predefined period, a new invoice is issued with an additional late payment fee attached. Some agencies will send violation notices directly to drivers instead of sending an invoice, since they are legally barred from issuing invoices since invoicing could be considered extending credits to customers.

TBP transactions typically account for less than 25 percent of total traffic on AET facilities. Nonetheless, problems with TBP collections and leakage (non-payment) occur for many reasons such as not getting a clear image of a license plate, incorrect address of registered vehicle owners from DMVs, out-of-state customers since there is no method to enforce non-payments. As such, toll agencies using TBP typically include a toll surcharge, often 50–100 percent above the ETC toll rate, to offset collection and leakage expenses as well as the higher cost of video transaction processing.[23] A few agencies have introduced a tiered video payment system, in which license plates are preregistered and payments assessed to the registered plate accounts. Toll rates are set to incentivize advance plate registration, since this reduces cost and collection risk to the toll agency for non-ETC transactions. An example is the Washington State Department of Transportation's (WSDOT) fee of $2 per trip, on top of the base toll for TBP, as against a 25-cent charge for adding a license plate to an existing ETC account.(16)

[23] According to the Toll Benchmarking Survey (2019) conducted by KPMG International. This is an international benchmarking study with over 55 percent of the toll agencies being from North America.

Most States have payment enforcement techniques, such as a registration hold, that prohibits renewing the vehicle registration until unpaid toll charges are paid. However, with only a few exceptions, these holds are limited to vehicles registered in the State the toll facility is located. The proportion of uncollectible license plate transactions varies among agencies, but it tends to be considerably higher for billings to out-of-State vehicles. The lack of registration holds or inability to pursue out-of-State violators is a concern, especially for toll agencies near State borders or with high out-of-State traffic, such as agencies in the northeast United States. A few multistate agreements related to violation and toll payment enforcement have been established, such as that involving Maine, Massachusetts, and New Hampshire.

Although national ETC interoperability is not meant to address out-of-State violations, it could help reduce the effort of collecting tolls by identifying out-of-State customers with ETC accounts that would not have been recognized by local toll agencies. From peer listening sessions conducted as part of this study, several agencies expressed the need for a national effort, such as a national agreement to pursue out-of-State violators, instead of individually determining piecemeal solutions among themselves.[24]

ELECTRONIC TOLLING BUSINESS MODEL

To fully understand the challenges and possible solutions, it is helpful to understand the primary ETC business model used in the toll industry. Virtually every transponder in the United States has been issued by some local tolling entity, typically the one most frequently used by a particular customer. In many cases, back-office operations and account management may be outsourced to third-party payment services; however, ownership of the accounts still resides with an individual agency. Even as statewide or regional interoperability agreements were being established, account ownership remained with individual agencies. As such, tolling interoperability involved periodic exchange of transaction and revenue reconciliation between home and away agencies, most commonly on a peer-to-peer basis. While this approach was viable within limited interoperability regions, extending it nationwide among more than 100 different agencies presents challenges.

The lack of national interoperability causes customers to be confused about which facilities accept their home ETC transponders and accounts. This can lead to violation fees for customers who are outside their interoperability region and assume their home ETC accounts are interoperable. The impact on businesses with fleets of vehicles, such as trucking and rental car companies, and on travelers who drive between interoperability regions is compounded because of the nature of their operations. Large vehicle fleets incur higher cost and level of effort for managing multiple accounts and ensuring vehicles have appropriate transponders and license plates associated with regional ETC accounts.[25] These direct and secondary costs are ultimately borne by the public, businesses, and the economy at large. Although no national statistic exists for the potential traffic between existing interoperability regions, an estimation of less than 1 percent of total traffic has been modeled and reflects industry feedback. Chapter 5 includes additional context on interregional travel.[26]

[24] Input obtained from vendor interviews conducted as part of the first peer exchange/listening session.
[25] Based on input obtained from vendor interviews conducted as part of the first peer exchange/listening session.
[26] CDM Smith's Nationwide Sketch Planning Model, 2015.

ENHANCED REGIONAL INTEROPERABILITY: THE STEPPINGSTONE TO A REGIONAL HUB-BASED NATIONWIDE INTEROPERABILITY MODEL

With the introduction of ETC, drivers gained the choice to use transponders and pay tolls with their registered toll accounts instead of using cash. However, toll agencies recognized that different transponder protocol technologies and non-connected back-office systems prevent drivers from using their ETC accounts to electronically pay tolls at neighboring facilities. ETC tolling incompatibility was a particular concern for regions with closely located toll facilities operated by different agencies, such as within Texas, Florida, and California, and in greater New York, New Jersey, and Pennsylvania. See chapter 5 for more details on interoperability regions.

> We want to continue to pursue partnerships with other agencies even if they aren't contiguous to the State. It is cheaper for us to have this partnership rather than to pursue violations.
>
> ~ Chris Tomlinson, Executive Director, State Road and Tollway Authority (SRTA)

Many toll agencies recognized the advantages of toll interoperability for themselves and their customers:

- **Provide seamless customer experience.** With a single toll account and transponder in vehicles, customers only need to recognize the electronic toll branding at toll plazas, such as the E-ZPass® purple logo or California's FasTrak® logo, to ensure they can pay tolls electronically at that facility.

- **Increase the share of traffic using ETC.** Electronic tolling greatly improves traffic flow and collection efficiency and costs a lot less than cash collection. It also eliminates the leakage risk (and high cost) associated with TBP in AET systems. Hence, agencies strive to maximize the share of traffic that uses transponders and make the same account acceptable on multiple facilities to encourage higher ETC usage.

- **Avoid sending out violation notices.** Agencies would rather collect tolls from interoperable registered customers than pursue the more expensive process of sending out violation notices for payment collection. Agencies also have a better probability of receiving revenue from registered customers than from sending violation notices to out-of-State customers. Customers benefit from using their electronic toll accounts on more toll facilities and not being charged typically more expensive cash or pay-by-plate toll rates.

- **Leverage common technology.** Due to early proprietary ETC technologies, agencies that wanted to be interoperable had to use the same technology or equipment vendors, including the same transponder protocol. This allowed customers to carry one transponder in a vehicle. In the case of E-ZPass®, toll agencies adopted the time domain multiplexing (TDM) protocol, while California legislated the Title 21 protocol. Other major transponder protocols used nationally are the TransCore SeGo protocol and the

International Organization for Standardization (ISO) 18000-63 (6C) protocol. But since ETC emerged with different technologies in different parts of the country, this also defined early limits on State and regional interoperability regions.

- **Fulfill legislative or regional mandates.** Toll agencies in California must abide by a 1990 legislative mandate (Senate bill 1523) for interoperability so that customers only use a single device in their vehicles to electronically pay tolls anywhere in the State. In other parts of the country, such as Colorado, regional agreements are in place where a single toll agency operates a regional CSC for multiple local toll agencies to save operational costs and make it simpler for customers to go to one place to open and manage their regional toll accounts. A regional CSC makes it more cost-effective to use the same transponder technology and have local toll systems interoperable with the regional CSC.

More recently, the toll industry has begun to shift focus toward expanded and enhanced regional interoperability. Nationally, several existing interoperability regions have formed over time. Some networks operate to serve different toll agencies within a State while others have expanded to multiple States. The E-ZPass® Group, the Central US Interoperability (CUSIOP), and southeast region are example of toll agencies interoperable across multiple States. California, Oregon, and Colorado are examples of States that are currently only interoperable across multiple facilities and toll agencies within their State boundaries. Key milestones in this progression to enhanced regional interoperability are described below:

- **Establishment of IAG**. One of the earliest, and still the largest, regional ETC networks is operated by IAG's E-ZPass® system. Originally established by multiple agencies in the greater New York, New Jersey, and Pennsylvania region, it has expanded across 18 States—from Maine to Illinois, and south to North Carolina—and has more than 42 million transponders in circulation. E-ZPass® members predominantly use the TDM protocol for their transponders. The original IAG, formed in 1990, included seven agencies in three States.

- **Establishment of statewide network in Florida**. In Florida, a Statewide network was established among several independent agencies. The largest agency, the Florida Turnpike Enterprise, part of the Florida DOT, operates the turnpike and several other expressway and toll bridge facilities. In total, there are about 18 million transponders in use in Florida. Several of the Florida facilities have shifted to cashless AET in recent years, including entire systems operated by the Miami-Dade Expressway Authority and the Tampa Hillsborough Expressway Authority. Recently, Florida embarked on a central back-office and clearinghouse operation that processed most ETC and TBP transactions. Florida became interoperable with toll agencies in North Carolina and Georgia in 2013 and 2014.

- **Establishment of statewide interoperability in California and subsequent change in protocol.** In California, Statewide toll interoperability was established through State legislation as electronic tolling was just beginning in the late 1980s. The legislation, known as Title 21, effectively defined the technology requirements and became the foundation for its own ETC protocol. The ETC technology was branded Statewide as

FasTrak. It also mandated all toll facilities in the State to be fully interoperable. Today there are about 6 million transponders in use statewide, and the number of participating agencies has grown to 13. The State pioneered the use of switchable transponders when Los Angeles County Metropolitan Authority (LA Metro) began operating high-occupancy toll (HOT) lanes in the Los Angeles area. The switch enables users to identify when a vehicle has three or more occupants, which entitles the vehicle to free, or discounted, toll levels along the system. As with most interoperable systems, ETC accounts are managed by the individual agencies, but all FasTrak Title-21 protocol transponders are usable on all toll facilities in California. In 2019, California regulatory changes mandated the adoption of the lower-cost ISO 18000-63 (6C) protocol and the full transition from the Title 21 by 2024.

- **Establishment of statewide interoperability in Texas.** Texas established full statewide interoperability, even though there are numerous independent agencies and several ETC transponder brands in use. The Dallas area toll system, operated by the North Texas Tollway Authority, was the birthplace of RFID electronic tolling when it initiated its TollTag® system. Currently, compatible TransCore, 6C, and SeGO protocol transponders are accepted at all toll facilities in the State. Texas, Kansas, and Oklahoma all became interoperable in 2019, establishing the CUSIOP Region.

Other States have either only one ETC operator within their States, or they have multiple different toll agencies, which is the case in Washington, Michigan, South Carolina, and Louisiana. Figure 8 shows the current ETC brands operational statewide or regionally. Each color denotes the State or region across which electronic tolling is currently interoperable.

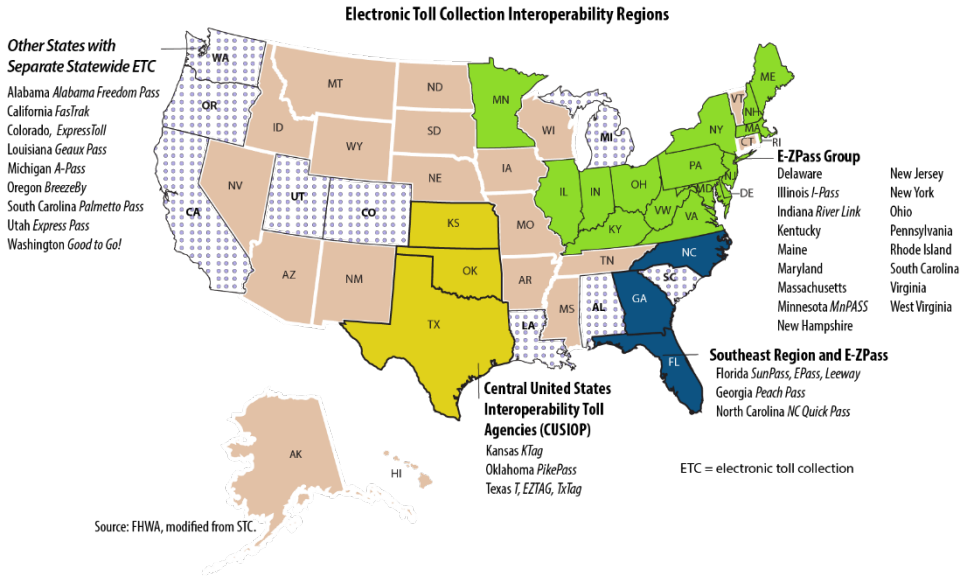


Figure 8. Illustration. Current electronic toll collection brands operational statewide or regionally.

As part of the enhanced regionalization process, many agencies are shifting from a peer-to-peer method of information exchange to a hub-and-spoke system for handling national interoperability. This will enable consolidated account management and data processing and

simplify data exchange within each of the four regions. The hub operators will facilitate interagency data transfers and transaction processing but will not replace back-office operations and ETC account management, which will continue to be the responsibilities of the member agencies. This process is discussed in more detail in chapter 5.

CURRENT APPROACHES TO ACHIEVING EFFECTIVE NATIONWIDE TOLL INTEROPERABILITY

Throughout the past decade, three approaches have emerged from different stakeholders within the tolling industry directed at achieving effective nationwide toll interoperability.

- Approach 1: regional hub model
- Approach 2: third-party payment services
- Approach 3: national interoperability clearinghouse

Regional Hubs

This approach connects existing interoperability regions by establishing new regional hubs to exchange data and process transactions and payments. It maintains the current agency ownership business model, where agencies continue to manage customer accounts directly. As planning for nationwide interoperability has progressed, this approach became the primary focus because it leverages and builds upon already existing regional interoperability regions. Challenges to overcome remain, which fall into two broad categories:

- **Roadside technology and vehicle identification.** The primary challenge with vehicle identification stems from multiple incompatible ETC technology protocols in use across the country. Transponders that can be read by some systems but not by others in different parts of the Nation create an issue that needs to be resolved on the in-vehicle and roadside technology ends. See chapter 4 for more details.
- **Business side of interoperability.** Several processes, standards, and protocols are associated with back-office processing, account management, payment guarantees, communications, and information exchange need to be harmonized across jurisdictions to effect nationwide interoperability. See chapter 5 for more details.

These challenges call for addressing both technological and institutional barriers to achieving interoperability and may entail initial and ongoing costs to make and maintain interoperable systems. Chapters 4 and 5 discuss this current trajectory towards achieving interoperability, the progress made to date and the timeline for achieving effective nationwide interoperability through this approach.

Third-Party Payment Services

These services operate in parallel with the primary ETC business model of agency-to-agency transaction and revenue exchange. It moves away from the agency ownership model to one in which transponders would be issued, and accounts maintained, by competing third-party payment services. These services would guarantee payments to toll agencies that accept the third party's ETC devices. However, the trend of third-party payment services managing individual

customers has the potential to alter the current business arrangement and eventually challenge the agency ownership model as these providers consolidate and expand their market share. Chapters 6 and 7 provide more detail on the developments in this approach.

National Clearinghouses

Under this approach, a national clearinghouse is responsible for transaction and revenue exchange to achieve interoperability. Individual agencies communicate directly to and from the clearinghouse, which is responsible for revenue redistribution and related functions nationally. This approach maintains the current agency ownership business model, where agencies retain customer accounts. The Alliance for Toll Interoperability (ATI) was established in 2008 to develop and administer the clearinghouse for its members nationally. ATI membership includes many toll agency members of IBTTA, but ATI is not directly part of IBTTA itself. It did eventually develop a national clearinghouse model, often referred to as the ATI Hub, but had limited success due to cost issues and other factors. There was little support from the toll industry for a national clearinghouse approach, in as much as this would so drastically impact the industry and alter the established interoperability regions. More discussion of the now discontinued ATI initiative is included in appendix A of this report.

CHAPTER 4. ROADSIDE VEHICLE IDENTIFICATION USING MULTIPLE TECHNOLOGIES

The issue of multiple incompatible ETC technologies will need to be addressed as the toll industry attempts to achieve nationwide toll interoperability. The cornerstone of interoperability is that all agencies correctly identify vehicles as they pass through electronic tolling points to determine the home agency responsible for ETC accounts outside the local area.

This chapter elaborates on the roadside technology issue related to nationwide toll interoperability and the potential means to address it. The chapter begins with background information on the need for accurate vehicle identification at tolling points in the age of AET. It provides historical background on the various ETC protocols and a review of toll industry efforts to address the issue through testing and research IBTTA. Finally, the chapter examines three methods that could be used to overcome the technology issue, summarizes feedback received through the peer exchange listening sessions, and discusses how nationwide interoperability can be achieved while still maintaining multiple transponder protocols.

AUTOMATIC VEHICLE IDENTIFICATION—A PREREQUISITE FOR ELECTRONIC TOLL ASSESSMENT

ETC technology has enabled a gradual shift from manual, cash collection to automated, electronic collection. Initially, vehicles equipped with ETC transponders shared toll lanes with cash vehicles. Gradually, exclusive ETC lanes were introduced, eventually leading to high-speed nonstop multilane electronic tolling. ORT emerged, with automated toll gantries open only to vehicles with transponders (see figure 9).

The cornerstone of all high-speed electronic tolling is the highly accurate and automated identification of vehicles passing under electronic toll gantries forms the basis of revenue collection, auditing, and accountability. All vehicles must be electronically identified and classified, and assigned the correct toll, to properly process cashless toll transactions.

Vehicle Identification Using Transponders

As ETC emerged in the late 1980s and early 1990s, no formal technology standards or protocols were established by the U.S. Government or the U.S. toll industry. This section identifies the various types of transponders currently available and in use across the United States that largely lack overlapping technology or functionality.

Figure 9. Photo. Vehicles driving under an all-electronic toll gantry on the Illinois Tollway.

Read-Only and Read-Write Transponders

Most transponder technologies in use are read-only, which means the roadside reader only reads information from the tag at the time of the transaction. Some transponders offer read-write capabilities, which means the roadside reader reads information from the tag, then transmits and writes information back to the tag within the same transaction.

Read-write technologies have mostly been used in ticket toll systems, where the toll charge is based on the distance traveled and the specific points of entry and exit. When a vehicle enters a facility, an equipment (reader) reads transponder information and writes an entry point number back on to the transponder. When the vehicle exits the facility, both the transponder account information and the point of entry from the tag are read to compute the proper toll. Most toll agencies using a ticket toll process now use computing logic to match stored entry and exit transaction data, eliminating the need for read-write transponders.

Switchable Transponders

In recent years, the toll industry has seen a significant growth in tolled express lanes, which are usually limited to vehicles equipped with valid transponders. Some of these facilities, often known as HOT lanes, offer toll-free use or reduced toll rates based on vehicle occupancy. In recent years, major HOT facilities in southern California and northern Virginia have resulted in the development of switchable transponders. These transponders allow the user to identify the number of vehicle occupants, which may offer toll-free HOT lane usage. Occupancies are usually field verified by agencies as well, but the switchable tag allows the system to automatically assess the proper toll. The transponder always remains active; the switching action only identifies when eligible for toll discounts. The same transponder is usable on other interoperable traditional toll facilities, too, but the occupancy data are simply ignored.

Proprietary and Non-Proprietary Transponders

In the absence of national standards for transponder technology, de facto ETC standards have emerged in different geographic regions as toll agencies procured and adopted transponder protocols developed by vendors. Many of these are currently in use. For example, in the northeastern United States, a protocol referred to as TDM became the standard supplied to the early members of IAG, which established the E-ZPass® region. The proprietary SeGo protocol is developed by TransCore and widely adopted by Texas and Florida toll agencies. The TDM and SeGo protocols are open source for free licensing by others.

Although proprietary protocols could be procured initially competitively, some toll agencies and States did not want to be locked into a single vendor long term. Changing transponder protocols would have been costly to switch out roadside equipment and potentially replace transponders that had already been distributed to customers. California established transponder technology standards through Title 21, a regulation that required from the outset in 1991 all toll agencies within the State to use the same technology.[27] Beginning in 2009, toll agencies in Utah, Georgia, Washington, and Colorado started adopting the ISO 18000-63 (6C) protocol adopted from supply chain logistic industries.

CURRENT TECHNOLOGIES IN USE IN THE UNITED STATES

At its peak, there were between six and eight protocols in use in the country, with regions embracing different protocols. In the United States, five ETC protocols are predominantly used. These protocols are largely incompatible and cannot be read by most readers of other protocols. Figure 10 shows the following transponders currently in use nationally:

- **TDM (became open source in 2013).** This protocol is used throughout the northeast, Atlantic Coast, and Midwest in the entire E-ZPass® system. It is, by far, the protocol used in the largest share of transponders, with approximately 42 million tags in circulation. It includes read-write capability, which has been important on some of the legacy ticket system turnpike facilities in the E-ZPass® network.

- **6C (non-proprietary).** The most rapidly growing protocol is 6C, a lower-cost sticker tag type transponder which has always been open source and available to all technology suppliers. It is now used in Washington State, Colorado, Georgia, Louisiana, Ohio, North Carolina, Michigan, and California.

- **SeGo (became open source in 2018).** TransCore developed the SeGo protocol by adapting the ISO 18000 6B protocol for tolling use. The TransCore protocols are dominant in Florida, with more than 18 million tags. This protocol also dominates in the southwest United States, including Texas, Oklahoma, and Kansas.

- **Title 21 (non-proprietary).** This technology is still in use throughout California. It is a read-only transponder that was also used in the past in Colorado. California will be

[27] California Code of Regulations Title 21, Division 2, Chapter 16 (§§ 1700 — 1707.1).

phasing 4.5 million transponders to the 6C protocol by 2024, but in the meantime all California agencies still accept Title 21 and 6C transponders at all facilities.

Figure 10. Photo. Electronic toll collection transponders used in the United States. (Counterclockwise from top-left: time domain multiplexing protocol interior tag; TransCore® SeGo protocol interior sticker tag; Title 21 protocol switchable tag; 6C protocol 3-position switchable tag; 6C protocol 2-position switchable tags; 6C protocol headlight sticker tag; 6C protocol interior sticker tag; bumper mount tag.)

THE SEARCH FOR A SINGLE NATIONAL TRANSPONDER PROTOCOL

IBTTA provides important connections between tolling developments in the United States and other nations, including trends related to ETC. As Federal initiatives concerning nationwide interoperability emerged in 2009, IBTTA formed a steering committee to begin planning for nationwide interoperability. After the passage of MAP–21, IBTTA formed the following four subcommittees:

- **Roadside Operations Subcommittee –** Deals primarily with transponder protocols and readers, of which there were more than six in use at the time the subcommittee was formed.

- **Back-Office Subcommittee –** Focuses on interagency financial transactions and information exchange standards.
- **Marketing and Communications Subcommittee –**Focuses on the need for national symbols and communications to support nationwide toll interoperability.
- **Governance Subcommittee –** Addresses issues associated with oversight and management of the interoperability effort.[18]

To overcome incompatibilities between transponder protocols and roadside tolling equipment, the IBTTA steering committee envisioned a selected national protocol that would become the protocol of choice for all toll systems and toll facilities. The process would involve most agencies choosing to use the selected technology. Any agency unable to use the selected technology could offer a second transponder to customers who wished to have nationwide interoperability. The second transponder would be readable on all participating facilities in the country. As existing systems were replaced over the years, it was expected that the United States would ultimately have a single, fully compatible technology in use across the country.[10]

In fall 2013, the steering committee issued a request for information from the vendor community, and in early 2014 the committee issued a draft *National Toll Protocol Requirements Document* for the country, soliciting comment from the vendor community and other stakeholders. Candidate protocols were nominated by toll agencies and vendors, and three protocols were ultimately selected: TDM and SeGo, because of their wide use in the United States, and ISO 18000-63 (6C) because of its cost-saving potential. By September 2014, the IBTTA board of directors formally adopted a refined document, including proposed business rules.[18] The board also recommended that toll agencies plan to make the future national protocol available by late 2016 to customers who wished to use it for tolling anywhere in the United States. The three candidate protocols were subjected to independent testing in a multiphased process that cost more than $2.2 million (see figure 11). FHWA provided about $1.5 million, after IBTTA responded to a Notice of Funding Opportunity in 2016.

In establishing a complex test plan, the Roadside Operations Subcommittee recognized that, at least during a transition period, introducing a single national protocol might now require systems to read two or more transponder types. The two technologies "must work together while retaining very high levels of accuracy." Testing was needed to verify that different combinations of protocols would not reduce reliability. This included laboratory trials and field testing, and incorporated three major parts:

- Part I: Handshake degradation and correlation testing
- Part II: Laboratory performance testing
- Part III: Field performance testing

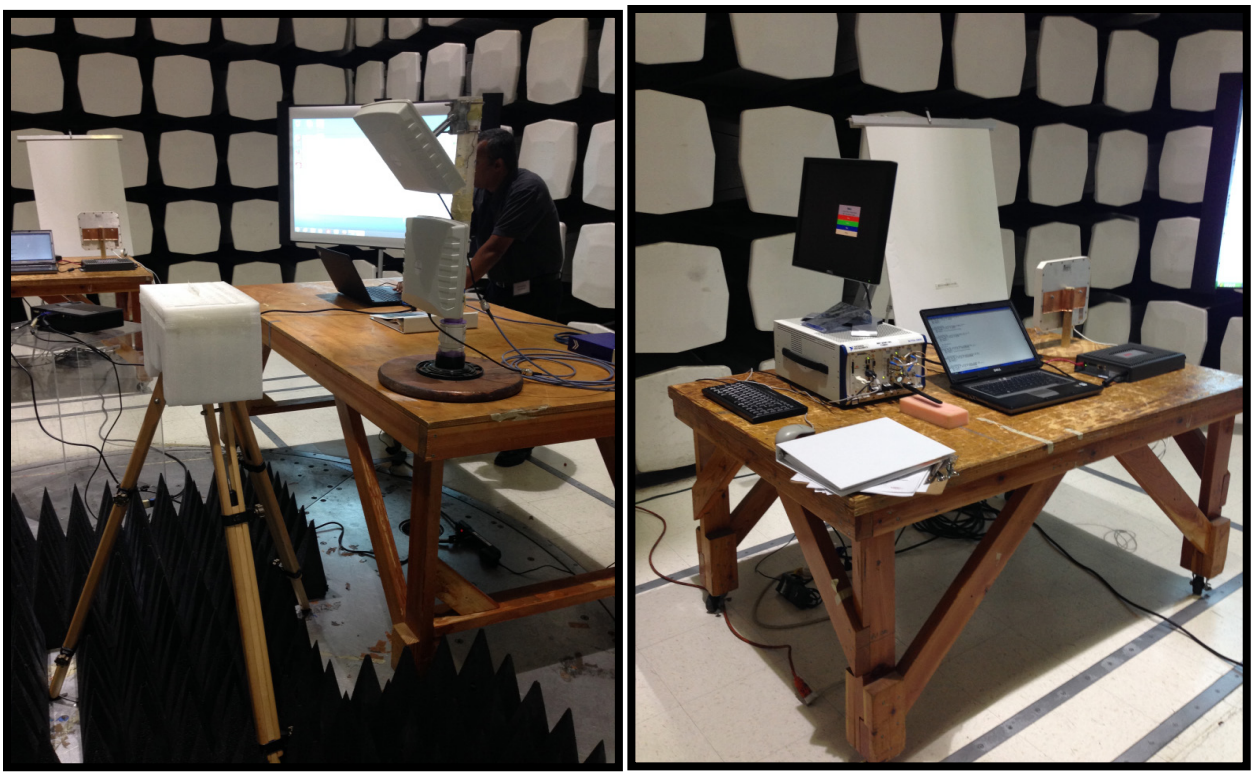


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Figure 11. Photo. OmniAir® equipment lab testing.

While the testing provided valuable insight, the IBTTA committee conducting this study did not select a single national protocol. The three candidate protocols all passed the tests, however, further testing did not occur due to inconsistencies between laboratory and field test results. According to IBTTA's 2019 report to FHWA:

> Although the laboratory testing process failed to generate a "national" protocol, the process and commitment needed to develop and conduct the testing had generated enormous, detailed information about the technical and operational requirements the toll agencies need to be able to 'read' and process ETC tags from other regions and operators.[28]

Cost Considerations for Transitioning to a Single National Protocol

A key reason why a single national protocol was not selected was a concern about the inequitable cost burden of adopting and supporting a single protocol for a nationally interoperable system. Toll agencies that were not using the selected technology would incur significant investment to transition to a new technology, while also managing the obsolescence of existing technology and infrastructure—possibly well before its useful life was over. As such, the act of choosing a

[28] International Bridge, Tunnel and Turnpike Association. (2019). *U.S Tolling Industry Interoperability Efforts.* Federal Highway Administration (unpublished).

protocol would unequally distribute the cost burden, with some agencies incurring no cost and others significantly investing to support what is often a tiny fraction of out-of-state traffic.

Some of the cost considerations of supporting a new single national transponder protocol are described below:

- **Roadside equipment:** Retrofitting lane equipment includes installing and tuning compatible AVI readers (approximately $12,000–$15,000 for new hardware alone at current market rates). Upgrading lane controller software could cost hundreds of thousands of dollars, depending on the configuration of toll points. Closing a toll lane has direct financial costs, but also causes inconvenience to the driving public. When lanes are closed, congestion ensues, and the public typically voices legitimate concerns. Toll lanes are closed as part of technology upgrades, and these technology upgrades are carefully planned and often include updating the camera technology, the detection system, and other elements.

- **Back office:** Change in transponder protocols also requires upgrades to back-office toll system functionalities, databases, reports, and system logic. For instance, protocols have different data formats (e.g., transponder ID field length), and toll agencies need to be able to inventory transponders of different protocols separately. System changes also incur cost for implementation, oversight, and testing. Back-office changes to support adding a new protocol could add hundreds of thousands of dollars to a new or more recently installed back-office system. Alternatively, toll agencies with legacy systems incapable of being upgraded could be forced to procure entirely new back-office systems, potentially costing several millions of dollars.

- **Replacement of transponders:** Although toll agencies can keep their local transponder protocols under the IBTTA approach, the eventual shift to a single national protocol has multiple cost implications. Some toll agencies may need to swap out their customers' legacy transponders, especially those located close to other toll agencies using the national protocol. Besides the cost for the new transponder, swap-out costs include shipping, handling, packaging, and potential return and proper disposal of old battery transponders.

- **Marketing and communications:** Costs will likely be incurred to communicate and implement an exchange of equipment with the traveling public, and to implement systems for enabling returns and issuing new devices at a large scale.

- **Potentially more costly new protocol:** Depending on which protocol is selected, the single national protocol could be more expensive than the one it replaces, thereby adding a long-term cost burden to toll agencies and customers. For instance, non-switchable ISO 18000-6C sticker transponders have been procured for as low as 47 cents per transponder, while TDM and SeGo transponders are approximately $7–$8 per transponder. If toll agencies currently using 6C switch to a more expensive protocol, transponder acquisition costs could be in the millions annually.

As a high-level hypothetical approximation, based on minimal upgrade of lane equipment and back-office toll systems, the upfront cost of converting to a national single protocol could conservatively be $900 million to $1.1 billion. Out of the 129 toll agencies in the United States with a combined 346 toll facilities, not all toll facilities would need to be upgraded because some of them would already be using the selected national protocol. Other assumptions include:

- **Upgrading lane systems, back offices, and CSCs ($300 million)** – Assuming that most toll facilities have multiprotocol readers, lane system upgrades could be reduced to minimal hardware and firmware upgrades, tuning, and testing, instead of wholesale system replacements. Back-office host systems would need software updates such as database, interfaces, and reporting changes. While CSC costs include procedural changes and handling customer inquiries.

- **Swapping to the 6C protocol only ($600 million)** – Assuming that customers with transponders using either the TDM or SeGo protocols will need to be sent replacement 6C transponders. Costs include price of new transponders, shipping and handling, and cost for disposal of batteries from TDM transponders.

- **Swapping to the TDM protocol only ($650 million)** – Assuming customers with transponders using the 6C or SeGo protocol will need to be sent replacement TDM transponders. Costs include price of new transponders and shipping and handling.

- **Swapping to the SeGo protocol only ($850 million)** – Assuming customers with transponders using either the TDM or 6C protocols will need to be sent replacement SeGo transponders. Costs include price of new transponders, shipping and handling, and cost for disposal of batteries from TDM transponders.[29]

These high-level estimates do not consider the cost of transitioning to a more expensive transponder in the long term, such as going from the less expensive 6C protocol to the costlier TDM protocol.

Evaluating the above considerations could indicate the overall cost of shifting to a single national protocol. However, any entity developing a reliable analysis of costs would have to begin by resolving which protocol would become the selected national protocol. That one decision would govern not just the unit quantities and costs of some of items outlined above, but also the infrastructure, back-end, implementation, and phasing costs that would be incurred by specific agencies across the country.

[29] The transponder swapping cost analysis was developed based on the following data sources for a number of existing transponders in circulation: [i] SeGO, Florida: 18.1M transponders based on Florida Department of Transportation, Enterprise Toll Operations, FY2019 Annual Report (2019), page 14. Overview available at: https://floridasturnpike.com/wp-content/uploads/2020/04/02_Overview-1.pdf; [ii] SeGO, CUSIOP: 16.6M from David Hoffman, North Texas Tollway Authority as part of data gathering prior to the peer exchange listening session on February 1, 2021; [iii] TDM: 41.7M from the E-ZPass® website. https://www.e-zpassiag.com/about-us/statistics; [iv] 6C: 7.7M from Mark Parry, Utah Department of Transportation, 6C Coalition Presentation, 6C Coalition Annual Meeting, April 3, 2020.

ACHIEVING ROADSIDE TOLLING INTEROPERABILITY

The effort to select a national protocol was not without its breakthroughs. It made toll agencies realize they did not need a single national protocol to achieve national ETC interoperability, and that it was viable to keep the three candidate protocols as other protocols were being phased out. By recognizing and testing the three candidate protocols, toll agencies were able to identify a common set of transponder protocol requirements and performance levels. Arising from a parallel effort by toll agencies developing the framework of connected interoperability regions, toll agencies using TDM, 6C, and SeGo are now coordinating on programming of transponders. This includes issuance of agency IDs and transponder ID fields so that any transponders can be uniquely identified and read by any toll agency. Furthermore, the single national protocol effort has led toll agencies to start discussing national approaches to transponder and reader equipment certification and standards setting.

> The E-ZPass Group has several initiatives underway that will advance the cause of interoperability. Firstly, most E-ZPass members are anticipated to install multiprotocol readers at their facilities by 2023. Secondly, we are working on the procurement of an IAG Reciprocity Hub, which would provide operational efficiencies and the ability to connect to other regional hubs in order to further advance interoperability. Lastly, the E-ZPass group continues to expand its own membership, which is currently 19 states with several others in initial stages of discussion. This growth also advances the cause of interoperability.
>
> ~ P.J. Wilkins, Executive Director, E-ZPass

A key aspect of the technical acceptance of the three protocols is that a combination of tolling technologies has significantly improved in recent years to provide toll agencies cost-effective, accurate, and reliable methods for identifying ETC customers. Some of these technology trends are described below.

> Educating customers to make sure they include license plates on the accounts so they can be billed on an interoperability transaction is important. Our customers hate paying tolls but they love the PIKEPASS and they love the interoperability. We are all-in for nationwide interoperability.
>
> ~ David Machamer, Assistant Executive Director, OK Turnpike

Automatic License Plate Recognition

ALPR creates a technology solution for some agencies to overcome the multiprotocol challenge. Toll agencies can use license plate images instead of the transponder reading to identify vehicles from outside their local interoperable region, without needing to install multiprotocol readers (see figure 12).

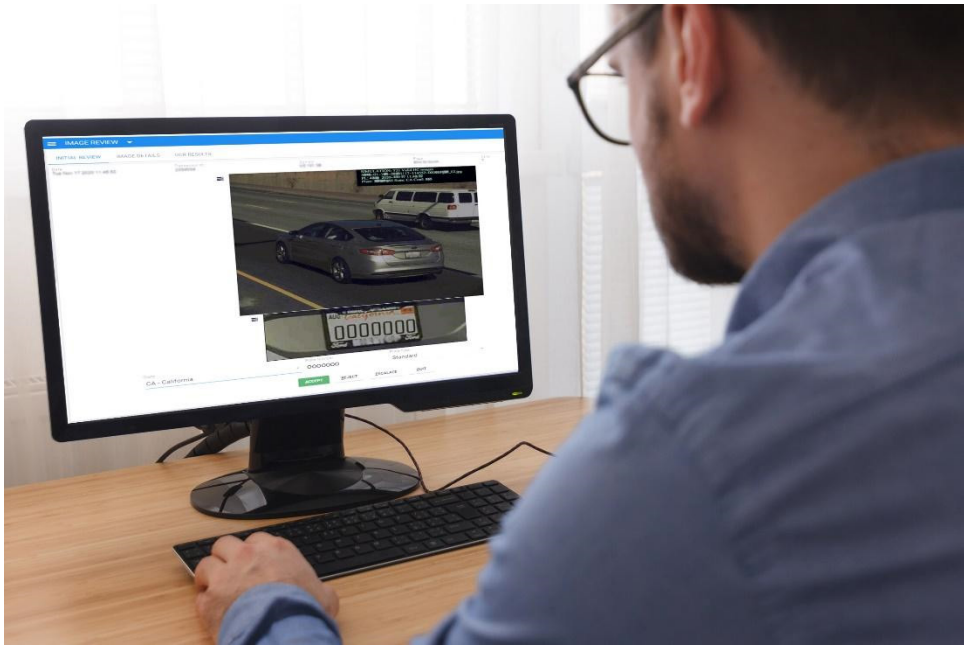
Not all toll facilities have ALPR technology. Some toll agencies still accommodate electronic toll transactions within traditional toll lanes, and a few even use toll gates for ETC enforcement. These agencies did not historically need to invest in video enforcement. Implementing this solely as a workaround to support multiple transponder protocols could add significant costs for a

relatively smaller benefit of recognizing away account revenues. However, the industry has been trending toward AET, which necessitates that toll agencies implement ALPR. As discussion of a national protocol selection occurred in the mid-2010s, several large E-ZPass® toll agencies, such as the New York Thruway and Metropolitan Transportation Authority, started conversion to AET, thus helping spur greater acceptance of ALPR adoption.

Multiprotocol Readers

At the outset of ETC, reader technology was limited to accurately reading a single protocol at a time. However, multiprotocol readers enable toll agencies to become interoperable despite their continued use of different protocols. Multiprotocol readers present unique challenges that relate to the environment in which electronic tolling operates. Three key realities are discussed below.

- **High speed of vehicles passing through a toll zone.** An electronic toll transaction includes several communication steps between the transponder and the antenna/reader system. These steps include recognition, or handshakes, reading tag content, writing content back to the tag (in certain cases), and transponder validation. In a typical AET application, vehicles passing through a toll zone at 70 miles per hour move about 100 feet per second, which means the above steps must be accomplished in no more than 0.2 seconds.[21]



Source: FHWA.

Figure 12. Photo. License plate reader user screen.

- **Multiple vehicles simultaneously passing through a toll zone.** In a multilane cashless environment, several vehicles pass the gantry at the same time, and they may be of different sizes and classifications, which determines the toll rates they are charged (see figure 13). When multiple transponders are read at nearly the same time, the toll system needs to properly link each transponder to the appropriate vehicle, even if the vehicles

shift between lanes while passing the toll point. The multiprotocol reader does not know which type of transponder with which the vehicle is equipped. As a vehicle approaches the toll point, the multiprotocol reader will cycle through trying to read each of the different protocols. It is important this does not slow down the process such that the vehicle has moved beyond the tolling zone before its transponder's protocol can be read correctly.

- **Multiple transponders in a single vehicle.** In some cases, a single vehicle may have more than one transponder (see figure 14). This is common with trucks that travel among jurisdictions using different transponder protocols. Historically, only one of the transponders would be readable at a given toll facility. For example, a vehicle from the northeast United States may have E-ZPass® as its primary transponder. But the driver may also have a SunPass device for frequent visits to Florida. In the past, the E-ZPass® would not be read in Florida, and the SunPass would not be read in the northeast. When multiprotocol readers are installed, ETC readers can now read both transponders. Agencies would need to ensure that only one of the transponders is charged. They typically establish back-office procedures that prioritize charging, usually giving highest priority to the home agency system. As toll agencies introduce multiprotocol readers, this problem can become significant, at least during the transition process. However, as more agencies shift, and nationwide interoperability is more firmly established, the need for multiple technologies on one vehicle could disappear.

Figure 13. Photo. High-speed toll collection gantry.

For more than a decade, multiprotocol reader technology has been available and able to accurately read any two protocols at a time. However, their widespread deployment for interoperability has been limited because some widely used protocols were proprietary, barring competing protocols from being used on a competitor's multiprotocol reader. For instance, TDM

and SeGo were proprietary protocols owned by different vendors. They could not be used together on the same multiprotocol readers made by either vendor. This effectively prevented toll agencies in Florida, which used the SeGo protocol, from using multiprotocol readers to read E-ZPass® customers equipped with TDM transponders, and vice versa. The lack of standards and certification programs for multiprotocol operations also hampered adoption since toll agencies had to invest in greater testing efforts to ensure accuracy of their systems. There is also the cost of acquiring new technology and upgrading infrastructure. Today, there are at least four companies providing multiprotocol readers to the U.S. toll industry, all of which read the major protocols in use, including TDM, ISO 18000-63 (6C), and SeGo. More recently, new technologies have been developed that can simultaneously and accurately read all three protocols. These technologies enable operators to read transponders that use any of the three leading national protocols in use in the future.

Many operators in the United States have already converted to multiprotocol readers able to read two protocols. Several operators plan to adopt multiprotocol readers that accurately use the three leading national protocols by the end of 2021.[30]

Figure 14. Photo. Multiple electronic toll collection (ETC) transponders mounted to a vehicle windshield to enable driving through different ETC regions. (From top: TxTag SeGo protocol tag from the Texas Department of Transportation; time domain multiplexing protocol tag from E-ZPass® Group.)

Multiprotocol Transponders

Another way to address the multiprotocol issue is to provide transponder technology that incorporates more than one ETC protocol in a single onboard unit (OBU) in the vehicle. Transponders with two protocols have been in use for a few years. More recently, multiprotocol transponders have become available, making use of all three protocols that will remain in use in

[30] According to input received from the toll agencies' peer exchange/listening session, April 1–2, 2020.

the future. These include devices built into new vehicles, referred to as an Integrated Toll Module® (ITM®).

Over the past few years, a few agencies have offered multiprotocol transponders as an option to their customers enrolled in ETC tolling programs. As new toll facilities were developed in North Carolina, the roads were opened as cashless and all-electronic. The North Carolina Turnpike Authority (NCTA) offered customers a choice of transponders. One of the choices was a multiprotocol transponder supplied by TransCore, known as E-ZGo Anywhere. It included both TDM and SeGO protocols and was interoperable with the E-ZPass® system. The standard NCTA tag was a lower-cost SeGo sticker tag tailored for the NCTA system but was also compatible with systems used in Florida and Georgia. In 2018, NCTA became one of the first toll facilities to install multiprotocol readers. Today the system can properly read TDM, 6C, and SeGo technologies. More recently, the Central Florida Expressway Authority (CFX) began offering a Uni tag version of its E-Pass transponder. The dual-protocol transponder includes both SeGo and TDM technologies and is usable throughout Florida and the entire 17-State E-ZPass® network. CFX had previously installed dual-protocol readers and was the first Florida agency to accept E-ZPass® transponders. Within Florida there are multiple transponder brands, with SunPass the most dominant.

All agencies use the SeGo protocol (or other TransCore protocol) and all transponders in the State are readable and accepted at all toll facilities in the State. However, the Uni transponder is readable throughout the entire E-ZPass® network as well. More recently, the Florida Turnpike has announced that it, too, will join the E-ZPass® system, and will accept E-ZPass® transponders.

Multiprotocol transponders and multiprotocol readers would create the case where a vehicle effectively has three devices, all of which can be simultaneously read by roadside readers.

A Single de facto Protocol

> For North Carolina we are very supportive of MAP-21. We use tri-protocol (TDM, SeGO, 6C) readers... It seems that 6C is the de facto national protocol everybody agreed [to] but it isn't official yet.
>
> ~ J.J. Eden, Executive Director, North Carolina Turnpike

Although the 6C protocol has a relatively small proportion of the current transponder population, many toll agencies are rapidly procuring and adopting it. As a non-proprietary protocol used by 28 other industries, including supply logistics and airlines, its technology maturity and cost of transponders convinced Utah, Georgia, and Washington toll agencies around 2010 to adapt it for tolling. The 6C sticker transponders cost less than $1, enabling toll agencies to make the business case that they can quickly recoup the cost of transitioning and reap millions in savings over the long term. The 6C Coalition, formed in 2012, is the 6C tolling user group that created and maintains 6C standard for tolling and has developed a tolling-specific certification program. The combination of a published standard and a product certification program reduces implementation risks and cost of testing for toll agencies. The 6C Coalition started with Utah Department of Transportation, SRTA, E-470, and WSDOT and has now grown to more than 40 members. Toll agencies in

Florida, CUSIOP, and E-ZPass® are in the process of procuring 6C transponders and compatible multiprotocol readers. Although toll agencies still have a large installed base of their respective protocols, long-term 6C's cost competitiveness and proven technology could become the national de facto protocol of choice due to market forces.

FEEDBACK ON TECHNOLOGY ISSUES FROM PEER LISTENING SESSIONS

The peer listening sessions with toll agencies, conducted as part of the study in April 2020, provided valuable input about tolling technology challenges. Toll agencies reported experiencing several challenges with TBP, especially with collections and violation processing across State lines. Participants confirmed an overwhelming preference for transponder-based solutions, even if it implies additional investment in new technology to accommodate.

Participants also recognized a need to move the interoperability efforts forward with the three preferred protocols: TDM, 6C, and SeGo. A clear majority of operators indicated their intent to install multiprotocol readers, with some reporting they have done so already. California toll agencies discussed the replacement of Title 21 transponder technology with 6C transponders, a transition that will take place over several years. This will eliminate yet another protocol in use today, reinforcing the ultimate consolidation to the three protocols. In the meantime, both Title 21 and 6C transponders can be read in toll lanes statewide.

Participants also are increasingly accepting of third-party mobile payment applications. These applications are largely a result of cashless AET collection and frustration with the difficulty of video toll enforcement and collections across State lines.

KEY TAKEAWAYS ON TECHNOLOGY ASPECTS OF ELECTRONIC TOLL COLLECTION INTEROPERABILITY

Key takeaways regarding the technology aspects of ETC interoperability, as presented in this chapter, are summarized below:

- Several different transponder protocols have been in use across the country over the years, each mostly incompatible with the others. This is a major stumbling block standing in the way of the vision that one ETC account will work everywhere in the country.

- In its efforts over the last decade, the IBTTA interoperability committees sought to solve the technology problem of multiple incompatible protocols by trying to identify a single national ETC protocol, including extensive comparative testing. Ultimately, no single protocol was selected, but the industry did settle on a final set of three protocols for the future: TDM, 6C, and SeGo.

- At least three solutions to overcoming the lack of a single protocol are technologically feasible and are currently being explored. These include multiprotocol readers, multiprotocol transponder, and the use of license plate imaging for away agency vehicle identification. Additionally, the rise of the adoption the non-proprietary cost-competitive 6C protocol leaves the possibility of eventual transition to a single national protocol open. As newer agencies adopt 6C and older agencies are able to make a successful business

case for transition as per their assets' lifecycle needs, it could become the de facto protocol of choice nationally.

- Based on recent trends, and feedback from the industry peer listening session, it is becoming clear that the majority of the toll agencies are electing to install multiprotocol readers (i.e., readers that will be able to accurately read all three of the surviving ETC protocols).

- The use of multiprotocol transponders, including built-in integrated transponder modules in new vehicles, will likely co-exist, but will not become a formalized industry solution.

- While the U.S. toll industry will not have a single national ETC protocol in the foreseeable future, new technologies can be used to overcome the problem, and this will not impede the ultimate attainment of nationwide toll interoperability.

CHAPTER 5. BUSINESS SIDE OF NATIONWIDE TOLL INTEROPERABILITY

The introduction of ETC on toll facilities in the United States necessitated development on the ability to manage accounts, handle electronic financial settlement, and provide customer interface systems, often collectively referred to as back-office operations. Each ETC toll customer typically opens a prepaid account with a home agency and is issued one or more transponders for individual vehicles. As toll transactions occur, the toll amount is deducted from account balances. In most cases, balances are automatically replenished when they reach predefined levels through linkages to credit cards or bank accounts.

Electronic toll interoperability then involves the exchange of transactions between away and home agencies and ultimately the transfer of revenue. The exchange of information between agencies, and particularly between disparate interoperable States and regions, introduces challenges that need to be addressed before nationwide interoperability can be achieved. These issues are collectively referred to as the business side of interoperability.

This chapter introduces the basics of toll collection back-office operations, and it describes typical account structures, account management techniques, linkages with various external financial instruments, and customer interface. It then delves into interagency interoperability procedures and business rules and information exchange methods. A cornerstone of interoperability involves ETC payment guarantees between home and away agencies. This can require extensive, continuing information exchange between agencies to identify valid accounts, vehicle plate numbers, and more.

The chapter then presents challenges with the regional hub approach regarding business-side transactions such as interstate enforcement and collection, privacy, institutional issues, governance issues, and differences among agency policies and business rules. The chapter also summarizes input from toll agencies and operators obtained through the peer exchange listening sessions. It then presents the emerging toll industry consensus on how nationwide toll interoperability will be achieved in the future, from the back-office and business side-perspective.

OVERVIEW OF ELECTRONIC TOLLING BACK OFFICE

Typical Electronic Toll Collection Transaction Flow

Electronic tolling shifted from direct customer interaction in toll lanes and toll plazas to a complex network of electronic payment transfers and account management, generally referred to as the back office. Almost all ETC accounts in the United States are issued and managed by some local agency, generally referred to as the home agency. When toll customers enroll in ETC, they typically open an account with a local toll agency. They are issued one or more RFID transponders to be mounted on their vehicles for use in tolling. While there are small variations, almost every ETC account is owned by an existing toll agency. That agency is responsible for managing the account, including posting of toll transactions against prepaid account balances, and providing opportunities for customer interface to handle payments, disputes, and customer inquiries.

When opening a typical ETC account, the customer provides a name, address, identification of the vehicle (or vehicles) associated with the account, and, in most cases, a credit card or bank account for automatic account replenishment. Agencies provide customers with many types of accounts or other ways for customers to pay tolls. Virtually all traditional ETC accounts involve prepayment of tolls, established at the time the account is opened. While the prepayment amount can vary among agencies, or by customer choice in some cases, a minimum balance threshold is typically established. When the remaining balance drops below this threshold, the account is automatically replenished using an electronic linkage to a credit card or bank account. Other variations include post-paid accounts, where the customer pays a monthly invoice, or accounts where the customer provides a credit card the agency charges for each toll transaction.

The agency then gives or mails the transponder(s) to the customer who mounts the tag on the vehicle windshield or affixes the sticker tag, per agency-provided instructions. In many cases, tag distribution has become a retail process, in which a customer purchases the tag at a retail outlet. The tag only becomes valid after the customer sets up the account and establishes funding. In these cases, the customer opens the account online or otherwise through a CSC, then enters the unique tag ID number from the purchased tag, which then links the tag to the account. Under either approach, the related vehicle license plate number is also added to the account.

A single ETC account may have more than one transponder associated with it. Each transponder has a unique tag ID number, and that tag ID is then linked to the specific account. In addition, customers will also be asked to provide license plate information for the vehicle for which each transponder will normally be associated. Hence, in most cases, the ETC account will have both the tag ID and the license plate number (including State of registration) for each vehicle associated with the account. This enables the vehicle to be identified though either proper reading of the transponder by roadside readers, or by means of license plate imaging when no valid transponder has been read. In theory, either the transponder ID or the license plate number can be used for transaction processing, although the tag ID is given priority.

At the tolling point, the following describes the actions and decision progression on most AET facilities:

- **T1 (tolling point):** The transponder reader detects the tag in the vehicle and associates it with the respective account. As each ETC transaction is recorded at a tolling location, a transaction message is generated and electronically sent to the back office for processing. Each transaction message will include the date, time, and location of the toll transaction, as well as the vehicle classification and the proper toll charge amount. Based on the tag ID, the proper ETC account is identified, and the toll charge is deducted from the current prepaid balance in the account.

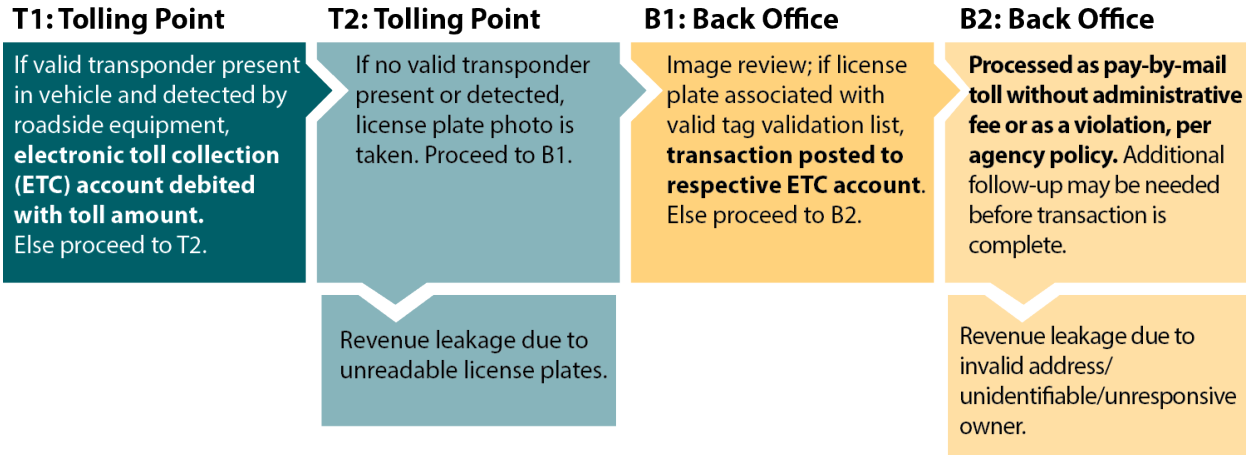
- **T2 (tolling point):** If a vehicle is not associated with an account or is not carrying the device that allows for such association, the toll agency takes an image of the vehicle's license plate to identify the owner of the vehicle passing a toll point.

- **B1 (back office):** The toll agency extracts the license plate information from the image, either through an automated or manual process, and either matches it to an account or

sends the license plate information to the State's DMV, or to a private firm, to find the name and address of the vehicle's registered owner.

- **B2 (back office):** Depending on a toll agency's policies and business rules, a bill or violation notice is sent by the toll agency to the vehicle's registered owner to collect the unpaid toll and additional processing fees.

Figure 15 presents the typical high-level decision flow for ETC. Most agencies represent this at a detailed level as a system transaction flow chart, indicating specific business rules and policies for each step. Examples of such specific rules include number of invoices sent before a transaction is deemed unpaid, number of days after which an unpaid invoice is assessed a late-payment charge, and whether a pay-by-mail transaction is processed as a violation or assessed a separate cash toll rate. These policies and business rules may differ across jurisdictions and may evolve or change over time for a specific agency or operator.



Source: FHWA.

Figure 15. Diagram. Transaction decision flow for electronic toll collection.

In recent years, toll authorities in some regions have established consolidated back-office systems, serving multiple agencies in the region. These are collectively treated as a home agency within the system, but each account is still associated with the single agency in which the account was initiated. In most cases, individual agencies operate separate back-office systems.

Account Management

The typical back-office system involves a network of computers and workstations used to manage thousands (or millions) of ETC accounts. Many toll agencies outsource back-office operations to third-party vendors, although some back-office operations are managed and operated by toll agency staff. The typical setting includes automated ETC transaction posting and account monitoring, as well as units for license plate image review and processing. This section describes some of the functions associated with account management in a typical back office.

A key element of ETC account management is constant monitoring and maintenance of proper status for each account, and for each associated transponder. Under normal circumstances, most accounts show a valid status, but this can then change. For example, if the account balance drops

to (or below) $0, the account status is designated negative balance. This can occur for various reasons, such as when the linked credit card is no longer valid. It is important for agencies to establish proper business rules in this case because it can be common for an account to temporarily go negative when a high toll charge hits the account, but before a routine account replenishment has occurred. It is important that agencies establish policies regarding the acceptability of a transaction, even when the account has a small negative balance. This may vary from agency to agency.

Some transponders may be reported as lost or stolen, or accounts may simply be closed. This alters the status of the account and associated transponder and licensed plate numbers. Hence, all agencies maintain frequently updated lists of valid accounts and devices, often referred to as TVLs.[17] These lists are important to the interagency interoperability process. TVLs are usually updated daily. In some cases, daily differential validation lists are prepared. These list all accounts and transponders that have changed status within the prior 24 hours. It is important to recognize that because the accounts include any transponders and vehicle license plates associated with it, when an account status changes, the status of associated tags and plates also changes. TVLs are frequently transmitted to each agency tolling location, as well as any interoperable agencies. This enables the validation of each transponder at the time it is read at the roadside.

Image Review and Violation Processing

When vehicles use exclusive ETC lanes, or any lane on fully automated AET systems, and no valid transponder is read by roadside equipment, a license plate image transaction is created and sent to the back office for processing. Part of a typical back office is set up for processing these video transactions, which can either become violations, pay-by-mail transactions in AET systems, or converted to effective ETC transactions by association with valid ETC accounts. Most video transaction images are machine readable, using optical character recognition, while some require human review and interpretation.

Before either a violation or pay-by-plate invoice is sent, the plate number is first checked against the full inventory of license plates associated with valid ETC accounts. This may be in accounts managed by the home agency, or valid tag lists from other interoperable agencies as well. If the license plate number (and appropriate State of registration) is found on an ETC valid list, the license plate image transaction is usually converted to an ETC transaction, and the toll charge is deducted from the ETC prepaid account balance as if it were a direct-read ETC transaction.

If the plate is not found in the valid list, it is treated as either a violation or pay-by-plate transaction depending on the business rules. Video tolls are typically only billed to customers on cashless all-electronic toll facilities, where all vehicles are permitted through the automated toll point with or without a valid ETC account. In all other cases, only vehicles with valid transponders are authorized to use these lanes; hence the video transaction is considered a violation. Agencies have different policies for handling violations—some may not send a notice until multiple violations are recorded, while others may send separate notices for each violation. In most cases, violation notices include appropriate administrative fees in addition to the unpaid tolls.

Violation enforcement and associated collections and fee payments are considerably more challenging for out-of-State vehicles. The same is true for valid pay-by-mail toll bills sent under an AET system. Most States include some form of disincentive for non-payment, such as denied renewal of vehicle registration, until back payments have been made. But these arrangements rarely extend across State lines. This was a common concern expressed during the peer listening sessions conducted as part of this study.

Figure 16. Photo. State Road and Tollway Authority walk-in customer service center, Atlanta.

Customer Interface

Another typical element of back-office systems is customer interface. This encompasses various means of communicating with ETC customers and provides services related to opening and closing accounts, transaction dispute processing, replenishing negative balance accounts, overall support in managing customer accounts, reporting lost or stolen tags, updating credit card or bank linkages, and other forms of updating account information. Various channels are provided for customer interface, including walk-in CSCs, telephone call centers, online services, and kiosks.

Most agencies also offer anonymous accounts, in which account balance replenishment is often made in cash. Customer services centers, as shown above in figure 16, and remote kiosks provide this type of opportunity. A few agencies, such as the Central Florida Expressway System, have designated previously cash toll lanes for automated account replenishment, as the demand for cash transactions has declined in the face of ETC growth. Customer feedback surveys conducted by various toll authorities (such as SRTA, WSDOT, and TCA) indicate that anonymous accounts are very limited in the toll industry; most customers prefer the convenience of automatic account replenishment when balances drop below target minimums.

Additional Back-Office Functions

Other back-office functions include setting toll rates, proper financial audits, interfacing with other agency ledgers and record systems, credit card clearinghouses, and financial settlements with other interoperable agencies. It generates various management and statistical reports, monitors tolls system performance and maintenance needs, and provides for overall system security and other administrative functions.

In addition to credit card and bank clearinghouses, the typical ETC back office may also integrate with other external financial instruments. For example, many agencies allow their transponders to be used for other payments, such as airport parking charges. In most cases, these transactions are handled separately from the ETC prepaid balances for toll charges and may require a separate customer authorization. It would not be unusual, for example, for a charge of $50 or $100 for several days of airport parking. This charge would typically be applied as a direct credit card charge to the account linked to the ETC account, but it would not be deducted from the prepaid toll balance.

Back offices also handle revenue transfers from certain third-party payment service accounts, such as rental car companies and certain truck tolling arrangements.

INTERAGENCY INTEROPERABILITY AND BUSINESS RULES

Typical Interagency Business Rules

For tolling agencies, business rules are a set of instructions for how the tolling system takes data from the lane and processes the data as transactions or violations. Depending on the type of tolling facility, these rules may include vehicle classification, toll rates, trip building, toll discount plans, high-occupancy vehicle discounts, account handling, and mailing of notices of violation or tolls.

Each agency tends to have its own set of legacy some going back decades. It is uncommon for two agencies to have identical business rules. It is for this reason that interagency interoperability agreements containing a unified set of procedures and business rules are key to achieve reciprocity between agencies.

Interoperable back-office business rules typically include:

- **General requirements.** These detail broad rules that each participating agency adheres to, such as the requirement that all agencies provide time synchronization to a National Institute of Standards Technology time source.
- **Account requirements.** These describe how IAG handles account issues, such as associating one account with multiple transponders.
- **Marketing activities.** Because of the interconnectedness among agencies, each agency keeps the others notified of marketing activities associated with IAG.
- **Reconciliation and settlement.** These describe how the home agency reconciles transactions from away agencies, and vice versa. These rules may describe how reconciliation occurs between the hubs—for example, participating agencies must reconcile at an agreed-upon frequency. They also describe how the hub and local agency reconcile transactions. The rules would also detail how reconciliation issues and disputes among agencies are handled, such as disputed tolls, transaction fees, and settlements.
- **Reporting requirements.** These help ensure traceability, these rules detail how the agencies demonstrate that data have been transferred and received.
- **Performance requirements.** These help ensure that agencies send their transactions, settlements, and other data in a timely manner.
- **Testing requirements.** These help ensure all agencies participating in the interagency agreement meet the same minimum operational standards.
- **Notification of updates and maintenance.** These requirements detail how notification occurs to agencies and hubs, should they need to modify their tolling systems or operations or conduct maintenance activities. For example, all agencies must provide a minimum of 30 days' notice to the other hubs and agencies when scheduled maintenance activities may impact another agency or the processing of transactions.
- **Data exchange.** The business rules regarding data interchange may be included in the interagency agreement or contained in a stand-alone document.

Interface Control Document

For tolling, an ICD for software and systems engineering describes all interface information produced by a toll system and any external system connected to it. ICDs also describe the interfaces between subsystems or to a system or subsystem. In this report, the ICDs described would be for information exchange among interoperable agencies, regional hubs, and with their respective CSCs. ICDs for interagency CSCs detail the interface file and reporting specifications and define the formatting for every file and report exchanged among CSCs. The interface file permits customers to use any toll facility that is participating in the interagency while maintaining only one toll account that has a consolidated transaction statement. It also permits away agencies to find the name and address of customers whose toll cannot be collected from the home agency if the transaction is returned as rejected by the home agency.

Several different types of interface files are needed to support home and away CSC functions and may include such file names as:

- Transaction
- Transaction reconciliation
- Tag status
- Correction reconciliation
- Customer license plate
- Acknowledgements

- Tag status update
- Invalid tag customer
- Correction
- Non-toll transaction
- Non-toll reconciliation
- Non-toll correction reconciliation

General file requirements described in the ICD detail the exact way files must be named, data field types, character types, character limits, valid values, how they should be compressed, etc. Like the interface files above, the ICD would also describe the various standardized reports for both toll and non-toll transactions that home and away agencies require to operate and perform reconciliation between the CSCs.

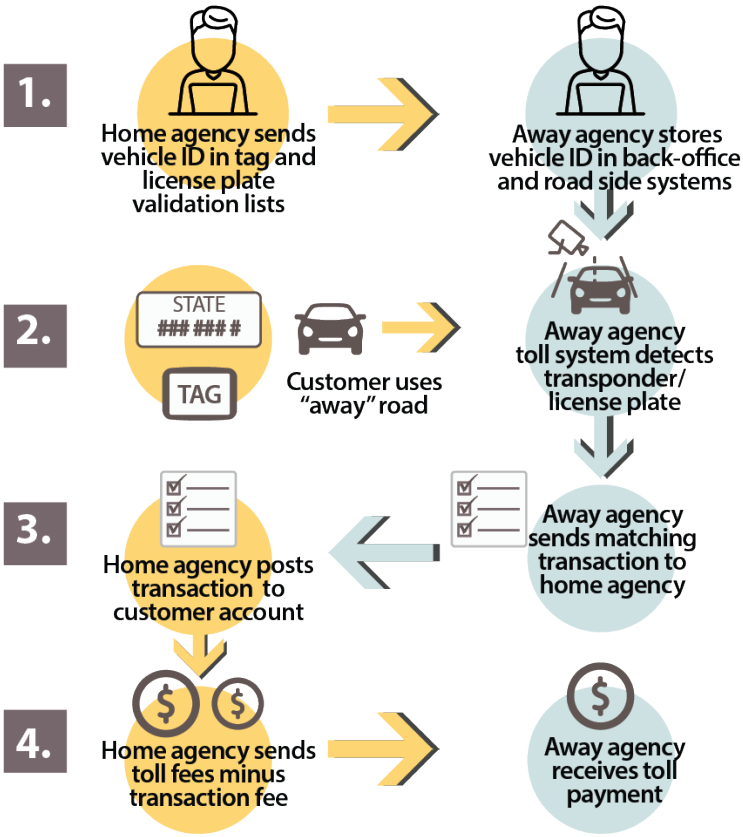
Interagency Payment Guarantees

A key aspect of toll interoperability is that the home agency guarantees toll payment to the away agency, provided the transponder and associated ETC account are valid at the time the away transaction occurs. Accounts may become invalid, either temporarily or permanently, for various reasons, most commonly when they reach a negative balance. Sometimes transponders are lost or stolen, or accounts are simply closed by drivers. Figure 17 shows the typical interoperable agency transaction processing and information flow.

For ETC interoperability to work, the home agency guarantees it will pay the away agency the appropriate toll charge, unless the account has been removed from the latest list of valid accounts provided to the away agency. Thus, providing and updating valid tag lists is one of the most important elements of interoperability. With more than 86 million unique ETC transponders in use, and around 100 or more home agencies managing accounts, the frequent changes to tag lists and the need to distribute them is likely to be an increasing challenge in the future.

In developing *National Interoperability Business Rules*,[31] the toll industry established a national standard for each bulk TVL that includes all transponders (and accounts) identified by the home agency as good tags. According to the interoperability business rules, tags in the bulk TVL with a valid tag status are good tags until they are identified as zero, negative balance or invalid on the TVL or dropped off the next bulk TVL. The rules also stipulate that bulk TVLs must be updated by each home agency at least once per week. The business rules also require each agency to circulate to all other interoperable agencies a differential TVL each day, unless the full bulk TVL is updated each day.(22) The differential list would only include tags and accounts that have changed status since the most recent new full bulk list. In practice, most interoperable agencies update and circulate the bulk lists more frequently than once per week, with many doing so daily. Since the home agency guarantees toll payment at the away agency if a tag is on the most recently updated bulk TVL, it is in the interest of the home agency to refresh and circulate the most complete list as often as possible.

[31] NIOP Business Rules: This document contains the business rules established to support National Interoperability for the sole purpose of coordinating the exchange of toll Transactions of multiple organizations that utilize, operate, and manage toll facilities. https://www.ibtta.org/ibtta-interoperability-committee-iop; by the IBTTA Interoperability Committee last viewed 1/17/2022.



Source: FHWA.

Figure 17. Illustration. Typical interoperable agency transaction processing and information flow.

In most cases, bulk TVLs include both transponders and associated license plate numbers. Future steps toward nationwide interoperability will standardize this process for all participating agencies. In this way, the away agency can develop an effective ETC transaction which can be forwarded to the appropriate home agency based on either the transponder tag ID number (priority), or the associated vehicle license plate. Either would be covered by the home agency, although the associated toll would reflect the ETC rate in either case.

Transaction Processing and Financial Settlement

In a typical interagency ETC transaction the away agency reads the transponder, and the system verifies the tag is acceptable and on the latest-available bulk TVL. The unique tag ID includes a code identifying the home agency that owns and manages the ETC account for the tag. Agencies typically accumulate transactions from tags from different agencies for some period. At predetermined intervals, such as once per day, each agency transmits to the respective home agency the various individual transaction messages recorded from accounts managed by that agency, often with summary reports documenting transactions and total revenue transfer requested. The home agency processes the transactions and posts them to each appropriate account. On a predetermined schedule, the home agency ultimately transfers the total toll charges incurred to each away agency, completing the typical financial settlement.

There are also rules regarding the maximum age of a transaction the home agency will agree to process. Historically, there has been some variability in transaction age limits among different agencies and interoperable networks. For example, the E-ZPass® system would accept transactions up to 60 days, while California would accept transactions up to 14 days. This is one of several disparities in business rules among different interoperability regions.

It is in the interest of the away agency to forward each transaction to the home agency as quickly as possible. In some cases, there may be a delay of a few days before the full transaction can be finalized, such as when video license plate imaging requires manual review. By the time the home agency receives the transaction from the away agency, a few ETC accounts may become negative, or even be closed. Because the home agency sets age limits for transactions it will process, it is important that all participating agencies agree to a maximum transaction age maximum. As part of the movement toward nationwide interoperability, the latest *National Interoperability Business Rules* has compromised on a limit of 30 days.

Interagency Processing Fees

For the most part, interoperable toll agencies have not charged a processing or handling fee for interagency ETC transaction financial settlements. Agencies believe there is approximately the same number of away agency transactions on their toll facilities as away transactions made by their home customer accounts. An exception is Texas, where multiple interoperable distinct agencies have agreed to a fixed fee per transaction settlement. Where applicable, these charges are deducted from the net interagency revenue transfer.

As industry interoperability expands nationwide, the balance between incoming and outgoing transactions may begin to change. When nationwide interoperability is reached, and a single tag is accepted everywhere, there is increasing likelihood that high-volume users may choose the least-cost account option, even if most of its transactions may be made on away facilities. This is particularly likely with large trucking or other commercial fleets that use many toll systems across the country.

Agencies have different account and device costs, such as monthly account management fees or initial tag procurement costs. In many cases, agencies assess lower toll rates to transponders they issue. There was concern within the industry that if any typical tag becomes valid everywhere, agencies with low costs of accounts (or high local discounts) might wind up as the home agency for a disproportionately high share of the nation's transponders while having a lower share of transactions. This can be a particular concern since the home agency is typically assessed a credit card fee for prepaid balance replenishments. This would place an extra burden on home agencies, especially if a disproportionate share of transactions on its transponders took place on away agency toll facilities.

In discussion of business rules for nationwide interoperability, a nominal standard financial settlement charge has been discussed. It will likely be established as a percentage of the toll amounts being transferred Discussions per the IBTTA interoperability committee suggest that the transfer fee may be in the range of 2 percent. This would come close to offsetting disproportionate credit card fees on account replenishments.

Dispute Handling

From time to time, customer disputes can arise, especially with respect to license plate image-based transactions. For example, customers may claim they did not make a certain transaction, or they were not on a certain road at the time of the event. Such disputes typically do not surface until after the transaction has been posted to the customer's account, often after a monthly list of transactions has been received.

Agencies have different business rules for handling disputes, particularly regarding how long to retain detailed electronic video image records of individual transactions. Interoperability compounds the challenge, to some extent. In all cases, the home agency that posted the transaction and manages the account will raise the dispute. But the potential error underlying the dispute may have likely occurred at the away agency location. The *National Interoperability Business Rules* document established a requirement that all participating agencies "maintain records related to toll transactions for a minimum period of 180 days from the transaction date."[17] It also established limits on submitting disputes and response times for home and away agencies.

BUSINESS-SIDE CHALLENGES OF NATIONWIDE INTEROPERABILITY

A key business-side challenge to reach nationwide interoperability is the inherent inconsistencies in agencies' business rules and back-office incompatibilities. As regional toll interoperability has been established and refined over the years, many inconsistencies have been eliminated, at least those related to information exchange and communication among agencies within each region. However, inconsistencies still remain and may be greater among different regional networks, requiring future adjustments and consensus to be reached.

Legal Statutes. Aside from the MAP–21 interoperability mandate, some States' laws promote interoperability, such as California's Street and Highway Code (SHC) 27565, for internal State interoperability, and Oregon's ORS 383.014 for interoperability between Oregon and Washington State. However, existing legal statutes can also inadvertently create barriers to interoperability. For instance, California's SHC 31490 addresses tolling privacy and SHC 27565 allows four data fields to be exchanged to support interoperability. Because the toll amount and toll plaza/lane interoperability fields are not explicitly listed under SHC 27565, there is concern that consumer rights groups could challenge interstate interoperability. Potential lawsuits from those who oppose tolling may make toll agencies less willing to change their current interoperability approaches and agreements.

Governance. Convincing toll agency boards and other stakeholders to authorize and allocate funding to interoperability is a challenge. Most tolling regions have formalized governance of their interoperability regions through agreements and memorandum of understandings (MOU), such as CUSIOP and western region members that executed agreements in 2016 and 2017, respectively.[20] Some agreements are binding, as with CUSIOP, while the western region's MOU has non-binding language absent of enforcement language. This highlights toll agencies' reluctance to relinquish tolling powers to an outside organization. When the western region begins ETC interoperability between its members, it would benefit from additional binding interoperability agreements in order to progress towards effective interoperability governance.

Communications. Educating customers and the general public on nationwide toll interoperability is a challenge, especially if interoperability is phased in across the country. With more than a dozen ETC-branded programs nationally, it is confusing at best. At worst, it is dangerous to try to sign for all interoperable ETC account logos the same way regions display multiple logos on signage today. IBTTA in 2015 worked with focus groups to develop a potential national logo for national interoperability.(26) The effort also included human factors testing to develop a logo for inclusion in the *Manual of Uniform Traffic Control Devices*. Existing customer ETC account agreements need to be updated, and toll agencies need to determine if customers must actively opt in or opt out of national interoperability terms. Additional communication efforts can lead to better understanding among customers. Finally, customers can be better served by agencies updating standard operating procedures and providing training to customer service representatives on topics such as handling disputes and customer engagement across multiple toll agencies.

EMERGING CONSENSUS ON THE OPTIMAL NATIONWIDE INTEROPERABILITY APPROACH

Interoperable Tolling Regions

While several issues remain to be resolved, general consensus has emerged within the U.S. toll industry on how to achieve the business side of nationwide toll interoperability. The cornerstone of the planned solution is establishing and refining four interoperable regions, as shown in figure 18. These four regions are expected to include most toll agencies and operators in the Nation.

E-ZPass

E-ZPass® in the northeast and Midwest States is the most well-established interoperable toll network. It already includes 18 States and 27 agencies, and it has issued more than 42 million ETC transponders. E-ZPass® recently added Minnesota, and North Carolina will formally become a full member in the near future. It had already established peripheral interoperability with CFX, a major Florida toll agency, and it recently announced future linkages with Florida Turnpike and Georgia's SRTA.(6)

Southeast Region

Florida has long been fully interoperable with multiple agencies inside its own borders. This has included dozens of toll facilities operated by more than a half dozen agencies. In recent years linkages have been established with Georgia. As it expands its interoperability network, the southeast region plans to add South Carolina, with two local toll facilities, and eventually Alabama, with a series of privately developed and operated toll roads and bridges around the State.

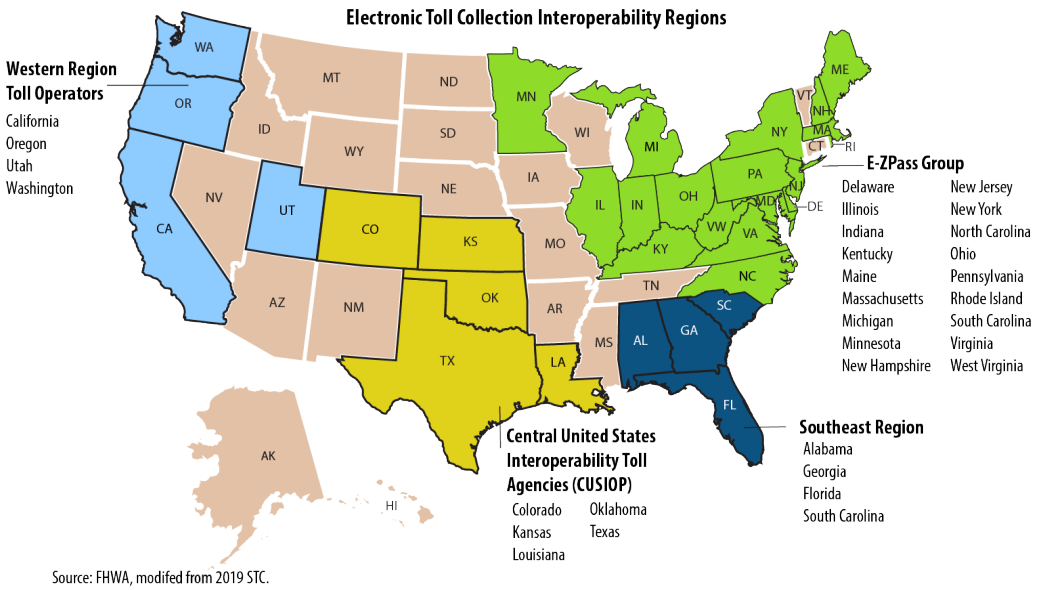


Figure 18. Illustration. Interoperable tolling regions and States.

Central United States Interoperability Hub

For many years, multiple toll agencies, and some privately operated toll facilities, in Texas have enjoyed full electronic toll interoperability. This has included transponder systems under multiple brand names, all using a common ETC protocol. In recent years, toll agencies in Oklahoma and Kansas were added into the central region network, with full interoperability and information exchange. The three States use compatible protocols, but each with their own unique tag brands, with a combined 24 million customers.(30) The group has now been redefined as the CUSIOP Hub. Colorado and Louisiana are expected to be added in the near future, forming a five-State regional hub system. CUSIOP has played a lead role in defining potential nationwide interoperability solutions, especially related to back-office and institutional issues.

> Our board is committed to moving forward and getting the (E-ZPass) hub in place soon and our members are committed to have multiprotocol readers installed in their lanes. All members are making efforts to get multiprotocol readers in all lanes by 2021 to be interoperable in 2022.
>
> ~ PJ Wilkins, Executive Director, E-ZPass

Western Region

California has more than a dozen toll agencies and operators, including toll roads, toll bridges, and a large network of express toll lanes. The agencies have historically been part of the California Toll agencies Council (CTOC), and all used the same Title 21 FasTrak transponders. All California toll facilities have been fully interoperable since their inception, as prescribed in the Title 21 legislation. As part of the regional interoperability developments, the western region formed to include CTOC, Washington State, Oregon, and Utah.

Shift to Hub Operations

In all cases, the future regions are currently in operation (see figure 19), although some will add States and agencies by 2023. In all cases, interagency communication connections already exist. In some cases, the existing regions use peer-to-peer communication, in which data from one agency are transferred electronically to all other interoperable agencies individually. This requires sizable data transfers each day by each agency, especially in daily updating and transferring of large bulk TVL files to each interoperable agency, even where relatively few away transactions may be generated. The E-ZPass® and California networks presently use a peer-to-peer communication technique.

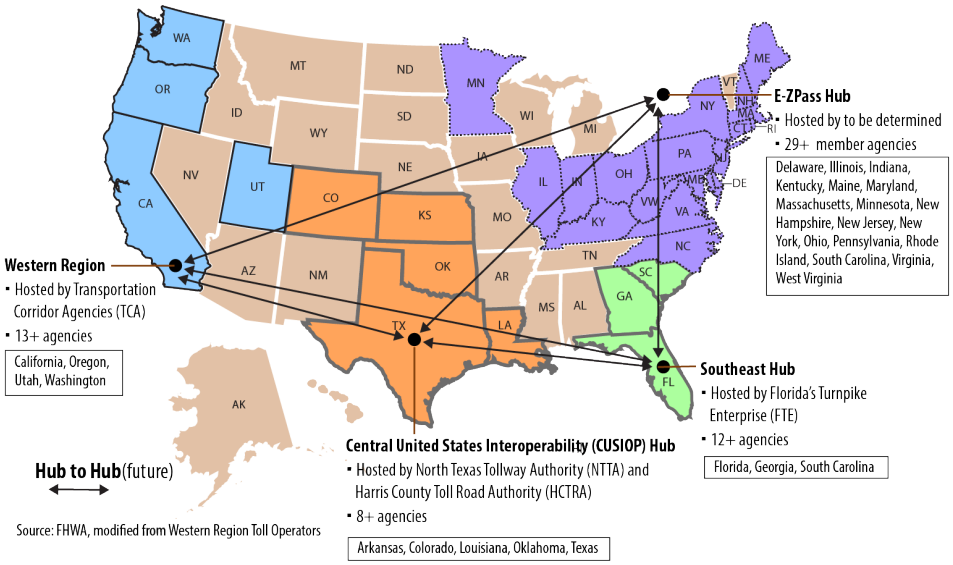
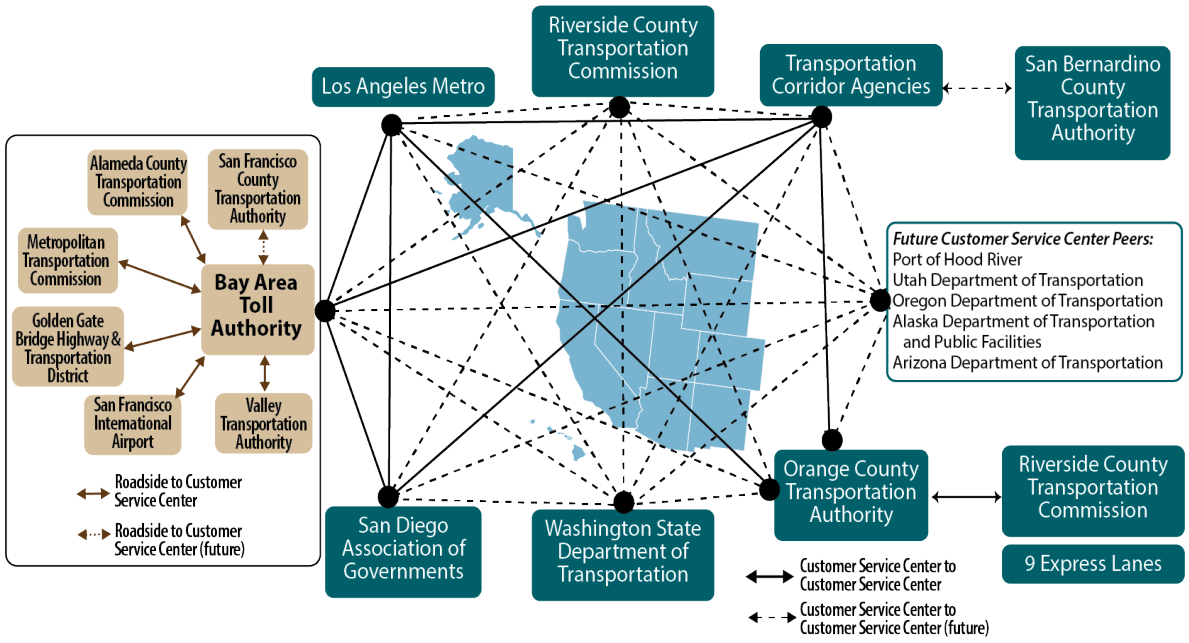


Figure 19. Illustration. Four regional interoperability hubs.

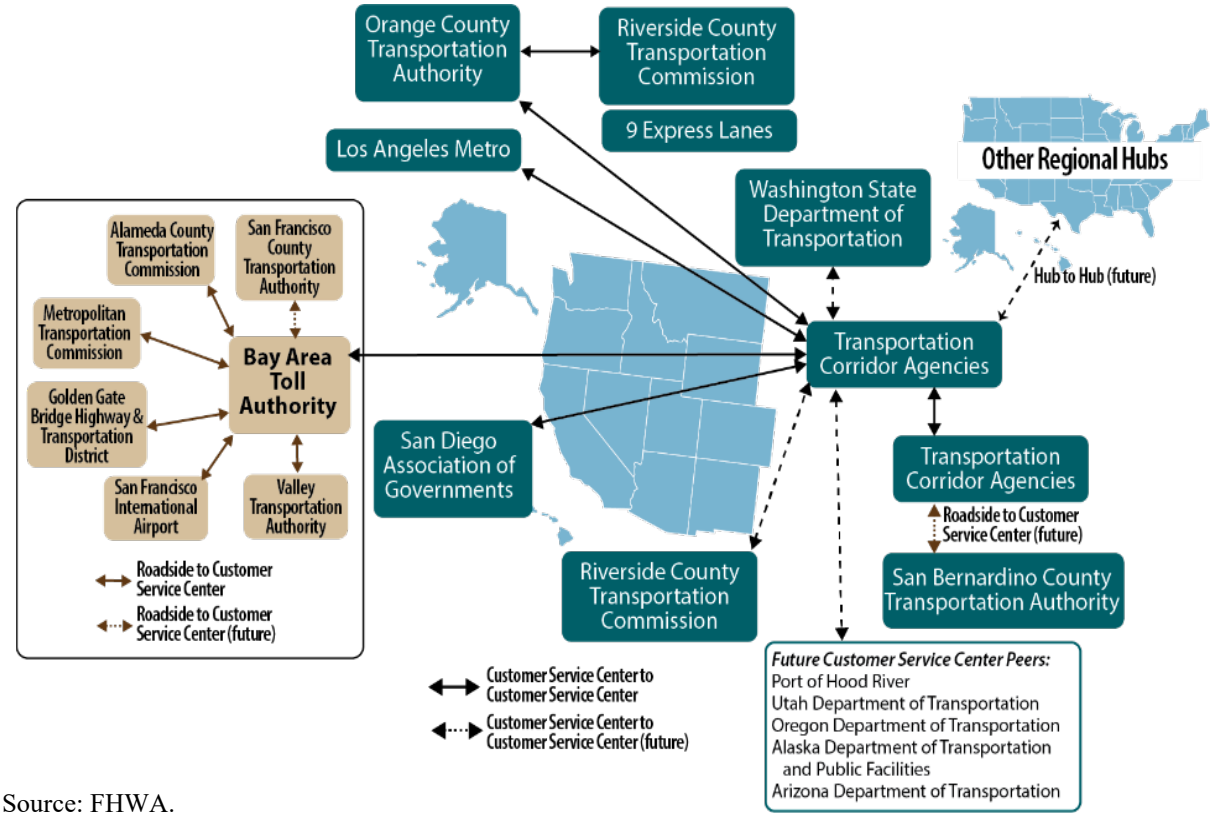
Figure 20 shows a typical peer-to-peer network, using the western region as an example. Information from each agency is transmitted periodically to all other agencies, depending on home and away agency transaction patterns. The figure also demonstrates how some agencies within the overall network use a common back-office and customer service arrangement, such as in the Bay Area or some local express lane systems serviced by other nearby agencies. Other regions, such as the CUSIOP in the southwest and central States, have adopted a hub-and-spoke system of data exchange. The current plan is for all four regions to convert to the hub-and-spoke system (illustrated in figure 21 for the western region). In the western region, TCA in southern California would operate the future hub, which would receive and transfer data communications to and from all participating agencies, eliminating the need for peer-to-peer communications. Similar arrangements are now in use in the central and southeast interoperability regions.

Once all four regions have shifted to the hub-and-spoke system, there will be four major toll interoperability hubs in operation in the United States. Each will be handling all transaction, settlement and other data transfers among all agencies participating in each region. This will create the opportunity to reach effective nationwide interoperability by creating data transfer links among the four hubs.



Source: FHWA.

Figure 20. Illustration. Western region peer-to-peer interagency communication.

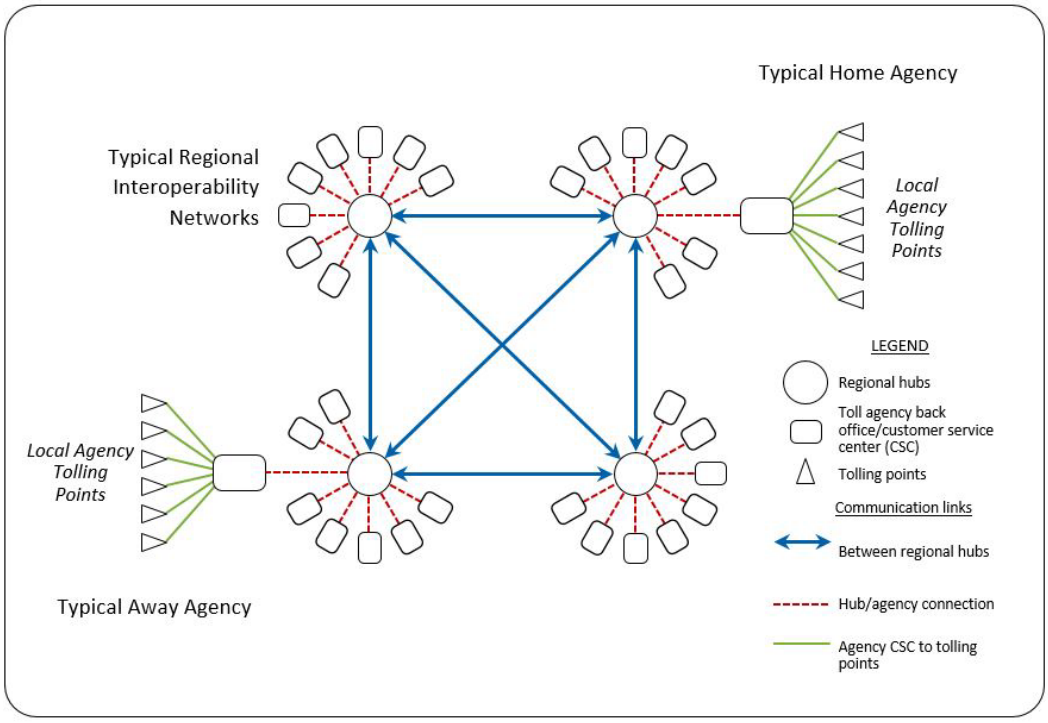


Source: FHWA.

Figure 21. Illustration. Planned western region hub-and-spoke system.

Figure 22 shows the planned communication configuration for nationwide interoperability. The illustration depicts the four regional hubs and eight member agencies. (In practice, many regions

will have many more interconnected agencies, such as the E-ZPass® Group that currently serves 27 different local agencies.) In figure 22, a typical home agency is depicted in the upper right corner, and a typical away agency in the lower left hub. In practice, any agency in the national network can become a home or away agency on any given transaction. The graphic also displays six or seven local agency tolling points, all connected to the illustrative local agency back-office and customer service system. The red, dotted lines in figure 22 represent communication linkages between each hub and the hub's regional member agencies.

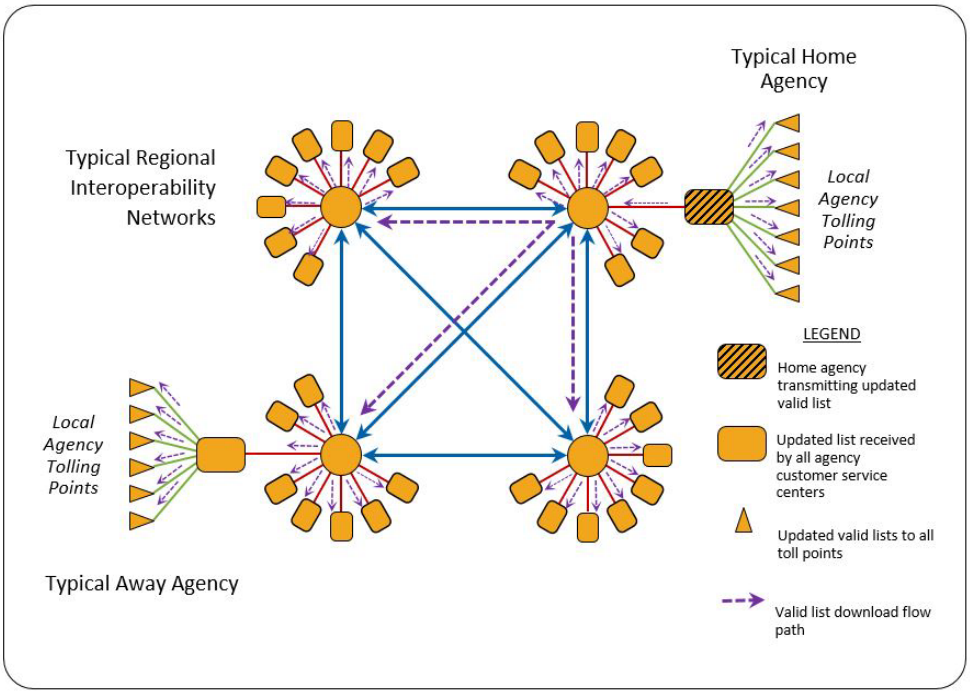


Source: FHWA.

Figure 22. Illustration. Planned nationwide interoperability communications configuration.

The blue bi-directional arrows represent communication pathways between each of the four regional hubs. Each hub will create two-directional connections with the other three hubs. This will enable the flow of data within each region to be extended among each region, thereby creating a nationwide toll interoperability system.

An important component of ETC payment guarantees in regional or nationwide interoperability is the bulk TVLs and the periodic differential TVLs. The home agency that manages and maintains the various ETC accounts develops and updates the lists. This is shown as the typical home agency in figure 23. Each time an updated list is generated by the home agency back-office system, it is automatically downloaded to the hub. This download flow path is shown in figure 23 using purple, dotted arrows along the inter-hub connections. The hubs then download the list to the back-office system of each interconnected agency in each region. The local agency systems then typically download the validation lists to the various tolling point systems along the agency's toll facilities, where it will be used to validate each transponder or license plate transaction encountered at each toll point.



Source: FHWA.

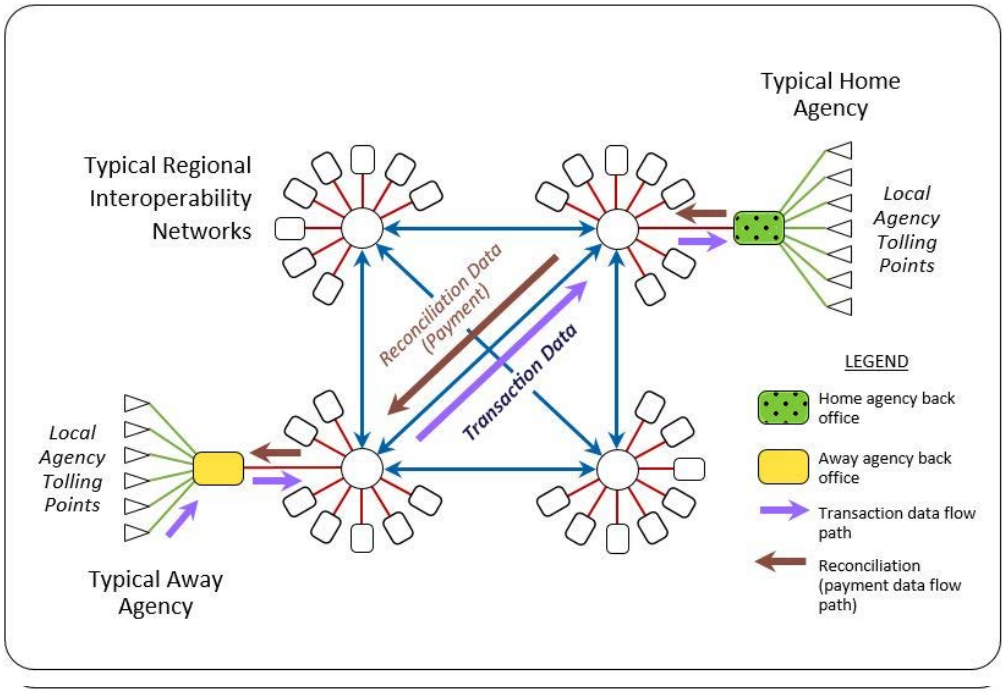
Figure 23. Illustration. Nationwide distribution of home agency tag validation lists.

Given the size of the TVLs and the number of interconnected agencies, the periodic updates and downloads will require large volumes of database transfers. The shift to nationwide interoperability will increase the magnitude of transfers and file sizes from three to five times current regional networks, depending on how many local agencies are within a given region today.

The typical toll transaction filing and reconciliation process is illustrated in figure 24. The process begins at a tolling point at the typical away agency, depicted as a yellow solid rectangle in the lower-left portion of the figure. The general flow of the transaction data is depicted with purple arrows from the away agency to the home agency. When the transponder is read at the tolling point and the account is found on the valid list, a transaction message is generated and sent to the away agency back-office system. The transponder ID number includes a code for the toll agency that issued and manages the ETC account. This tells the away agency where to route the transaction. The transaction message from the away agency is effectively a request for toll reimbursement from the appropriate home agency for the toll amount. Since the home agency is not operating

> There are also back-office costs that need to be absorbed. Even in the absence of the need of complete overhauls in the back office, the cost of developing the hub itself is significant. We project $7M over the next 5 years to maintain and increase interoperability. There is good participation in sharing costs between seven agencies.
>
> ~ James Hofmann, Executive Director, North Texas Tollway Authority

the tolling point, the back-office system will transfer the transaction message to the regional hub. In practice, the away agency will accumulate transactions to be sent to other agencies and send them as grouped listings, but this may vary by agency and region.



Source: FHWA.

Figure 24. Illustration. Interagency flow of transaction and reconciliation data.

The hub system for a particular region will recognize the home agency and transfer the transaction to the hub system for the region in which the home agency is located. Again, the hub system will likely accumulate transactions headed to different hubs and transfer the information in groups. When data are received by the home agency hub, they will be processed and routed to the appropriate home agency back-office system, shown as a green solid rectangle in the upper-right corner of the graphic. The transaction will be posted to the appropriate account, and a financial settlement of the toll will be issued by the home agency. The reconciliation data will be routed back through the respective hubs and eventually back to the away agency, completing the interoperable toll transaction.

While figures 21–23 depict the planned toll industry's nationwide interoperability structure, the actual process will include several new business rules for dealing with disputes, interagency acknowledgements, and information storage. Some of these remain to be worked out by toll agencies and the four major regions. However, the U.S. toll industry has identified the overall pathway to effective nationwide toll interoperability.

TRAVEL DEMAND FOR NATIONWIDE TOLL INTEROPERABILITY

When considering the cost-effectiveness of investments, the toll industry needs to achieve true nationwide interoperability, a question often arises about how much travel demand there is between different parts of the country.

Scarce information exists about surface travel patterns in the United States, especially as it relates to passenger car travel. Data regarding goods movement do exist, including some level of very long-distance trucking, but even that data does not provide clear average daily demand patterns. To be sure, most trips using electronic tolling are within local areas and internal to States. But there is still some interstate travel that likely crosses between interoperable toll regions, especially by commercial vehicles.

In 2015, CDM Smith developed a nationwide sketch planning model for estimating revenue, cost, and travel impacts associated with hypothetical tolling of portions of the interstate highway system. The tool was used to test theoretical policy options but created estimates of nationwide travel patterns for trips using portions of the 47,000-mile interstate system. As one measure of overall interregional travel, this study revisited trip patterns within the national sketch model, in the context of movements between major current and planned toll interoperability regions.

Trip patterns were developed for both passenger cars and trucks. The estimation of longer-distance trip patterns began with the Traveler Analysis Framework database, which estimates long-distance passenger trips by various modes, and the Freight Analysis Framework database, which estimates truck patterns based on goods movement data. These were then calibrated to 2011 travel demand levels based on control volumes on major links of the entire interstate system, separated by cars versus trucks, as provided in the national Highway Performance Monitoring System database.

Matrix estimation techniques were then employed to get the best traffic assignment fit over the entire interstate system, at 2011 levels. The data have not been updated in recent years, but the patterns are still generally relevant in terms of the relative proportion of demand moving between the four tolling regions. In total, the model includes patterns for more than 113 million daily trips, almost 94 million of which have one or both ends in the four tolling interoperability regions.

Estimated Interregional Roadway Travel Demand

For purposes of estimating interregional demand, trip pattern data were first aggregated to State zone levels. Patterns were then further grouped into the four major interoperable regions to provide a broad indication of typical interregional travel levels. Table 4 shows the specific States included in each interoperable region, for purposes of this analysis. A few States are not yet in the regions, but plan to join soon. States not included in any regional network generally do not have tolls, or at least have no organized toll interoperability.

Table 4. States belonging to each interoperable tolling region.

Hub	States
Western Region Hub	California Oregon Utah Washington
Central United States Interoperability Hub	Colorado Louisiana Kansas Oklahoma Texas
Southeast Hub	Alabama Florida Georgia South Carolina
E-ZPass Hub	Delaware Illinois Indiana Kentucky Maine Maryland Massachusetts Minnesota New Hampshire New Jersey New York North Carolina Ohio Pennsylvania Rhode Island Virginia West Virginia

Table 5 provides a concise summary of average daily trips within the sketch planning model, which move between the four toll interoperability regions. Trip estimates are broken down by passenger car and truck categories, as it might be expected that a higher proportion of truck trips travel long distances between regions than cars. Overall, just over a half million trips per day move between regions, or about 0.53 percent of total trips. Just under ½ percent of car trips are interregional, while about 1.7 percent of truck trips are long distance moving between regions.

By far the largest share of interregional trips are found along the eastern portion of the nation, with more than 405,000 trips per day traveling between the States of the E-ZPass® and southeast regions. This represents close to 80 percent of all interregional travel within the planning model. Almost 50,000 trips per day move between the central region and either the southeast or western regions. Relatively little travel was found in the model between E-ZPass® States and the western

region States. In total, trucks represented almost 23 percent of interregional trips, even though they represented only about 7 percent of total trips in the sketch planning model.

The figures in table 5 represent typical overall travel between the four major tolling regions, and they are not limited to trips using toll facilities. On the other hand, a single interregional trip that uses toll roads may pass through several toll points and may generate multiple toll transactions. Hence, the values in table 5 should not be considered an estimate of interregional toll transactions that would need to be processed with nationwide toll interoperability.

The data in table 5 are intended to only provide a rough indication of overall interregional travel demand and were calibrated to recorded traffic data as of 2011 levels. Some change in trip patterns may have emerged since then.

Table 5. Approximate interregional average daily trip distribution in the United States based on CDM Smith's 2011 model.

	Average Daily Interregional Trips (000)		
Interregional Movements Between	**Passenger Cars**	**Trucks**	**Total Vehicles**
E-ZPass and Southeast	321.8	83.8	405.6
E-ZPass and Central	0*	3.1	3.1
E-ZPass and Western	0*	1.1	1.1
Southeast and Central	34.9	12.5	47.4
Southeast and Western	0*	0*	0*
Central and Western	30.9	13.1	44
Total Interregional Trips	387.6	113.6	501.2
Total Trips in Planning Model	87,074.00	6,699.00	93,773.00
Interregional as Percentage of Total	0.45%	1.70%	0.53%

*Indicates interregional volume from model is less than 100 trips per day. Source: CDM Smith.

INPUT FROM TOLL AGENCIES FROM PEER LISTENING SESSIONS

Handling out-of-State violators and AET revenue collections were discussed in the peer listening sessions conducted in April 2020 with tolling agency representatives. This arises out of the continuing shift in the industry to cashless AET. Collections of pay-by-mail billings with AET (as well as violation enforcement and collections) have proven much more difficult for out-of-State vehicles. Most States with AET systems have payment incentives, such as registration renewal holds, but these seldom apply across State lines.

Agency representatives are looking for potential new Federal regulations that might facilitate enforcement and collections across State lines. In the absence of that, participants indicated an increasing level of support for third-party mobile payment apps, or other third-party payment services, which may reduce leakage problems due to cashless toll deployment or ETC violation enforcement. The industry also recognizes this will become more of an issue as larger intercity turnpikes begin to institute AET, since these facilities tend to have a much higher share of out-of-State traffic.

Legal considerations, particularly privacy laws, were also discussed during the listening sessions. States have different laws about what information can and cannot be included in interagency data transfers. Since the laws are at the State level, some interoperable agencies may find it difficult to provide standardized information that has been agreed upon in interoperability business rules. This will be a focus area in the future trajectory toward nationwide interoperability.

The sessions also brought to light questions about the cost of nationwide interoperability, and the possibility that a few smaller agencies that experience relatively low levels of ETC demand between some outer regions may opt out of a nationwide system. One participant mentioned work to date suggests that developing regional hubs capable of handling and exchanging information between regions could cost $7–$10 million. There have been a few cases of agencies questioning the cost/benefit of these sizable investments. Based on information provided during listening sessions, it appears that a majority of agencies are on board with nationwide interoperability, and with the planned regional inter-hub data transfer as the most effective way of achieving it.

KEY TAKEAWAYS ON THE BACK-OFFICE ASPECTS OF ELECTRONIC TOLL COLLECTION INTEROPERABILITY

The U.S. toll industry has identified the pathway to effective nationwide toll interoperability through regional hubs that develop interoperability agreements governing the exchange of information, payment, and translation of business rules. This is an ongoing process but is targeted to result in effective nationwide interoperability in the short term (2–3 years.)

The key components of interagency interoperability are interagency payment guarantees; frequent updating and sharing account information of home accounts; and business rule agreements addressing issues such as violations, interagency processing fees, and disputes. Business rules governing tolling in different regions and States across the country can differ in several ways, which makes interagency agreements on tolling interoperability complicated. Legal and governance issues pose ongoing challenges to executing these agreements. The out-of-State violators issue also continues to be a challenge.

While interregional travel data are scarce, estimates point to the volume of interregional travel (i.e., travel between the various hub regions, such as between the southeast region and the western region) as potentially significantly lower than the volume of interstate or inter-facility travel within the hub regions. As such, the market demand for interoperability between the hubs may be significantly lower than the demand for interoperability within the region.

CHAPTER 6. INTEROPERABILITY ALTERNATIVES: THIRD-PARTY PAYMENT SERVICES

An alternative to agency ownership of customer accounts is interoperability through third-party payment services. Third-party payment services are private firms that have ETC accounts with multiple toll agencies on behalf of their customers. Their clients typically maintain a consolidated account while the payment service provider handles the interfaces with multiple toll agencies. This chapter will discuss how third-party payment services address technology, financial, institutional, and communications issues. It also discusses how third-party payment services complement and address some of the shortcomings of the regional hub approach.

THIRD-PARTY PAYMENT SERVICES

Third-party payment services are generally private companies without toll collection facilities that offer toll customer services, including issuing transponders and managing ETC accounts. Third-party payment services arose from trucking firms and rental car companies needing an interoperability solution to consolidate ETC account management across multiple toll agencies while obtaining toll discounts typically granted only to local ETC account customers. Customers have a single ETC account with a third-party payment service, which in turn has multiple ETC accounts with various toll agencies. The customer only interacts with the third-party payment service, and toll agencies only see the service provider as their customer.

Challenges of Third-Party Payment Services

> Third-party payment services can function as a catch-all and handle edge cases not addressed by hub to hub approach.
>
> ~ Joe Clavelle, Bestpass

The interoperability approach of third-party payment services is to conform to every local toll agency's ETC program. This entails adopting the transponder protocol their customers or end users want to be interoperable with. For example, to be interoperable with E-ZPass® and Texas, the third-party payment service could choose to issue multiple transponders, rely on license plate-based accounts offered by local regions, or issue multiprotocol transponders. In addition, third-party payment services sometimes develop expensive interfaces with toll agencies to exchange vehicle information and transactions. Since there is a brute force approach of adopting multiple technologies to conform, the third-party payment services incur cost to develop and maintain interoperability with toll agencies. Due to the cost of developing and maintaining system interfaces and ETC accounts, third-party payment services can be selective about where they want interoperability coverage.

Financial Challenges

To maintain a complex network of coverage of interoperable toll agencies, service providers command a premium cost for simplifying toll payment management for its customers. Anecdotally, one third-party payment service enabled one of its new trucking clients to reduce four full-time staff positions originally dedicated to paying ETC tolls across the country. In addition, third-party payment services can reduce the amount of prepaid cash deposit its clients would have tied up with individual ETC accounts. Third-party payment services can negotiate

lower prepaid deposit amounts with toll agencies based on actual toll usage with financial guarantees. Therefore, third-party payment services fill a niche financial business case for their customers and toll agencies.

Governance, Legal, and Communications Challenges

For-profit companies' interoperability goals are driven by their own business cases, without public oversight. The consequence is that gaps occur in interoperability coverage nationwide, and will likely continue to occur, where some States and small toll agencies may never be interoperable. Although these private firms may not be constrained by tolling statutes, they are subject to consumer protection and privacy laws that can be complex and restrictive. In addition, third-party CSCs do not address equity concerns.

Third-Party Payment Services—Trucking Industry

Nationwide toll interoperability is of key importance to the U.S. trucking industry, which accounts for a substantial portion of longer-distance travel among interoperability regions across the country. Well before the current interoperability trajectory had emerged, the trucking and rental car industries saw a need for regional, and eventually national, tolling account structures. This demand was generally filled by the emergence of third-party payment services. These continue to operate today, in parallel with the full interoperability plan development.

PrePass and Tolling

Originally known as the HELP program, the PrePass program for trucking began in the late 1980s as a collaborative project between a group of State DOT directors and trucking company executives.(31) In the 1990s, initial research known as the Crescent Project involved several western States, from Texas to British Columbia.(31) The project tested methods to provide opportunities for prequalified trucking companies to obtain authorized bypass of participating roadside weigh stations. The research ultimately decided on RFID technology, similar to technologies used in ETC, as the primary method of identifying vehicles authorized for bypass.

The ability to bypass weigh stations is significant to many in the trucking industry. A typical five-axle truck has diesel fuel efficiency of 5–7 miles per gallon, and it is estimated that the need to stop and re-accelerate to full speed can require about ½ gallon of diesel fuel, as compared to simple operation at highway speeds. Hence, a single stop at a weight station can cost a large truck as much as $2, in addition to the value placed on delays and lost travel time.

The weigh station bypass program, which became known as PrePass, is operated by the PrePass Safety Alliance, a nonprofit corporation focused on overall commercial transportation safety. More than 500,000 trucks are enrolled in the service. Participants must be prequalified to allow for weigh station bypass authorization. After operating bypass services for more than a decade, a new service known as PrePass Plus was offered, which provided a modified transponder unit capable of both weigh station bypass and electronic tolling. Initially the tolling service integrated only with the massive E-ZPass® network. But over time, multiprotocol transponder devices were introduced, which expanded toll industry coverage. Today, the third-party tolling service is accepted throughout the E-ZPass® States, plus Florida, Texas, Oklahoma, Kansas, and California.

The PrePass tolling system provides a single bill for truckers covering all agencies and manages all toll reconciliation and payments to the agencies. Services have recently been expanded through a system known as INFORM Tolling, which provides fleet operators with dashboard account management services and near real-time toll transaction information that can be used in passing along toll charges to shippers on a timely basis. Information provided by the PrePass Safety Alliance indicates that customers enrolled in the tolling program receive all discounted toll rates offered by the various agencies.

Bestpass Truck Tolling

Bestpass was initially formed by the NY State Trucking Association subsidiary of the American Trucking Association in 2001. It was originally designed as a form of account consolidator service for commercial vehicle E-ZPass® accounts. Many legacy toll agencies offer significant volume discount programs to commercial account holders, a practice dating back to before the days of ETC when commercial accounts were typically issued toll charge cards by different agencies. In general, the higher the volume of commercial toll charges per month, the higher the percent discount the account would receive.

Source: Bestpass.

Figure 25. Illustration. Maps of coverage areas of various Bestpass tolling account types, depending on customer preference for national or regional interoperability.

In its original form, Bestpass would open one or more large accounts, which included thousands of transponders. The transponders would then effectively be reissued to participating trucking companies, large or small. Collectively the thousands of transponders would generate huge monthly revenue, qualifying for larger-volume discounts, depending on local agency policy. The benefits of the toll discounts each month would then be distributed among participating Bestpass customers.

Bestpass also provides important account management services and other benefits to fleet operators. By the early 2010s, Bestpass had enrolled over 75,000 commercial vehicles, all using transponders which were still issued by one or more home agencies but reissued though Bestpass. The original services extended throughout the E-ZPass® network. More recently, Bestpass has expanded services nationally, and Bestpass now has more than 500,000 transponders in circulation, annually processing more than 85 million toll transactions.

Bestpass issues single or multiple transponders to customers, depending on the States in which a customer operates, as shown in figure 25. Bestpass works with more than 40 toll agencies to register its transponders tied to fleet accounts, commercial ETC accounts for large vehicle fleets. By registering transponders with accounts at multiple local agencies, Bestpass also qualifies its transponders for local discounts given to local ETC customers. Discounts include using toll roads during off-peak hours, volume discounts, and bus discounts. Toll agencies benefit by leaving customer interactions to Bestpass, and Bestpass also guarantees toll payments even if Bestpass is not able to collect from its customer.

Third-Party Payment Services—Rental Car Industry

The Nation's rental car industry has always presented a unique challenge to tolling, especially as the toll industry moved to ORT and eventually AET. The rental car fleet in the United States is owned and registered by a handful of companies. They are continually rented and operated by different travelers on a short-term basis. While it is the renting customer who typically decides to use a toll facility, the vehicle is owned by the rental company, creating a retroactive challenge for automated toll collection—namely, how to properly charge a cashless toll to the temporary driver of a vehicle.

Rental cars are typically not limited to specific geographic territory, and they have a sizeable number of one-way rentals—for example, a vehicle rented in Maryland might be returned in Florida, or somewhere else outside the home agency jurisdiction, and even outside a regional interoperability network. Hence, the rental car industry stands to benefit from a nationwide tolling solution.

In general, cashless electronic tolling for rental cars typically involves a three-step process:

- The toll agency identifies the vehicle as it passes through an electronic tolling point, either through license plate imaging or through a typical transponder read (if present); this identifies the vehicle owner as the rental car company.
- The rental car company determines which customer had rented the vehicle on the day of the particular toll transaction to determine who is responsible for the toll charge.
- The customer is billed, or the toll costs are charged to the credit card used in the original vehicle rental agreement.

Several third-party payment services emerged to assist in this process. They would typically contract with one or more rental car companies to handle electronic tolling billings and payments. In most cases, rental car companies would provide (and continually update) a list of all vehicle license plates associated with their entire nationwide vehicle fleet. The third-party payment services would then provide these lists to all participating toll agencies, along with a guarantee of toll payment. The rental car companies would provide information and instruction to their rental customers about the use of AET lanes.

As with any typical video license plate reading, before the agency would designate the vehicle as a violator of a TBP customer, the master list of rental car license plates would be checked by the agency operating the toll project used. If the plate was found on the rental car list, a video toll

type transaction would be sent to the third-party service that would make the guaranteed payment.

In some cases, the rental cars would be equipped with special RFID transponders in the vehicle or added at the time of rental. These would sometimes need to be activated by the customer to be readable by the toll agency. However, given that rental vehicles are frequently relocated to different regions, the in-vehicle device may not always be readable on a particular toll facility. In this case, the default license plate imaging approach would be used.

In most cases, the third-party payment services would typically assess a daily service charge to the customer only if the car had been used for at least one electronic toll transaction in a given day. This service charge would be the primary source of revenue for the third parties. In addition, toll agencies with differential rates for ETC, cash, and video transactions would usually assess the toll to the third-party service at the lower ETC rate since they received guaranteed payment without the need to track down the individual vehicle owner and absorb collection risks. The third-party service may then charge the rental customer the higher video or cash toll rate because this is the rate they would have had to pay if they paid the charge themselves. The difference between the higher video or cash toll rate and the reduced ETC rate is an additional source of revenue for third-party payment services.

Over time, the industry has become concerned about increasing levels of daily service charges applied by the third parties, especially in high tourism States such as Florida. Some States have attempted to set limits on service charges. In recent years, there has been some consolidation in the rental car third-party payment service business through mergers and acquisitions.

While still representing less than 1 percent of total vehicles and toll transactions in the United States, the rental car third-party payment services model represents a truly nationwide toll interoperability approach, where one vehicle can use most toll facilities and have tolls assessed electronically. However, with daily service charges and other costs, it remains a niche service for a particular target market unlikely to alter the industry trajectory toward hub-to-hub-based interoperability.

Emerging Third-Party Payment Services

Beyond those serving trucking fleets and rental cars, other third-party payment services have emerged in recent years. They follow a similar business model: establishing accounts with individual drivers and payment agreements with various individual toll agencies. They tend to appeal to less-frequent users who do not wish to establish transponder accounts with a local

> We are moving towards mobile payment and the commercialization of the back office as cloud-based by the end of the year. This will be opened up to the providers (Sirius XM, Tesla, etc.) to facilitate payments and transactions for us by the commercial sector.
>
> ~ J.J. Eden, Executive Director, North Carolina Turnpike

TCA has several agreements with third-parties. We are looking at different payment and account management methods. We are doing license-plate recognition and then letting the third-parties reconcile with our numbers matching GPS location. We are working with Gentex on the ITM that includes all 3 protocols.

~ Samuel Johnson, Chief Executive Director, TCA

home agency, but who still desire the advantages of electronic tolling such as nonstop cashless collection. Two examples include BancPass, now called PlusPass, and Pay Tollo.

PlusPass is headquartered in Austin, Texas. BancPass was founded in 2012, when it first introduced a mobile toll payment application for smartphones. Today it serves around 200,000 customers in about seven States, with a few others expected to be added soon.[32] PlusPass offers two primary toll payment options:

- **Mobile app accounts** – Customers download a smartphone application and link the account to a particular vehicle license plate. Prepaid balances are not required, and enrolled vehicles are authorized to use cashless AET facilities. A nominal 15 percent service charge is added to the toll, which is charged directly to the credit card or bank account linked to the PlusPass account.

- **Tag-based accounts** – In some States, PlusPass offers a toll sticker (RFID transponder), which is the primary protocol in use in the market where the customer is located. Customers obtain a starter kit online or through selected retail outlets and a smartphone application for account management and replenishment. In many cases, such as in Houston, tags are issued on behalf of local toll agencies, although account management is handled by PlusPass.

Source: RV Toll Pass.

Figure 26. Illustration. TransCore multiprotocol transponder.

The service is specifically tailored for less-frequent toll customers. In a recent vendor listening session, PlusPass stressed that toll agencies may well be able to reach a 90 percent ETC penetration or more, but getting the last 5 or 10 percent will be extremely difficult. The company

[32] Based on interview with Shannon Swank, BancPass on August 7, 2020.

is technology-neutral and will provide transponders that best fit the local markets where customers reside.

Another way of addressing the hurdle of interoperability in regions that have a vast installed base of toll systems is with multiprotocol readers that can only accurately read two of the three major protocols concurrently (TDM, SeGo, and 6C). Firms are responding by developing multiprotocol transponders to be compatible with existing roadside systems. In the mid-2010s, TransCore launched multiprotocol transponders that operate with toll readers that have two or more protocols built in. See figure 26 for an example. TransCore provided North Carolina Turnpike Authority with a transponder that uses both the TDM and SeGo protocols. Since 2018, Gentex with TransCore created a multiprotocol transponder integrated into rearview mirrors called ITM, as seen in figure 27. Automakers factory-equip vehicles with ITM. Bestpass is serving as the third-party payment service and manages customers using the ITM.

Figure 27. Photo. Gentex Integrated Toll Module® multiprotocol transponder built into a rearview mirror.

CHAPTER 7. INTEROPERABILITY ALTERNATIVES: TECHNOLOGIES AND BUSINESS MODELS THAT MAY IMPACT THE HUB-BASED INTEROPERABILITY MODEL IN THE FUTURE

A logical pathway toward effective nationwide toll interoperability is becoming clearer and may well be fully accomplished within the next two to three years. It is an approach built on the combination of using RFID transponder and license plate capture technologies, supported with regional hub agreements about transaction data and payment exchange. This approach to interoperability is premised on agency-owned customer accounts. Several alternative third-party payment service business models already exist that serve a small but growing portion of the Nation's toll facility users. These alternatives generally supplement the primary ETC model, supporting edge cases and unique user needs—such as those of trucking and rental car industries—but do not impact the current trajectory toward regional hub-based interoperability.

> We will not achieve national interoperability with one device. [The industry] needs to start focusing on interoperability from a customer account perspective.
>
> ~ Shannon Swank, BancPass

Looking toward the future, several changes in electronic payment systems, vehicle and account identification technologies, and approaches to assess and collect transportation revenues may fundamentally alter the toll collection approaches of today. The research project team conducted extensive literature review and interviewed several stakeholders from the public and the private sectors to gather insights into coming changes. This chapter examines these potential changes in technology, mobility, and tolling business models that may eventually alter how tolls are currently collected in the United States and around the world, and thus the pathway to nationwide toll interoperability.

Several external factors combined with limitations of the current interoperability approach could provide an impetus toward alternative scenarios. For instance:

- **Limitations of the current ETC approach**. The current trajectory with RFID-based interoperability has shown that there will always be customers who are unable or unwilling to acquire separate technology or equipment to facilitate electronic tolling. This could undermine the achievement of complete electronic tolling interoperability capable of serving 100 percent of toll customers in an equitable manner.

- **Obsolescence of the single technology underpinning the current interoperability efforts.** A technology exclusively designated for the singular use of toll payment could be superseded by more efficient, user-friendly, multi-use, or ubiquitous technology. This could result from factors external to the toll industry, such as technology evolution and proliferation or customer preference.

- **Phasing out the agency-owned customer business model.** New approaches that deviate from the current model of toll agency ownership of customers could offer an alternative

that is more attractive to end customers, and thus has a faster uptake than agency-provided transponder tags.

> Institutional issues have been the main issue with interoperability, not the technology.
>
> ~ Marty Stone, Egis

- **Limitations or shortcomings of the current interoperability approach.** While the pathway toward hub-based interoperability is relatively clear at this point, there is still some possibility that technology, business, or legal hurdles may prevent the type of seamless, complete, nationwide interoperability currently envisioned. This could additionally provide impetus to alternative solutions.

Based on research and interviews with experts, three alternative scenarios to the current interoperability trajectory emerge as relevant for this discussion:

- **Alternative scenario 1:** A potential future scenario where built-in vehicle technology supersedes RFID-based technology currently implemented through agency-provided transponder tags. CV technology or other approaches employing onboard telematics are candidates for this alternative scenario.
- **Alternative scenario 2:** Smartphone-based applications that support toll payments could supersede RFID-based technology because of customer friendliness and availability.
- **Alternative scenario 3:** A comprehensive road usage charging approach that subsumes concepts such as tolling, congestion charging, and other roadway pricing policies and programs could render obsolete the current model of tolling as a separate and distinct pricing mechanism.

In the near term, several of these changes are likely to work in parallel with the identified pathway to nationwide interoperability, offering additional choices to both customers and toll agencies. However, in the long term, as these emerging alternatives create a new framework for national, and even global payment exchange, there is a possibility that they may alter the immediate goal of nationwide toll interoperability as it is currently envisioned. Although the exact nature and timing of some changes are uncertain, it is inevitable that the manner in which user fees are collected on the Nation's toll roads, bridges, tunnels, and express lanes will change in the future. As a result, the way the Nation achieves interoperability will likely need to evolve.

VEHICLES AS A MECHANISM FOR TOLLING AND TRANSPORTATION PAYMENTS (ALTERNATIVE SCENARIO 1)

The most likely scenario for vehicles being directly equipped for tolling as against toll agency-provided RFID tags is through CV technology. CV technology is a wireless connectivity solution included with a vehicle at the point of manufacture. There may also be aftermarket versions of a CV solution, but most of the benefit of this technology is realized through its bundling as part of the original equipment manufacturing system included with the vehicle. The main benefit is that wireless devices used for tolling are distributed with the vehicle. CV technology that is already being installed in vehicles for other purposes, such as safety, mobility, and intelligent transportation system functions, can also be utilized for transmitting transaction-related information to the toll system. In this manner, the cost of the radio is spread across more

applications and the utility of the in-vehicle system is enhanced. Further, the cost of distributing the toll transponder, and for carrying the inventory, is shifted from the toll agency to the automotive distribution system. Perhaps most important, nationwide standards for this technology as it is developing would help completely circumvent issuing multiple transponder protocols.

Lessons from the Integrated Toll Module

> The biggest change in toll collection in the future will be "self-identifying cars"; essentially the intelligence being built into cars will increasingly be used for vehicle identification and location sensing.
>
> ~ J.B. Kendrick, Kapsch

An early version of this, although not technically a CV approach, is ITM—operating in the 915 MHz band, as do all standard toll tags—included on certain models of Audi®. In this scenario, the electronic mirror assembly includes an electronics module that has the major tolling protocols integrated. Using this approach, the vehicle arrives pre-equipped to operate on toll roads that use IAG's SeGo protocol and the ISO 18000-63 (6c) protocol. The benefit of ITM is that it can be used today with existing roadside readers and equipment. The Audi® ITM can be read by systems that are deployed on toll roads now.

To make the Audi® ITM functional, a third-party payment service must activate the module at point-of-sale (or after) and update it with the user's account information. This step is performed by a third-party payment service. Each major protocol in the ITM is assigned an account from a participating toll agency. The system then relies on the nationwide interoperability network including the interoperability hubs and other arrangements to ensure the use of the toll account is linked and reconciled.

CV tolling is likely to use a similar approach from a distribution and activation perspective. The key difference is that with the Audi® ITM, the vehicle manufacturer has adapted the vehicle technology to work with existing tolling roadside systems. With CV tolling, the roadside system will need to add another protocol that can be read and used to charge transactions. But, with CV technology being potentially pervasive in the future—such that virtually every car sold will be equipped as a transaction device—ultimately, the toll agency will pay less for roadside solutions.

CV technology may come in a variety of flavors: dedicated short-range communication (DSRC), cellular vehicle-to-everything (C–V2X), fourth-generation (4G) Long Term Evolution (LTE), and fifth generation (5G). Automakers already install 4G devices in a large number of vehicles. According to Standard and Poor's, more than 40 million vehicles on U.S. roads that have a third generation (3G) or 4G wireless device as original equipment.[33] Many automakers see the opportunity to enable transportation transaction payments on their vehicles. The auto and toll industries recognize that the key for cooperation between them is to develop a standard so that:

- All automakers are building to the same transaction message.
- As toll agencies move to deploy CV readers for toll transactions, there is a well understood transmission protocol, in terms of the over-the-air interface and the data payload that includes the transaction data.

Among the CV tolling trials currently being established and conducted in 2020, the Central Texas Regional Mobility Authority, Kapsch, and Ford Motor Company are conducting a pilot. In this trial, Ford vehicles equipped with C–V2X radios will communicate with roadside units that will collect the transaction data. This pilot was announced in September 2020.

Infrastructure-Based Tolling Standards for Connected Vehicles

> Tolling using vehicle-embedded technologies enables broader business models. Cities and other jurisdictions not currently in the business of tolling can be enabled to collect tolls.
>
> ~ Suzanne Murtha, Chair of the Society of Automotive Engineers (SAE) J3217 Committee

SAE International has initiated a working group, designated as SAE J3217, which focuses on enabling infrastructure-based tolling. This standard is currently being shepherded through the SAE process, wherein use cases are considered and explored, and then the resulting impacts to the standard are incorporated. The SAE J3217 Standard is expected to be put to a vote in 2021. The intent of the standard is that the transaction message and associated security is independent of the air interface. That is, the resulting standard will be useful whether the vehicle radio is DSRC, C–V2X, 4G, 5G, or some future manifestation. Two key elements that need to be agreed upon for toll agencies to deploy SAE J3217 equipment are the transmission message is the same regardless of vehicle manufacturer and the air protocol is one the toll agency utilizes. This will be sorted out over time by automakers as to whether the system uses DSRC, C-V2X, 4G LTE, 5G, or one of the wireless protocols.

A benefit of CV technology is that the vehicle has GPS and its precise location is provided as part of the standard message. Initially, the vehicle tolling standard would be an additional protocol to be read by lane equipment, but in time, the expectation is that the toll reader becomes a CV roadside unit that can read the vehicle's account identity document, latitude, longitude, heading, and other relevant data. In addition, the standard contemplates the ability to provide relevant information about the cost of the trip via the over-the-air link. In this manner, the driver can be informed as to how much a particular journey will cost, or if there is no driver (a self-driving car, for instance), the vehicle automation system can make decisions based upon the cost data.

Challenges with Connected-Vehicle Based Tolling and Anticipated Timeline

The challenge with this approach is that it will take time to realize the benefit. The auto industry's process of standards development will not produce immediate results. Once the standard is developed and accepted, automakers will start to build applications based upon the standard.

The expectation is that the standard transaction transmission will be executed as a software application that can be sent via the preferred air interface. Since automakers are already planning to put wireless data devices in cars, uptake can occur quickly. This follows the wireless phone model, wherein the wireless phone becomes a multipurpose device that can run a variety of

> Tolling industry has to evolve from the mindset of owning the customer to earning the customer.
>
> ~ Tim McGuckin, MaaS America

applications. There are already more than 40 million vehicles equipped with 3G and 4G devices on U.S. roads.[33] There are approximately 17 million new vehicles sold each year,[34] many of which have wireless connectivity—the percentage sold with wireless connectivity increases every year.

Once the standard is accepted and installations begin to occur, the uptake can be rapid. The expectation is that automakers will further use CV-based tolling techniques to enable other forms of transaction-based transportation, such as parking and congestion pricing. However, it may take several years for the entire on-road vehicle fleet to be equipped with this technology. Until that time CV-based tolling is likely to coexist with the current model of tolling.

SMARTPHONE-BASED TOLLING APPLICATIONS (ALTERNATIVE SCENARIO 2)

> We don't want to have the same issues mobile app as happened with transponder protocols before. We want interoperability with mobile without conflict (proprietary issues).
>
> ~ Richard Carrier, GeoToll

In recent years several agencies have tested GPS-based technology for tolling applications. Notably, in 2018, the I–95 Corridor Coalition conducted a limited proof-of-concept using a location-based plug-in device along three tolled facilities. LA Metro conducted testing of enhanced GPS tolling in 2019. While vendors claim that machine learning and GPS geofencing can accurately differentiate vehicle position by lane, by recording millisecond positioning, these claims have yet to be substantiated by toll agencies. If successful, smartphone-based GPS technology would eliminate the need for license plate and transponder tolling. It would also ride on a ubiquitous device—the smartphone—to provide an application that serves as a single account or one-stop shop for not just tolling, but also other forms of transportation payments. Some agencies are beginning to adopt smartphone-based tolling as an additional option to supplement transponder and ALPR-based technology. Exclusive use of smartphone technology as the primary toll collection mechanism would still need to cross additional hurdles.

Challenges with Smartphone-Based Tolling

The challenge faced by any innovative technology, including smartphone-based applications, is not much different from the problems with RFID technology, which is coordination among providers and institutions. With several of these innovative, customer-focused services originating in the private sector, a key pillar for the success of these technologies would be effective collaboration between public and private entities involving data sharing and accommodation of business models that offer the best value for the transportation system and its users. As shown by recent MaaS pilots involving partnerships with public entities, these types of collaborations or partnerships come with their own set of challenges.

COMPREHENSIVE ROAD USAGE CHARGING (ALTERNATIVE SCENARIO 3)

Currently, several distinct, and sometimes overlapping, transportation revenue collection approaches exist in parallel to serve disparate policy goals, primarily through pricing of access to different road transportation assets. Aside from the primary source of transportation revenue—the motor fuel tax—tolling is the most significant revenue source. However, tolling exists within the larger context of road pricing, which also encompasses concepts such as congestion pricing, parking pricing, and road usage charging. It is possible that in the far future a comprehensive singular road usage charging system subsumes all other pricing approaches and comes to replace tolling and the motor fuel tax as they are currently known.

If a comprehensive, national road usage charging system is ultimately deployed, with all vehicles equipped with the necessary technology, it could completely alter the current toll collection paradigm. User fees for toll facilities may be collected through the same means as charges for all road usage (albeit at different per mile charge rates), and revenue distributed to appropriate agencies that finance and operate tolled facilities. It is likely that such a system could be administered by multiple third-party operators, which would transfer account management responsibility away from toll agencies as under today's industry model. These systems would likely operate nationally; hence, third-party operators would effectively ensure nationwide interoperability, much like the credit card industry does today.

Under this scenario, toll facilities would become separate jurisdictions (or priced entities). Revenue accumulated for miles driven on toll roads, which may have a higher per-mile rate than non-toll roads, would go to the toll agencies, while revenue for miles driven on other routes would go to State or local jurisdictions. Miles driven on express toll lanes (and some traditional toll projects) would be based not only on where the miles were driven, but also when the travel occurred, particularly with the proliferation of congestion pricing and other forms of dynamic or variable tolling. However, most of this will only occur if all vehicles contain onboard technology that identifies route and travel time, which will likely only occur if technology solutions can be developed, and proven, to effectively protect driver privacy.

Over the longer term, the impact of a road usage charging system on tolling, and nationwide toll interoperability in particular, depends on the following questions that, as of today, cannot be fully answered:

- Will there ultimately be nationwide deployment of a road usage charging system, or a national framework and account structure for road user charging?
- Will onboard technologies be developed that can provide a high level of individual privacy protection while still identifying vehicle location and time of travel?
- Will all vehicles ultimately be equipped with some form of onboard technology to provide location and travel time information?

CHAPTER 8. SUMMARY, CONCLUSION, AND LOOKING TO THE FUTURE

ETC emerged and proliferated in the United States over the past three decades, largely without predefined national technology or business standards. The business model for implementing ETC using RFID technology largely involved toll agencies—entities managing and operating distinct toll facilities—issuing transponders and managing associated ETC accounts, and thus effectively possessing their customers. However, as travelers needed to use facilities owned or managed by agencies other than their home agency, the need for local, regional, and national interoperability among toll facilities was quickly recognized. The prevalence of often incompatible technologies and operational policies across jurisdictional boundaries needed both a solution to the technology problem as well as a complex system of transaction exchange and revenue reconciliation among several individual agencies.

The technology issue became a major focus of extended interoperability research undertaken by IBTTA, the primary toll industry organization. An IBTTA committee over several years, with coordination and support from FHWA, explored the technical feasibility of transitioning to a single national tolling protocol. The committee undertook extensive independent testing of the three prominent protocols currently in use across the country. Although that process did not ultimately result in a single protocol, it did reinforce the acceptability of three main protocols, all of which effectively became open (nonproprietary) protocols that could be supplied by multiple technology providers.

The efforts to find a technology solution and the industry initiatives toward establishing standardized business processes have effectively led industry to eliminating the single national protocol as a solution to the interoperability problem. A key reason for this is the unequal burden that transitioning to a single national protocol would place on the agencies that are not currently using the selected protocol.

Among the considerations that would be associated with transition to a new technology include:

- Cost of acquiring, testing, and commissioning interoperable roadside and in-vehicle technology.
- Cost of back-office changes in technology and business processes.
- Public inconvenience of switching out obsolete hardware (transponders).
- Marketing and communications costs to implement the transition.

For agencies that do not receive a significant share of toll revenues from out-of-jurisdiction (away) customers or that witness sufficient market demand for interoperability, the benefits of an interoperable system are unlikely to match up to these costs.

THE PATH TO ACHIEVING EFFECTIVE NATIONWIDE INTEROPERABILITY

Even in the absence of an immediate solution in the form of a single national protocol, the U.S. toll industry is moving toward the goal of achieving effective interoperability.

Many of the business-side issues are being resolved by establishing and formalizing four major toll interoperability regions (or hubs) in the United States as follows:

- E-ZPass® region (northeast United States and the Midwest).
- Southeast region (Florida, Georgia, South Carolina, and Alabama).
- CUSIOP Region (Texas, Oklahoma, Kansas, Colorado, and Louisiana).
- Western region (California, Oregon, Washington, and Utah).

Within each of these regions, interagency communication connections already exist. In some cases, the existing regions are using peer-to-peer communication, in which data from one agency are transferred electronically to another interoperable agency individually. Each region is in the process of establishing regional hubs operated by one or more host agencies. The regions plan to ultimately communicate via a hub-and-spoke system, moving away from the peer-to-peer arrangement for data and revenue exchange. When fully established, a hub-to-hub communication network will enable interregional transactions, exchange and processing of information, and revenue reconciliation. This will provide the framework for nationwide toll interoperability.

Challenges to Achieving Effective Interoperability through Regional Hubs

The current trajectory suggests that nationwide toll interoperability will probably be achieved within the next 2–3 years. This would include the time needed for agencies to acquire technology, reconcile remaining business rules, establish four regional hubs, and eventually initiate hub-to-hub transaction and revenue exchange. However, several issues still need to be resolved:

- **Business rules challenge.** Implementing different policies and processes among toll agencies, such as processing time limits and rules for handling disputes. Individual State laws may also differ on questions related to privacy and the type of information that can be included in interagency transactions. Progress has been made within and among the regions on some of these rules. However, local legislation may still be needed, and various agreements would still need to be ratified.

- **Transitioning to a hub model.** Although there is intention to leverage current tolling interoperability regions, setting up the regional hub model will require investments. Back-office systems need to be adapted and regional hubs developed and maintained, which will require upfront investments and long-term financing.

- **Business case challenge.** Given the costs associated with establishing interregional hub-to-hub transfers, some smaller agencies may not be able to make a business case to justify the investment. Although there is considerable interregional travel between the E-ZPass® and southeastern regions, considerably less frequent interregional travel occurs between the E-ZPass® States and the western regions.

- **Out-of-state billing and violations processing challenge.** ETC interoperability is focused on allowing customers to use their ETC accounts nationally and for toll agencies to seamlessly collect tolls. However, it has not addressed the challenge of out-of-state

drivers who do not have ETC accounts. Toll agencies have expressed that collections and violation enforcement have been a considerable challenge due to lack of a national approach to violation reciprocity among States.

- **Legal implications**. The combination of new technologies to identify customers on toll facilities and new payment methods raises new legal hurdles for nationwide interoperability. Privacy laws and regulations at the Federal, State, and local levels could preclude certain technologies and the exchange of information for interoperability, thereby creating a patchwork of adoption and unraveling universal acceptance. For instance, exemptions on exchanging of personal identifiable information typically extended to public toll agencies may not clearly apply to third-party payment service providers.

> MTA has worked with the New York State Department of Motor Vehicles to obtain legal reciprocity for out-of-state toll violators. But a Federal compact or proactive role fostering legal reciprocity among States on toll violations would be helpful.
>
> ~ Allison C. de Cerreño, Deputy Chief Operating Officer, Metropolitan Transportation Authority

- **Customer communications.** As more payment channels are developed and incorporated for toll payments, the ability for toll agencies to communicate to interoperable customers becomes even more challenging. Signage and customer agreements are being developed to simplify communications for near-term interoperability.

THE CHANGING LANDSCAPE OF TOLLING BUSINESS MODELS AND TECHNOLOGY

The above clear pathway towards achieving effective nationwide interoperability is supported and bolstered by some key trends in the evolving tolling technology landscape.

Vehicle and Account Identification Technology

A key aspect of the technical acceptance of the three identified protocols is that a combination of tolling technologies has improved significantly in recent years to provide toll agencies cost-effective, accurate, and reliable methods for identifying ETC customers. These include:

- **ALPR –** Wider implementation of ALPR as more agencies convert from gated toll plazas to ORT and AET toll facilities.
- **Multiprotocol readers –** Wider implementation of readers that can read two protocols and recent introduction of readers that can read three protocols.
- **Multiprotocol transponders –** Development of transponders with the ability to communicate using multiple protocols.
- **A single de facto protocol –** Rise in adoption of a protocol that provides comparable performance to existing protocols at a lower cost. This is being witnessed in the rise in the adoption of the 6C protocol. Although 6C has a smaller installed base of distributed transponders nationally, it is fast becoming the cost-effective choice.

Third-Party Payment and Account Management Services

Several new third-party payment services have emerged that provide alternative payment and account management mechanisms for their toll customer clients and payment guarantees to tolling agencies. When a vehicle enrolled in a particular service passes through a tolling point, the toll charge is electronically billed to the service provider, which guarantees payment to the tolling agency. The toll charge is then applied to the individual customer account. Because the services are usually accepted at many toll agencies, interoperability is effectively accomplished by the service provider network and does not rely on agency-to-agency transfers of transaction data and payment reconciliations. Some key common characteristics of these services include:

- **Fleet customers.** The most prominent customers of such services are commercial fleet owners and rental car companies—toll customers with a high volume of toll transactions or significant travel across jurisdictional lines. In addition to services related to tolling, third-party services provide other services to their customers, such as specialized account data and accelerated release of transaction data.

- **Technologies.** Third-party payment services primarily rely on issuing the predominant transponder protocols used in areas driven by their customers and registration of customer license plates in other areas. Some third-party payment services also leverage GPS-based applications. New in-vehicle technologies have also created a demand for third-party payment services, such as multiprotocol transponders and transponder devices integrated into rearview mirrors. This necessitates the use of third-party account management since the tags are not issued by an individual toll agency.

- **Specific market.** However, these service providers are likely to remain a niche service in the tolling ecosystem. Today, even with several third-party services, electronic tolling with agency-issued transponders constitutes most electronic tolls.

TECHNOLOGIES AND BUSINESS MODELS THAT MAY IMPACT THE HUB-BASED INTEROPERABILITY MODEL

Looking toward the future, several changes in electronic payment systems, vehicle and account identification technologies, and approaches to assess and collect transportation revenues could fundamentally alter the toll collection approaches of today. There are three potential alternative scenarios with implications for tolling interoperability in the United States over the long term.

- **Alternative scenario 1:** Built-in vehicle technology supersedes RFID-based technology currently implemented through agency-provided transponders; CV technology or other approaches employing onboard telematics are candidates for this alternative scenario.
- **Alternative scenario 2:** Smartphone-based applications that support toll payments could supersede RFID-based technology because of their customer friendliness and availability.
- **Alternative scenario 3:** A comprehensive road usage charging approach that subsumes various concepts such as tolling, congestion charging, and other roadway pricing policies and programs could render obsolete the current model of tolling as a separate and distinct pricing mechanism.

Although these alternative scenarios may not have an imminent impact on the current trajectory of ETC interoperability, they may have implications in the medium-to-long term on how tolls are collected across the country. Toll industry stakeholders have already begun to contend with some of these developments, as described below:

- **Technical Interoperability.** As technologies that identify customers and vehicles on tolled road facilities broaden beyond the use of transponders and license plates, toll agencies will face the question of whether to invest in these new technologies to maintain interoperability.
- **Exchanging Payments.** With the rise of new transportation payment mechanisms, toll agencies benefit from potentially less-expensive methods for identifying and collecting payments from good customers instead of chasing violators with typical department of motor vehicle lookups, sending out violation notices, and going through violation escalation processes. These new transportation payment methods shift the ownership and responsibility for customers and their accounts from local toll agencies to third-party private entities.

In Summary

In summary, the in-development regional hub-based model is expected to provide effective nationwide toll interoperability in the short term, after the remaining business rule, policy, and legal challenges are overcome. In the longer term, however, this current model may become increasingly influenced by market and technology forces leading away from agency ownership of accounts. As the challenges of creating national interoperability in the near term are being addressed through a combination of a public-sector-led national regional hubs approach and private-vendor toll account aggregators, national interoperability appears to be a continually evolving concept and alternative technologies may play a role in continuing or expanding ETC interoperability.

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APPENDIX A. NATIONAL CLEARINGHOUSE EXPERIMENT—THE ALLIANCE FOR TOLLING INTEROPERABILITY

A national clearinghouse concept for interoperability uses a centralized approach, where individual toll agencies directly exchange toll information with a single tolling hub instead of having to connect with multiple agencies and/or through multiple layers of agencies. The clearinghouse is directly responsible for exchanging customer transponder and license plate data, posting transactions, and settling payments and takes on the complexity of connecting with all toll agencies.

Formed in 2008, the Alliance for Toll Interoperability (ATI) emerged from International Bridge, Tunnel and Turnpike Association (IBTTA) interoperability discussions at the time in order to develop a national clearinghouse for interagency toll transactions and financial settlement. ATI was not at odds with IBTTA, the primary toll industry trade association, but rather was formed by toll agencies to specifically focus on the potential of clearinghouse capabilities and interoperability, as delineated in the organization's mission statement: "Promoting and implementing interstate interoperability for the benefit of customers and member agencies."[17]

In 2008, interoperability through the use of transponders was a significant problem for a variety of reasons. First, multiprotocol reader technology was not ubiquitous among toll agencies. Second, the proprietary status of certain protocols (i.e., time domain multiplexing or TDM at the time and SeGo) limited the number of equipment vendors able to use them, therefore driving up costs to adoption. Requiring electronic toll collection (ETC) customers to mount multiple transponders with different protocols was not a customer-friendly solution.

Therefore, by 2010, ATI developed and piloted a national interoperability hub based on license plate capture with violation enforcement system (VES) cameras. The pilot involved seven toll agencies and 11 toll vendors, and successfully proved ATI's interoperability hub concept. Leveraging experience from the pilot, ATI subsequently contracted a vendor to build a national hub in 2013. Initially built to exchange license plates, ATI's hub was planned to eventually support transponder interoperability. It would also enable third-party payment services—private vendors without toll roads, but with tolling customers—to connect into the ATI hub, which could improve the pool of ETC accounts and customers. Figure 28 shows the functions the ATI clearinghouse was planned to provide.

ATI planned to finance its hub development by charging toll agencies three fees: a one-time sign-up fee, a monthly maintenance fee, and a transaction fee for transactions matched through the hub. ATI and its vendor negotiated pricing and terms with tolling agencies and interoperability regions to deploy the ATI hub.

As of 2020, the ATI Clearinghouse National implementation has not progressed, and is unlikely to move forward. Most toll agencies prefer the regional hub-to-hub model, since it leverages existing business processes, system interfaces, and agreements.

Source: Alliance for Toll Interoperability.
ATI = Alliance for Toll Interoperability; BOS = back-office system; IOP = interoperability.

Figure 28. Diagram. Alliance for Toll Interoperability's national hub serves as a centralized clearinghouse to pass interoperability information and transactions in a hub-and-spoke network.

CHALLENGES TO THE NATIONAL CLEARINGHOUSE APPROACH

The ATI hub's focus on license plate capture and standing up an interoperability hub was to demonstrate viability of a centralized clearinghouse concept. This approach bypassed having to deal with myriad transponder protocols used nationally and leveraged the license plates on every vehicle in the United States to enable any driver to sign up for interoperability. However, the drawbacks to relying on license plate captures are as follows:

- Lack of VES cameras on all toll roads, such as express lanes that only have ETC through transponders in Washington, Utah, and California.
- Blocked views by bike racks, dirty license plates, or poor image quality prevent capture of readable license plate images.

While the ATI hub has the challenge of interfacing with all types of toll systems, system changes are isolated rather than imposed on all other toll agencies. For example, if an agency wants to adopt a new standard for exchanging data, ATI can implement the upgrade, but continue to use other standards for other toll agencies.

Financial Challenges

The business case for the ATI hub to be financially viable is uncertain. For toll agencies, the cost of processing license plate-based transactions is higher than transponder-based transactions because human intervention is needed to manually review images to achieve acceptable accuracy. Toll agencies also tend to prefer transponder-based transactions because of revenue loss risks from difficulties with license plate image capture. These costs and revenue risks weigh into toll agencies' decision to sign up for the ATI hub.

Another conundrum is the ATI hub needs to have a critical mass of toll agencies signed up, otherwise the ATI fees for each agency would be prohibitively high. If too few toll agencies sign up for the ATI hub, the pool of potential interoperable customers will be small. A small pool of interoperability customers reduces the likelihood of processing a large volume of interoperability transactions. Too few interoperability transactions mean fewer transactions to spread the ATI costs over. The ATI hub faces the cost spiral caused when the high cost of joining the ATI hub discourages other toll agencies from joining. Finally, the ATI hub does not handle payment settlements, so agencies still need to create settlement procedures and agreements among themselves. These financial challenges are the primary reasons the ATI national clearinghouse is no longer being pursued.

Governance, Legal, and Communications Challenges

Governance of the ATI hub has already been established and used successfully to develop a pilot and procure a hub vendor. ATI does not address legal hurdles and differences in tolling policies, but the hub-and-spoke network makes it easier to handle technical differences rather than each toll agency coordinating connections to multiple systems. As a centralized hub, developing and communicating ATI interoperability is consolidated with ATI taking the lead.

APPENDIX B. APPROACHES TO TOLL INTEROPERABILITY OUTSIDE THE UNITED STATES

Examples of interoperability in other countries offer valuable lessons for progress toward nationwide interoperability in the United States. The following sections explore international tolling interoperability efforts, including the European Union (EU), Turkey, and Brazil, and explore interoperability in the payment industry.

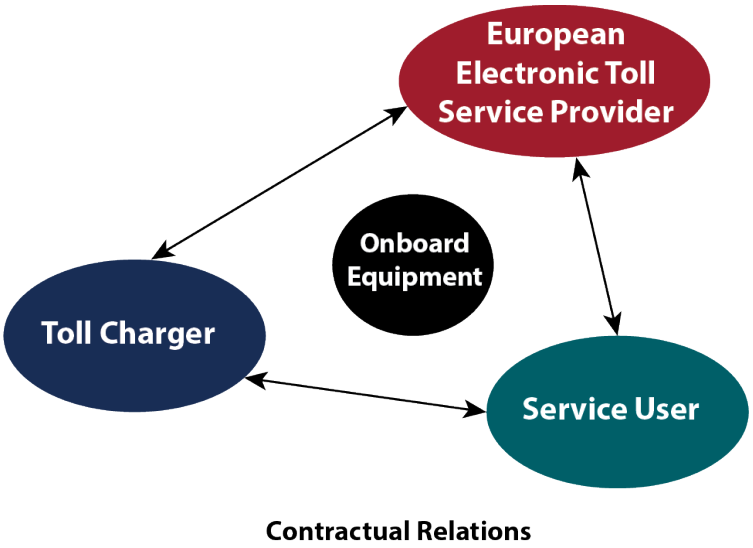
TOLLING INTEROPERABILITY IN THE EUROPEAN UNION

International electronic toll interoperability has been a major goal within the EU since its inception. Many toll roads, bridges, and tunnels exist in Europe, most financed and operated through a public/private concession model. However, somewhat like the United States, the different countries of the EU tend to use differing technologies, which are not always compatible.

Directive 2004/52/EC of the European Parliament and of the Council established the necessary conditions for tolling interoperability in the EU. A key focus of this directive is technological interoperability. It mandated that all toll road systems must provide tolling technology solutions through satellite positioning, mobile communications, or dedicated short-range communication (DSRC) based on 5.8 gigahertz frequency. The directive also underscored the need for a single subscription contract between clients and toll agencies for tolls and all forms of road usage charges.

This directive and the related European Commission Decision 2009/750/EC set the conditions of a European Electronic Toll Service (EETS) and the following three main stakeholder roles, as shown in figure 29:

- Toll chargers responsible for collecting tolls as taxes, concession fees, or duties.
- Service users who are using tolled infrastructure and liable for tolls.
- EETS providers who ensure interoperability to pay tolls within the European network by providing a single onboard equipment (OBE) and a single contract to the user.



Source: Adapted from Association of Electronic Toll and Interoperable Service.
EETS = European Electronic Toll Service; OBE = onboard equipment.

Figure 29. Diagram. European Electronic Toll Service business model.

The current EETS model is based on a contractual relationship among the above parties. The contract between toll chargers and EETS providers defines the conditions for acceptance of the front-end for collecting tolls. EETS is intended to ensure interoperability, in that tolling is enabled by a single vehicle device OBE, which is associated with a single account/contract, and the account is managed by a single EETS provider. The OBE stores the vehicle identification data and EETS provider data and serves as the link among the three contractual relations.

EETS was envisioned as complementary to local (statewide or regional) toll systems. Under the 2004 directive, EETS providers are obligated to make the service available along all EU-tolled roads by forming contracts with all the agencies. Certification and compliance are fundamental prerequisites to becoming an EETS provider. When there is a problem in EETS customer transactions, the EETS provider will pay the toll to the agency and clear it with the customer afterward. As such, the business model is based on trustful relations among the actors, provided certain conditions are met.

Between 2004 and 2007, several aspects of an interoperable system were explored by expert groups, which published reports with detailed specification of technologies, equipment certification procedures, enforcement and roles of financial institutions, and payment mechanisms. However, the directive was missing essential legal, commercial, and organizational aspects, including business model for risk management. Since the regulation failed to define a business context to make EETS affordable to service providers, it did not provide a pathway to effective EU-wide interoperability. A critical position paper by the Association of Electronic Toll and Interoperable Services pointed out the following main requirements (among others) for achieving EETS:

- A registration process that is annually renewed to establish founding principles of a trustful relationship between EETS providers and toll chargers.

- A way to fairly share and compensate for risk management between stakeholders.
- A European organization in charge of interoperability management.

Europe's tolling market is currently made up of many electronic toll systems, which are different in technology and procedure for collecting tolls. This creates barriers to the operation of the internal market, constraining the free flow of EU cross-border traffic.[18] The European Commission estimated the need to hold multiple devices to represent a cost of more than €300 million a year.

Between 2013 and 2015, the Regional EETS (REETS) project was implemented to support existing legislation by deploying EETS-compliant services in a cross-border regional area, including the following member States: Austria, Denmark, France, Germany, Italy, Poland, Spain, and Switzerland. The project had two main parts:

- Analysis phase: focused on contractual framework and risk management, certification, key performance indicators, and back-office interfaces.
- Monitoring phase: focused on coordination and running a pilot.

REETS resulted in a demonstrable increase in cooperation among the EETS market players toward achieving the goal of effective interoperability.

TOLLING INTEROPERABILITY IN BRAZIL

Brazil started Federal toll roads under management of the National Department of Roads, and then eventually auctioned as private concession. States in Brazil launched their own concession programs shortly after Law 9277/1996 allowed for the delegation of responsibilities for stretches of Federal roads to the States. Difficulties in managing these contracts led to a policy reversal in 2000. Accordingly, all toll roads that had operational and financial difficulties were returned under the oversight of the Federal government. In 2017, 11,191 kilometers (km) of toll roads were auctioned as private concessions by the Ministry of Transportation, Brazilian National Agency for Terrestrial Transportation (ANTT), or States under the delegation regime. Currently, Brazil has 55 private concessionaires operating nearly 300 toll plazas in 10 southern and eastern States.

With many private and independent concessionaires, along with inconsistent policies among States, tolling interoperability in Brazil was far from functional. To address this issue, Brazil's Departamento Nacional de Trânsito (Denatran) established the 915 MHz-based National System for automatic vehicle identification, known as Sistema Nacional de Identificação Automática de Veículos (SINIAV), as the new national protocol. The aim is to enable mandatory electronic registration of all road vehicles by using a single passive chip.

Following establishment of SINIAV as the national protocol, various concessionaires and agencies upgraded their tolling systems to comply with this push from Denatran. This section expands on several examples of such efforts.

In line with SINIAV efforts, the Transportation Agency of the São Paulo State in 2012 implemented a new all-electronic tolling (AET) system based on secure radio frequency

identification (RFID) in 19 Highway Concessions. The system enables multiple service operators to work independently and securely with their own base of customers. The toll plazas have the same infrastructure (an RFID reading system) to serve all certified operators, locally integrating all other aspects of vehicle identification and classification.

In the first 15 months since its launch, the number of service operators offering automation to end users quadrupled, and the number of hardware contractors increased from two to more than 10, decreasing the cost of a free-flow, all-electronic tolling collection portal by a factor of 10, and the end price of a tag by a factor of two, on average. This system is now under expansion to all States in Brazil under an official program regulated and developed by the ANTT.

In 2013, Brazil opened its first fully operational, all-vehicle multilane free-flow tolling system in São Paolo for a new phase of modern electronic fee collection. The State government, by Renovias (which manages 346 km of State roads), installed a free-flow tolling technology on the SP–340 motorway (Rodovia Governador Adhemar Pereira de Barros) that serves more than 2.25 million residents of the Campinas metropolitan region, a major center of industry and high-tech innovation north of São Paulo.

TOLLING INTEROPERABILITY IN TURKEY

In 1999, Turkey introduced a DSRC-based electronic tolling solution on existing toll plazas. The demand for DSRC boxes remained low, while the vehicle miles traveled on toll roads significantly increased. The General Directorate of Highways (KGM/TCK) decided to introduce a new ETC solution that ran parallel with the existing one. One requirement was to equip all vehicles so toll payments could be administered using ETC solutions.

Turkey decided to introduce mandatory ETC and demonstrated the efficiency and cost-effectiveness of RFID technology as an alternative to existing DSRC solutions. RFID technology was chosen because it was cost-effective—less than 2€ for an RFID tag—and easy to distribute (an RFID tag can be mailed). Additionally, there is no maintenance (no batteries, compared to DSRC OBU).

In 2013, Turkey introduced the new Fast Passing System (HGS) for tolling on its 2,000 km national highway network, heralded as the first full-scale use of passive RFID tags for electronic open road tolling in Europe. HGS is an upgrade of Turkey's earlier automatic passing system technology, which uses active RFID boxes in vehicles.[19] OGS is being gradually phased out, as vehicle owners in Turkey sign up with the new system and fit the thinner windscreen-mounted HGS tags. Turkish authorities chose to install a system based on the ISO 18000-63 (6C) standard, avoiding the European Committee for Standardization alternative. Although the newly installed system is not currently interoperable with the EU's system, developers claim that a shift to an EU standard can easily be done, if requested. The upgrade to HGS presents several advantages associated with modernization, not least its integration with a new electronic back-office payment system, which is underpinned by robust infrastructure for vehicle checking and enforcement. The technology allows vehicles to pass without stopping, a principal benefit of and reason for Turkey's latest toll system upgrade, incentive for drivers to register to HGS is presenting itself in the form of tollgates free of traffic queues.

GLOSSARY

away (customer)	Customers with electronic toll collection (ETC) accounts from interoperable toll agencies other than the toll agency whose facility the customer is using.
back-office system	Portion of overall toll system used to manage customer accounts, handle payments, process transactions and violations, handle financial reconciliation, support other customer service center needs, and interface with other external system including for toll interoperability.
business rules	Compilation of tolling logic and policies used by toll agencies, including defining account rules, laying out in-lane rules, conducting enforcement, processing transactions, setting toll rates, processing violations and collections, conducting image review, handling customer disputes, supporting audits and financial reconciliations, and handling interoperability processes.
connected vehicle	A wireless connectivity solution that is included within the vehicle itself and allows connection with other vehicles, road users, and the infrastructure.
customer service center	A toll agency's main point of contact (either in person, by phone, or online) with toll customers; functioning to manage customers, process transactions and payments, and interface with toll customers.
home (agency)	The agency where a customer's transponder is issued and their ETC account is managed is usually referred to as the customer's home agency.
home (customer)	Locally registered electronic toll collection customer.
hub	A toll agency designated a centralized clearinghouse within an interoperability region that will process interoperable toll transactions on behalf of toll agencies within its interoperability region with those outside of it.
hub-to-hub	The configuration where interoperability regions use centralized clearinghouses (hubs) to handle interoperability transactions by hubs communicating directly with each other. This is similar to a peer-to-peer setup where there is no intermediary in between hubs.
integrated toll module	Multiprotocol transponders compatible with existing roadside system and toll readers that have two or more protocols built in.

interface control document	A document that contains specifications on how toll systems communicate and exchange data with each other. It details all the interfaces, such as data formats, timing of data exchanges, and data transmission methods.
interoperability network/regions	Collection of toll agencies that have enabled their ETC customers to pay tolls electronically on each other's toll facilities without customers having to use any additional ETC device or open a new ETC account. Currently operating interoperability networks include E-ZPass®, Central United States Interoperability, Southeast Region, California, Colorado, and Oregon.
Mobility as a Service	The concept of integrating various forms of public and private transportation services, such as transit fare cards, ride sharing, bike sharing, parking, and toll accounts, into a common transportation service platform to create a more seamless experience for customers to plan, choose, and pay across multiple mode options.
multiprotocol reader	Readers that can read two or more radio frequency identification (RFID) protocols accurately. Although multiprotocol readers can be configured to read half a dozen or more protocols, most can typical accurately two protocols at highway speeds. Some multiprotocol readers are now being deployed to read three protocols at highway speeds.
multiprotocol transponder	Transponder devices that can communicate with readers using one or more protocols.
open road tolling	See all-electronic tolling.
peer-to-peer	The configuration of interoperability networks where a toll agency (peer) exchanges data, transactions, and payments directly with each other toll agency (another peer) within its interoperability network, without going through any intermediary agency. Contrast to peer-to-hub.
peer-to-hub	The configuration of interoperability networks where a toll agency (peer) exchanges data, transactions, and payments with a centralized agency (hub). The hub then handles the exchanges to the other peers in the interoperability network. Contrast to peer-to-peer. The term is derived from a bicycle's hub-and-spoke configuration.
protocol	The standard, a compilation set of guidelines and specifications, for how transponders and readers communicate to each other. Protocol standards prescribe the frequency used, data structures, and other technical parameters for over the air communications. Common

	protocols currently used for tolling include time domain multiplexing (TDM), SeGo, ISO 18000-63 (6C), and Title-21.
radio frequency identification	Technology that uses electromagnetic fields to wirelessly track objects. It is used in tolling to electronically identify a vehicle through the use of a transponder and a reader on the roadside connected to a toll system. RFID frequencies and devices used in tolling are in licensed portion of communication spectrum regulated by government regulators, such as the Federal Communications Commission. Also, commonly referred to as automated vehicle identification.
reader	A radio frequency identification device to uniquely identify ETC customers on toll facilities. The reader is mounted with an antenna on the roadside to communicate with transponders mounted on vehicles. Also see the term multiprotocol reader.
road usage charging	An alternative transportation revenue collection where vehicles are assessed a fee for the mileage driven and perhaps where and when they occurred.
roadside system	A portion of the overall toll system used to identify vehicles on toll facilities. This includes roadside readers to communicate with transponders, automatic license plate recognition (ALPR) cameras to capture license plates, electronic signage to communicate to drivers, and other equipment to identify where and when ETC customers used a toll facility. Depending on the toll agency and facility type, the roadside system may also manually review license plates, calculate dynamic toll rates, and calculate how much to charge a customer based on how far a customer drove on the toll facility.
third-party payment services	Consolidated toll bills service provided by private sector vendors to its customers, where the third-party payment service sets up ETC accounts at multiple toll agencies and registers its client transponders and license plates. This enables the customer to get one toll bill regardless where their vehicle drives, while the third-party payment services handles paying any toll transactions incurred anywhere it has accounts with.
toll-by-plate (pay-by-mail)	A method for customers to pay electronically where their vehicle’s license plates are identified through the use of ALPR cameras. If the license plate is already associate with a customer ETC account, then payment is automatically deducted. Otherwise license plates are used to track down

	registered vehicles owners, so toll agencies send either toll invoices and/or toll violation notices. Also commonly called Pay-by-Mail and video tolling.
tolling point	The area in a toll lane where the toll is recorded.
transponder	A radio frequency identification device mounted internally on windshields or externally on bumpers or headlights that communicate to roadside reader to identify vehicles as ETC customers. Some Depending on the transponder technology, some are shaped like a card deck and others as small as a sticker bandage. Some toll agencies that operate express lanes issue transponders with switches to allow customers to indicate the number of people in the vehicle to
tag/sticker	Alternate names for transponders.
violation enforcement system	See automatic license plate recognition

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