Documenting Effective e-Ticketing Implementation

PUBLICATION NO. FHWA-HRT-23-047

JUNE 2023

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

FOREWORD

Electronic ticketing (e-Ticketing) is an innovative process that automates the recording and transfer of information in realtime for materials as they are moved from the plant to the site. The real-time access of ticket information in electronic format via mobile devices provides imminent benefits of operational efficiencies and safer contactless delivery. The digitalization of ticket information also offers the opportunity of collecting valuable information, which otherwise is lost after construction is complete, to facilitate digital collaborative data exchange. The goal of this study is to gain a better understanding of e-Ticketing's potential capabilities and use cases for improving project delivery, oversight, and safety outcomes, its limitations, and departments of transportation (DOT's) implementation experience. It documents the state of the knowledge of e-Ticketing through interviews and case studies, presents a business case for e-Ticketing, and provides guidance on implementation planning. This study will inform highway construction, materials, and information technology practitioners responsible for implementing electronic construction (e-Construction) technologies within their agencies.

Jean A. Nehme, Ph.D., P.E.
Director, Office of Infrastructure Research
and Development

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.
FHWA-HRT-23-047

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Documenting Effective e-Ticketing Implementation

5. Report Date
June 2023

6. Performing Organization Code:

7. Author(s)
Suri Sadasivam (ORCID: 0000-0002-3980-1134), Roy Sturgill (ORCID: 0000-0002-0702-8351), Jagannath Mallela (ORCID: 0000-0001-9464-7937), and Gabriel Dadi (ORCID: 0000-0002-7903-3598)

8. Performing Organization Report No.

9. Performing Organization Name and Address
WSP USA
1015 Half St SE No. 650
Washington, DC 20003

10. Work Unit No.

11. Contract or Grant No.
693JJ319D000030/693JJ320F000474

12. Sponsoring Agency Name and Address
Federal Highway Administration
Office of Infrastructure Research and Development
6300 Georgetown Pike
McLean, VA 22101

13. Type of Report and Period Covered
Final Report; October 2020–July 2023

14. Sponsoring Agency Code
HRDI-20

15. Supplementary Notes
The Contracting Officer's Representative was Matthew Corrigan (HRDI-20; ORCID: 0000-0002-1230-8462).

16. Abstract
The practice of printing, collecting, maintaining, and retaining paper tickets is cumbersome, less safe, outdated, more expensive, less efficient, and less sustainable than paperless ticketing. The adoption of electronic construction (e-Construction) technologies in construction administration and delivery offers ways to overcome these inefficiencies. By leveraging the groundwork laid by e-Construction, electronic ticketing (e-Ticketing) has attracted wider interest by transportation agencies as an electronic solution for material delivery. e-Ticketing is a digital innovation that automates the recording and transfer of information in realtime for materials as they are moved from the production plant to the site. Since the first e-Ticketing pilot in 2015, the implementation landscape has been rapidly emerging. The 2020 construction season made the move to e-Ticketing even more relevant by increasing the need for touchless operations. State transportation agencies (STAs) have a diversity of practices regarding material types for which e-Ticketing is implemented, such as vendor and in-house solutions, and implementation approaches. In this context, this study documents the state of the practice and the state of the knowledge of e-Ticketing. The findings of the nationwide survey, conducted by the American Association of State Highway and Transportation Officials, on the practice of e-Ticketing, benefits and costs, implementation factors and challenges, and future plans of STAs are documented. Through the documentation of case studies, this study discusses the piloting experiences of nine STAs. In addition, this study presents a business case by documenting the strategic value of e-Ticketing with an illustration of benefits quantification. The study also presents additional information for implementation planning based on the analysis of the case study interviews, assessment of practice landscape, and review of emerging technological opportunities.

17. Key Words
e-Ticketing, material delivery, e-Construction, highway construction, quantity verification, advanced digital construction management systems

18. Distribution Statement
No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.
https://www.ntis.gov

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
168

22. Price
N/A

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 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AC	asphalt concrete
ADCMS	advanced digital construction management systems
AGC	Associated General Contractors
ALDOT	Alabama Department of Transportation
APC	Associated Pennsylvania Constructors
API	application program interface
app	application
AWP	AASHTOWare® Project™
BIM	building information modeling
BLE	Bluetooth® Low Energy™
BMS	bridge management system
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CMS	construction management systems
CMMS	construction materials management systems
COTS	commercial off the shelf
CSP	Cybersecurity Program
CSV	comma-separated values
DelDOT	Delaware Department of Transportation
DOT	department of transportation
DPS	dielectric profiling system
DWR	daily work report
eCAMMS	Electronic Construction and Materials Management System
ECMS	Engineering and Construction Management System
e-Construction	electronic construction
EDC	Every Day Counts
ETG	expert task group
e-Ticket	electronic ticket
e-Ticketing	electronic ticketing
FedRAMP	Federal Risk and Authorization Management Program
FDOT	Florida DOT
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
FME	feature manipulation engine
FTE	full-time equivalent
GIS	geographic information system
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HiCAMS	Highway Construction and Materials System
HMA	hot-mix asphalt
IC	intelligent compaction
ICT	intelligent construction technologies

ID	identification
IT	information technology
JSON	JavaScript Object Notation
LIMS	laboratory information management systems
LoRa®	Long Range
LoRaWAN®	Long Range Wide Area Network
MDMS	Material Delivery Management System
MnDOT	Minnesota Department of Transportation
NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NDOT	Nebraska Department of Transportation
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
NWZSIC	National Work Zone Safety Information Clearinghouse
PCC	portland cement concrete
PDF	Portable Document Format
PennDOT	Pennsylvania Department of Transportation
PMS	pavement management systems
PMTP	paver-mounted thermal profiler
PSA	Project Site Activity
QA	quality assurance
QC	quality control
QR	quick response
RFP	Request for Proposals
ROI	return on investment
STA	State transportation agency
TDOT	Tennessee Department of Transportation
UAT	User Acceptance Testing
UDOT	Utah Department of Transportation
WMA	warm-mix asphalt
WSDOT	Washington State Department of Transportation

CHAPTER 1. INTRODUCTION

BACKGROUND

Use of Paper Tickets for Material Quantities

The fundamental principles of highway construction management emphasize conformity of completed work and materials to project quality requirements and making payments based on the accurate determination of their quantities. U.S. Code of Federal Regulations (CFR), Title 23 Highways; related Federal laws; and directives, regulations, and policies established by the Federal Highway Administration (FHWA) set the minimal national standards for all Federal-aid highway construction projects (CFR 2013a; CFR 2013b; CFR 2013c; Weseman 1993; Van Ness 1989). Furthermore, State transportation agencies (STAs) and local public agencies have put mechanisms in place through their construction programs to verify pay quantities and qualities of completed work.

To ensure accurate determination of quantities of completed, paper tickets or weigh memos are being used on highway construction projects to track the quantities of materials hauled to a jobsite. Vehicle drivers collect paper tickets generated at a material production plant after a load is weighed using a scale. When the vehicle delivers the material at the jobsite, the STA, consultant inspectors, or contractor personnel climb on the side of delivery vehicle to collect paper tickets. The ticket taker collects and maintains the paper tickets for each truckload and records tonnage by lot numbers or location to prepare daily summary reports.

The practice of printing, collecting, maintaining, and retaining and archiving paper tickets is cumbersome, less safe, outdated, more expensive, less efficient, and less sustainable than using paperless ticketing. The advantages of going paperless in construction are well documented (Shah et al. 2017). Assigning inspectors or contractor personnel as ticket takers, amidst a chronic shortage of construction workers and high staffing turnover, is less efficient. With the use of paper tickets, critical construction data, such as tying quality data to placement location and fleet productivity, becomes difficult to capture after construction is complete. Furthermore, collecting paper tickets from a driver amidst live traffic, heavy equipment, and other construction activities in a work zone exposes workers to hazards and increases the likelihood for injury risks and fatalities.

Emergence of e-Construction

The adoption of electronic construction (e-Construction) technologies in construction administration and delivery offers ways to overcome these inefficiencies. FHWA defines e-Construction as "the collection, review, approval, and distribution of highway construction contract documents in a paperless environment" (FHWA 2021). The e-Construction process includes the following procedures:

- Electronic development of specifications, plan sheets, and three-dimensional models.
- Electronic capture of construction data.

- Electronic submission of construction documentation by stakeholders.
- Increased use of mobile devices, such as smartphones, tablets, and applications (apps).
- Increased automation of document review and approvals.
- Use of electronic or digital signatures.
- Implementation of secure document and workflow management accessible on any device in realtime.
- Use of advanced digital construction management systems (ADCMS) that enable and leverage the use of digital technologies on construction sites.

Many STAs have been mainstreaming various e-Construction technologies over the past decade. As of April 2019, and per the Every Day Counts (EDC)-4 Final Report, 46 agencies had piloted at least one e-Construction technology, while 15 of these agencies institutionalized e-Construction (FHWA 2019). The adoption of such technologies has resulted in widespread recognition of benefits associated with paperless workflows among all the stakeholders, including STAs and private sector entities. The STAs have progressed toward augmenting their information technology (IT) infrastructure in both hardware and software capabilities to strengthen electronic workflows, storage, connectivity, and devices. These developments comprise the groundwork for a wider interest in electronic ticketing (e-Ticketing) among STAs as an electronic solution for material delivery.

Introduction to e-Ticketing

As a market-ready digital innovation, e-Ticketing automates the recording and transferring of information in realtime for materials as they are moved from a quarry, production plant, or supplier facility to a construction site or storage facility. This paperless process uses technology to create, share, track, document, and archive material information, such as quantities, sources, and delivery information, in electronic or digital format. The process typically involves the transfer of data to a server for immediate access by multiple stakeholders, via mobile devices, for material verification and real-time operational decisions. Using electronic means simplifies the handling and integration of material certification, quality, and placement data into information systems for acceptance, payment, and source documentation. The electronic format of material and construction data is beneficial to creating and updating individual or group of data attributes in the ADCMS to make the system interoperable with other business information systems.

Furthermore, including material and construction data in the as-built digital model, which contains geometric and other nongeometric attributes or properties of highway infrastructure assets, creates a construction information model. In the future, from the building information modeling (BIM) perspective, the construction information model will become an essential element for creating a unified information model for lifecycle management of highway infrastructure assets. The e-Construction initiative, which was delivered under the Round 3 and Round 4 innovations of EDC, highlighted the technology and piloting of e-Ticketing in 2015 and later (FHWA 2015). Since these early years, the number of STAs adopting this technology has increased steadily. Many STAs have been piloting and demonstrating e-Ticketing on multiple highway construction projects for various material types. Among STAs, the material types for which e-Ticketing is implemented, vendor and in-house solutions, and implementation approaches are varied.

The implementation landscape, discussed in detail in chapter 2, is rapidly emerging. Some STAs are looking forward to implementing e-Ticketing with standard data items that replace the antiquated practice of paper-based tickets and handwritten notes by department of transportation (DOT) inspectors and contractor quality control (QC) personnel. In contrast, some STAs are advancing toward quality assurance (QA) automation by integrating e-Ticketing with other complementary technologies, such as intelligent compaction (IC). These differences in implementation approaches emphasize the necessity to document effective e-Ticketing practices across the country.

Maturity of e-Ticketing

The 2020 construction season made the move to e-Ticketing more relevant, due to the worldwide COVID-19 pandemic, by increasing the need for contactless operations and expanding the amount of project information that could be accessed digitally. Although some agencies developed commercially available or in-house e-Ticketing solutions during that construction season, many agencies allowed the use of image-based alternatives, such as graphics, photos, and scans of traditional paper tickets. Therefore, understanding the evolution and developmental stages of e-Ticketing is necessary. Various maturity levels of e-Ticketing technology types, which are also presented in figure 1, are discussed as follows:

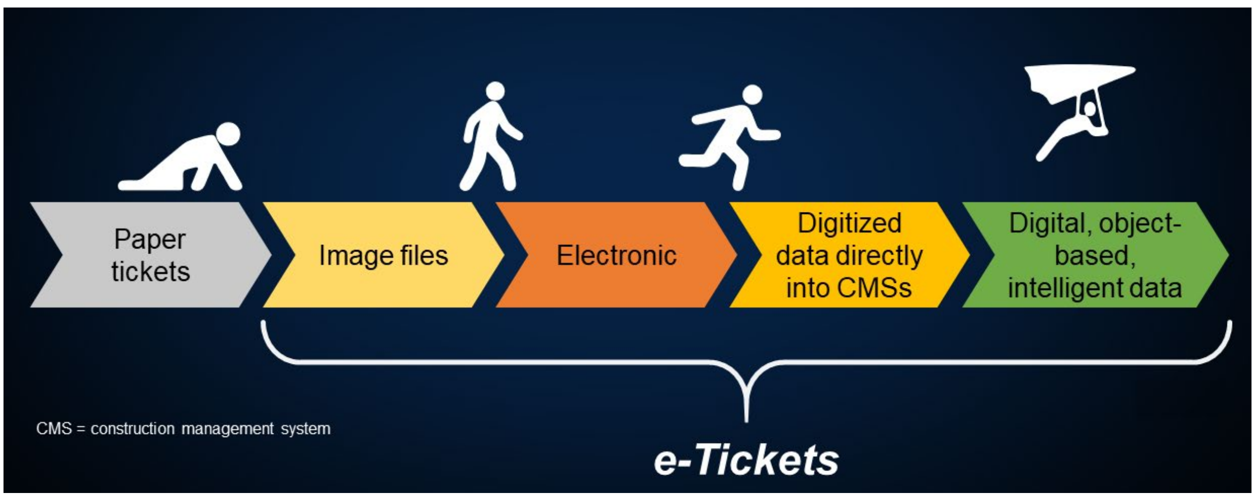
- Paper tickets—The traditional process entails printing delivery tickets on paper. The paper tickets serve as a bill of lading for the hauler and a source document to communicate material information and quantity and provide a basis for payment. The information from the paper ticket must be manually extracted and entered into the agency's construction management systems (CMS) for further processing and applications.

- Image files—The paper tickets are converted into an image form, such as a photo, PDF (Portable Document Format), scan, or fax, to enable electronic transmittal. The original paper ticket is still needed to serve as the source document and must eventually be delivered to the project or retained by the contractor or supplier. Because the image files contain unstructured data, the information must still be manually extracted and entered into the agency's business information systems.

- Electronic tickets (e-Tickets)—The tickets are produced in an electronic format and developed in-house or through a commercially available technology-based solutions. The e-Tickets are transmitted in realtime from load-out systems directly to field inspectors or through a server. The data may be placed in files with comma-separated values (CSV), text, or SQL (Structured Query Language) database formats and stored, queried, and used for further applications. Agencies that have implemented e-Ticketing solutions have achieved this developmental stage. The e-Ticket serves as a source document and must be securely stored and archived in electronic form.

- Digitalized tickets—e-Tickets are digitalized into semistructured data via compatible file formats commonly used for data exchange, such as JavaScript Object Notation (JSON) or extensible markup language, CSV and text files, etc., by using a standard data scheme for transmittal and exchange. The data fields are automatically extracted, transformed, and loaded via an application program interface (API) into an agency's ADCMS for further applications and archived under the ADCMS' protocol.

- Object-based tickets—The ticket data are structured as defined elements that are grouped intelligently, organized hierarchically, and linked with other datasets using a geographic information system (GIS) or BIM file formats, such as shapefiles, files in a geodatabase, Open Geospatial Consortium's® (OGC) InfraGML™, or industry foundation class alignment (OGC 2023.). The object-based ticket enforces data quality rules to validate data attribute and relationship requirements. In addition, the object-based ticket allows some operations, such as data retrieval or updating, to be automated by using a set of procedures. These procedures make the data easier to use in extensive data mining apps. By using this approach, processes such as payment can be automated based on the e-Ticket data transfer.



Source: FHWA.

Figure 1. Graphic. e-Ticketing developmental stages (Sadasivam and Sturgill 2021).

RESEARCH OBJECTIVES

The overall objectives of this study were to investigate and document e-Ticketing technologies; assess the current state of practice; and explore state-of-the-art deployment, use, and implementation efforts. This study focuses on establishing a state of the knowledge and practice related to the following factors:

- Practice landscape.
- Pilot implementation.
- Demonstration of benefits and costs.

- Deployment and implementation paths and challenges.
- Data standardization, use, and security.
- Verification of quantities.

REPORT ORGANIZATION

This report is organized into six chapters:

- Chapter 1 introduces e-Ticketing with a discussion on construction program requirements on material quantity and quality requirements, use of paper tickets, and the evolution of e-Construction.

- Chapter 2 presents the practice landscape of e-Ticketing with a discussion of the findings of an American Association of State Highway and Transportation Officials (AASHTO) survey among STAs to capture the state of the practice. This chapter also presents the information gathered from e-Ticketing vendors on the product capabilities.

- Chapter 3 describes the business case of e-Ticketing. This chapter discusses the strategic value of e-Ticketing, associated benefits and costs, and implementation considerations.

- Chapter 4 documents the findings of case studies conducted to document the e-Ticketing practices of nine STAs.

- Chapter 5 describes the implementation considerations for STAs seeking to implement e-Ticketing. The implementation considerations were summarized using the findings of practice landscape and case studies, as described in chapters 2 and 4, as well as an investigation of emerging technological trends.

- Chapter 6 describes the conclusions of this study.

CHAPTER 2. STATE OF THE PRACTICE

PRACTICE LANDSCAPE

In 2015, the Iowa DOT (Iowa DOT) piloted e-Ticketing on a highway construction project. The first pilot, which entailed using the e-Tickets for the delivery of asphalt mixture loads, provided a proof of concept that the hauling and placement of materials and their quantities can be electronically tracked and captured (Iowa DOT 2015). Following this first successful pilot, Iowa DOT conducted additional e-Ticketing pilots on asphalt and portland cement concrete (PCC) projects in 2016 (Iowa DOT 2016).

In 2019, the National Cooperative Highway Research Program (NCHRP) (Project 20-05, Topic 50-07) conducted a synthesis study to identify and document e-Ticketing practices around the country. The findings of this study culminated in the NCHRP Synthesis Report 545, *Electronic Ticketing of Materials for Construction Management* (Dadi et al. 2020). The report summarizes the implementation landscape of e-Ticketing technologies, including those STAs that had experience with e-Ticketing and their pilot efforts, success factors, and lessons learned, through a nationwide survey of 45 STAs. Figure 2 shows the 10 STAs that were using e-Ticketing at the time of the NCHRP survey.

Since the onset of the global COVID-19 pandemic, the use of e-Ticketing rapidly increased because of the need for contactless ticketing procedures. Twenty-four STAs were using e-Ticketing during the 2020 construction season, while five STAs were preparing for piloting (National Asphalt Pavement Association 2020). The STAs issued directives—through technical memos, policies, special provisions, and specifications—that encouraged the use of contactless ticketing alternatives, such as e-Ticketing technologies, PDFs, spreadsheets, scans, and photographs.

Supported by e-Construction technologies, and further accelerated by the needs of the pandemic, the practice landscape of e-Ticketing is rapidly changing. Therefore, conducting comprehensive data gathering and analysis to capture the state of the practice is important. This chapter presents the findings of two data gathering exercises, one conducted among the STAs through AASHTO to capture their implementation status and the other among the vendors.

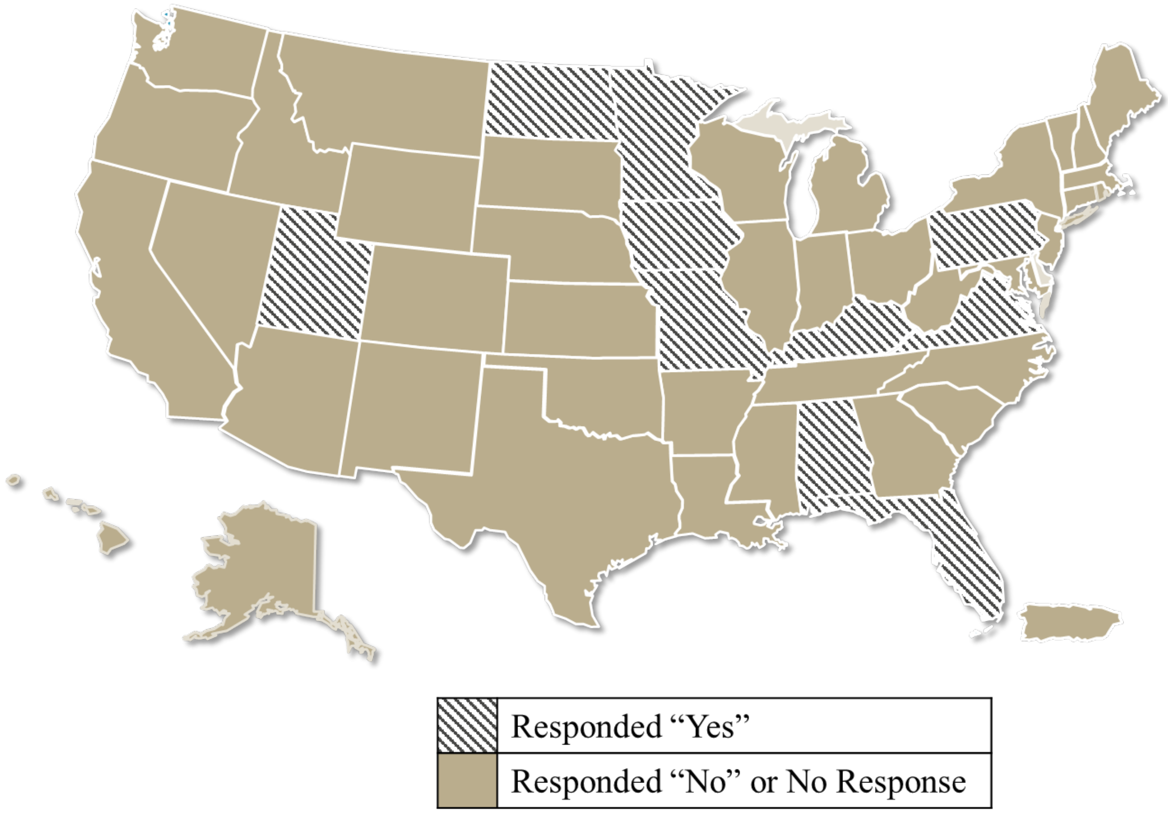


Figure 2. Map. NCHRP Synthesis 545: Map of States using e-Ticketing in 2019 (Dadi et al. 2020).

AASHTO Nationwide Survey

In coordination with the AASHTO Committee on Construction*,* a nationwide survey was conducted among transportation agencies with a questionnaire in the spring of 2021 to understand the state of the practice on e-Ticketing. The purpose of this survey was to gather information from the STAs on the status of adoption of e-Ticketing technologies, costs and benefits, data management practices, QA, future plans, and perspectives on the challenges associated with implementation. The following section summarizes the findings of the state-of-the-practice survey; these findings represent the practices that prevailed at the time of the survey. Appendix A presents the details of responses provided by each respondent agency.

Survey Respondents

The AASHTO Committee on Construction administered the questionnaire survey among the agencies using Momentive's® SurveyMonkey™, an online survey platform, and 75 responses were received (Momentive n.d). After removing incomplete and duplicate responses, the committee summarized 52 unique responses. Survey respondents included 51 STAs and the Ministère des et de Transports la Mobilité, PQ, Canada.

Status of e-Ticketing Adoption

Use of e-Ticketing

The survey questions focused on identifying the STAs that use e-Ticketing, the number of projects where e-Ticketing has been deployed, the extent of implementation, and the procurement of e-Ticketing on highway construction projects.

Of the 52 responding STAs, 26 indicated their use of e-Ticketing for highway construction, while the remaining 26 STAs did not use e-Ticketing at that time. Figure 3 shows these responses.

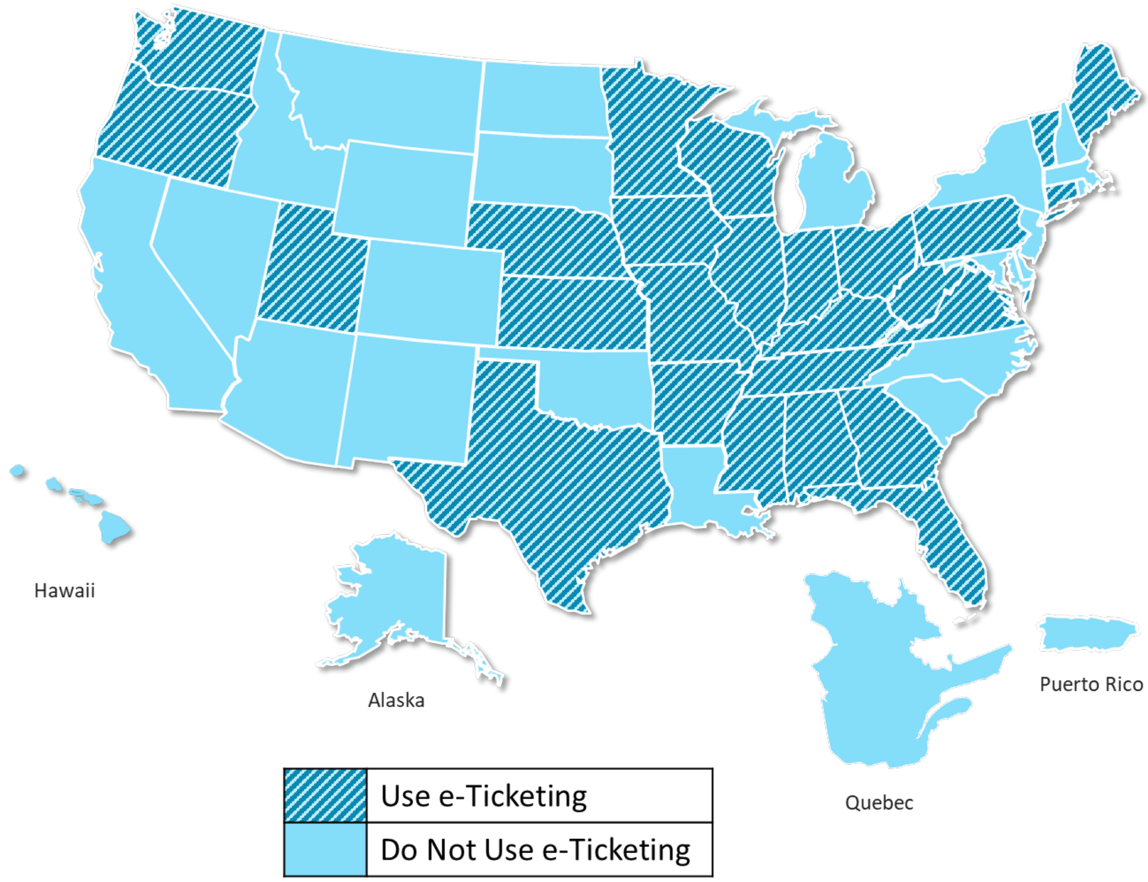


Figure 3. Map. AASHTO Survey: Map of agencies using e-Ticketing.

Of the 26 STAs that have used e-Ticketing, approximately one-third have tried e-Ticketing on 10 projects or fewer; another one-third have used e-Ticketing on 11 to 50 projects; and about one-fifth have used e-Ticketing extensively. Table 1 presents the frequency distribution of projects where e-Ticketing was deployed.

Table 1. Deployment of e-Ticketing in highway construction projects within an agency.

Projects to Date (No.)	Responding Agencies (No. Out of 26)	Agencies (Percent)
5 or fewer	6	23
6–10	3	12
11–25	5	19
26–50	5	19
51–100	4	15
101 or more	1	4
No response	2	8

No. = number.

Pennsylvania, Kentucky, Iowa, and Washington DOTs have used e-Ticketing on more than 50 projects, while Indiana DOT has used e-Ticketing on more than 100 projects. Two STAs did not track the number of projects. Texas DOT indicated that although e-Ticketing was an option for contractors to use upon the approval of the DOT engineer, the number of projects was not tracked.

On the extent of implementation, nine States have used e-Ticketing on individual projects, and eight States have conducted repeated pilots. Six STAs have used special provisions or specifications to implement e-Ticketing on their projects, whereas Indiana and Mississippi DOTs used special notes. Maryland DOT indicated that only digital scans and photographs of tickets were used as e-Tickets. Table 2 presents a summary on the extent of use by STAs.

Table 2. Extent of implementation.

Adoption Choices	Responding Agencies (No. Out of 26)	Agencies (Percent)
Individual pilot projects	9	35
Repeating pilot projects for gathering information and scaling up use	8	31
Extensive use by special notes	2	8
Extensive use by standard (or supplemental) specification	6	23

Mode and Product Type of e-Ticketing

e-Tickets are commonly handled through a variety of models, such as a digital photograph or scan of a paper ticket, or a standard e-Ticket. On the mode(s) of e-Ticketing, 19 of the 26 States with e-Ticketing experience indicated the use of stand-alone e-Tickets that are transmitted to a cloud, and 3 STAs received them directly. Seventeen of 26 States used PDFs, whereas 14 States allowed digital photographs or scans of paper tickets. Table 3 and figure 4 present the breakdown of responding STAs' use of various modes of e-Ticketing.

Table 3. Mode of e-Ticketing used by agencies.

e-Ticketing Mode	Responding Agencies (No. Out of 26)	Agencies (Percent)
Digital photograph/scan of a ticket	14	50
PDF	17	65
Standalone e-Ticket transmitted to a cloud and shared with DOT	18	69
e-Ticket directly received by a DOT information system	3	12

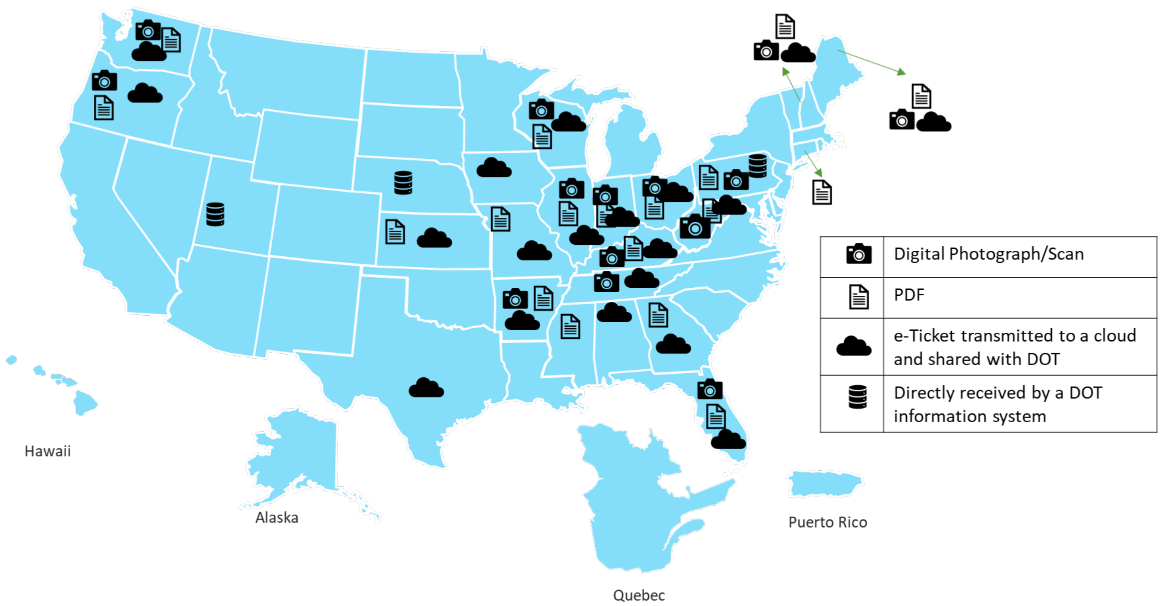


Figure 4. Map. AASHTO survey: Mode of e-Ticketing used by agencies.

Eighteen of the 26 STAs using e-Ticketing have opted for a vendor product, while 3 STAs have developed their own in-house solution. Table 4 presents the breakdown of the product type used for e-Ticketing. Of those STAs, Nebraska, Pennsylvania, and Utah DOTs have developed their own in-house solutions. Five STAs indicated the use of a combination of in-house and vendor solutions. However, further investigation showed that only Florida DOT (FDOT) has used a combination of in-house and vendor solutions. The Florida Turnpike Authority piloted a paperless ticketing solution on resurfacing projects where bar codes were created at the production plant, scanned at the jobsite with placement information, and later downloaded into a DOT database. Later, FDOT's Office of Construction adopted vendor solutions for e-Ticketing.

Table 4. Product type used by agencies.

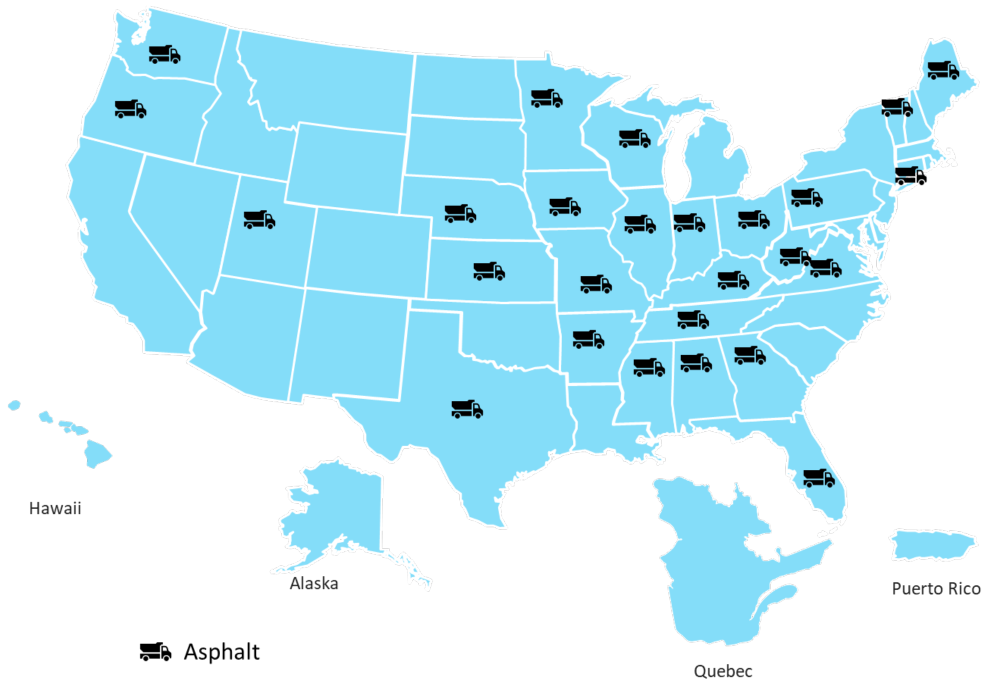
e-Ticketing Product Type	Responding Agencies (No. Out of 26)	Agencies (Percent)
Vendor developed	18	68
Developed in-house	3	12
Combination of in-house and vendor developed	5	19

Material Type

Table 5 presents the breakdown of e-Ticketing use by material types. Asphalt is the most preferred material type for e-Ticketing implementation. Figure 5 shows that all 26 STAs use e-Tickets for the delivery of asphalt at construction sites. As table 6 shows, most STAs have used e-Ticketing on paving projects with tonnage greater than 5,000 tons. Some STAs, such as those in Utah and Washington, required e-Ticketing on all size projects regardless of tonnage.

Table 5. Material type by agencies.

Material Type	Number of Responding Agencies (Out of 26)	Agencies (Percent)
Asphalt	26	100
PCC	11	42
Aggregates	9	35
Millings	0	0
Reinforcing steel	0	0
Prefabricated elements	0	0
Deicing salt/chemicals	0	0
Other bulk materials and other items	0	0



© 2021 WSP.

Figure 5. Map. AASHTO Survey: Agencies using e-Ticketing for asphalt.

Table 6. Tonnage of projects using e-Ticketing for asphalt concrete delivery.

Tonnage Range	Responding Agencies (No. Out of 26)	Agencies (Percent)
Less than 100 tons	2	8
100–500 tons	1	4
500–1,000 tons	2	8
1,000–5,000 tons	3	12
5,000–10,000 tons	7	27
10,000–25,000 tons	8	31
More than 25,000 tons	7	27
Unsure	8	31

Figure 6 shows that 11 and 9 States have used e-Ticketing for concrete and aggregates, respectively. None of the States used e-Ticketing for other material types, such as reinforcing steel, prefabrication elements, millings, or deicing salts, at the time of survey. Since then, Pennsylvania has expanded e-Ticketing to millings, salt, and liquid bitumen.

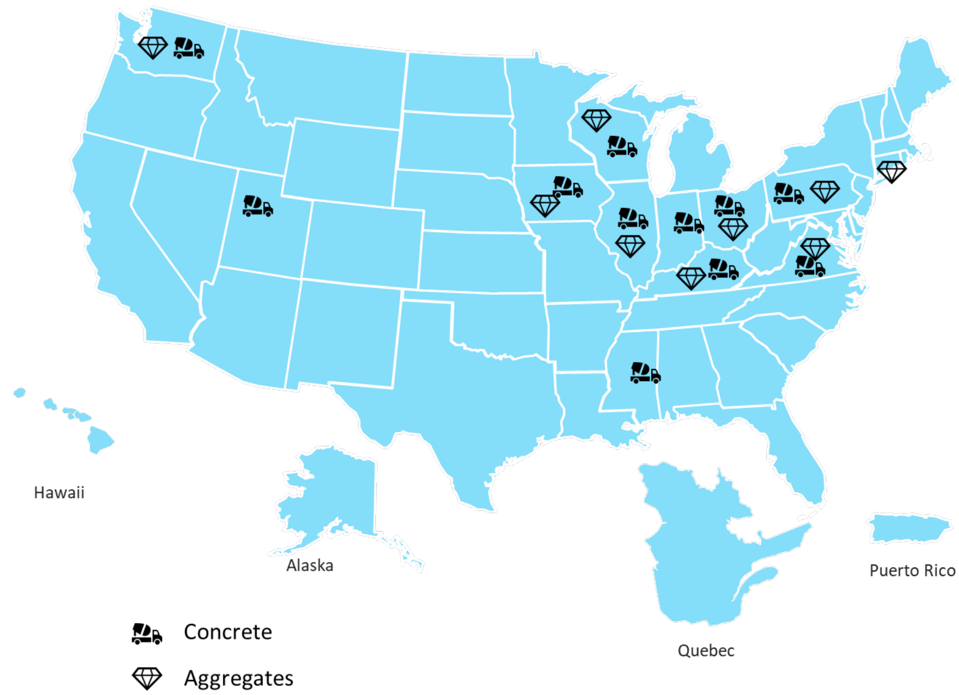


Figure 6. Map. AASHTO Survey: Agencies using e-Ticketing for concrete and aggregates.

In the survey, most STAs were interested in replicating their pilots on additional asphalt projects and expanding those pilots to aggregates and ready-mix concrete within a 24-mo period. Some STAs were interested in expanding their pilots to asphalt millings. Most STAs indicated they were unsure about expanding the pilots to other materials, such as deicing salts, reinforcing steel, or prefabricated materials. The STAs were focused on successfully completing the pilots for asphalt, ready-mix concrete, and aggregates. Table 7 presents a breakdown of the responding STAs' material type preferences for potentially expanding their e-Ticketing pilots.

Table 7. Agencies' future plans on expanding pilots to other material types.

Material Types	Within 12 Mo (No.)	In 12–24 Mo (No.)	In 24–36 Mo (No.)	Beyond 36 Mo (No.)	Unsure (No.)
Asphalt	12	1	2	0	1
Aggregates	9	6	1	0	4
Ready-mix concrete	9	6	2	0	4
Deicing salt/chemicals	2	0	1	0	9
Reinforcing steel	1	1	0	0	9
Millings	0	4	1	0	7
Prefabricated elements	0	2	0	0	8
Other bulk materials	0	0	0	0	7
Other items	2	0	0	0	6

Benefits and Costs

The AASHTO nationwide survey also focused on capturing benefit types and cost items associated with e-Ticketing to facilitate economic effectiveness assessments, such as benefit-cost and return on investment (ROI) analyses. Table 8 and figure 7 summarize benefit types considered by the responding STAs for implementation.

Table 8. Benefit types related to e-Ticketing.

Benefit Types	Responding Agencies (No. Out of 26)	Agencies (Percent)
Reduced paper documentation	24	92
Safety benefits	24	92
Readily available material quantity information	20	77
Time savings in review and consolidation of material quantities	19	73
Real-time material tracking	19	73
Archived material placement location	13	50
Production tracking	11	42
Disadvantaged business enterprise requirements	1	4
Wage and payroll requirements	1	4
Motor carrier requirements	2	8

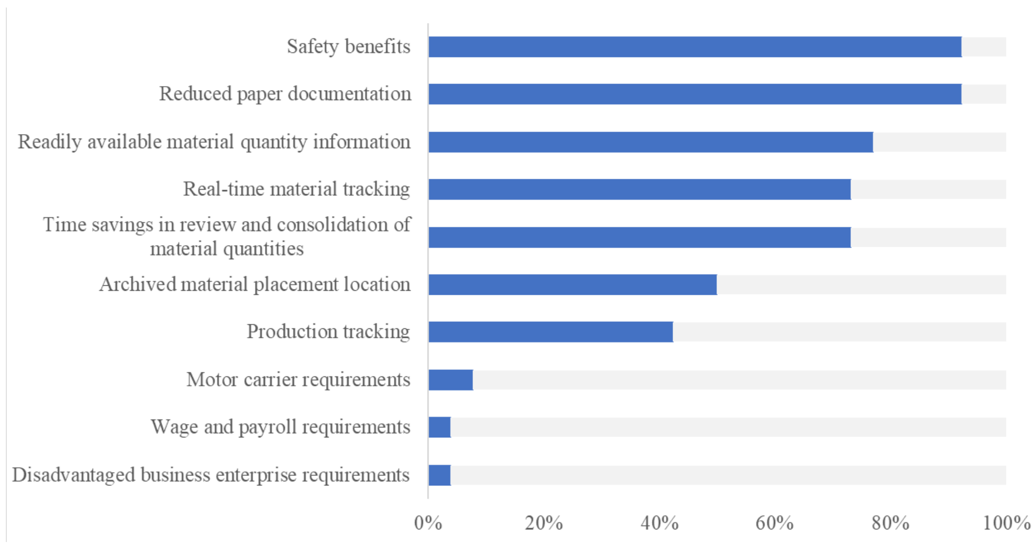


Figure 7. Chart. AASHTO survey: Percentage of agencies identifying benefit types.

Most STAs recognized that the benefits of e-Ticketing include monetary savings associated with a reduced use of or elimination of paper tickets and safety associated with the elimination of an in-person ticket taker at the jobsite. Many STAs also recognized the benefits of material quantity information in or near realtime; the ease of automating electronic data in reviewing, summarizing, and reconciling material quantities; and real-time monitoring of cycle times that construction vehicles take to haul materials from the production plant to the jobsite and return back to the production plant. Other than Nebraska, none of the STAs have calculated the ROI on e-Ticketing. Most STAs had challenges in quantifying both benefits and costs, and Pennsylvania indicated it would use the information to perform future ROI calculations.

Table 9 and figure 8 summarize the cost items the responding STAs considered for implementation. STAs considered the cost of equipment upgrades to suppliers and haulers; the passing of such costs through bid items; and technology costs, including vendor licensing fees, devices, and supporting technologies. A few STAs indicated they had incurred no additional costs because e-Ticketing was used as a contract option on projects. The contractors, who already possessed the technological capabilities, saw value in opting for e-Ticketing for fleet management purposes and voluntarily adopted the technology on such projects. COVID-19 was another factor to consider because some STAs did not have adequate lead times for extensive deliberations on costs due to pandemic imperatives. However, as table 10 shows, approximately one-half of the STAs identified some cost items as significant deterrents to the implementation of e-Ticketing.

Table 9. Cost items related to e-Ticketing.

Cost Items	Number of Responding Agencies (Out of 26)	Agencies (Percent)
Manufacturer/producer/production plant equipment upgrades	16	62
Costs from the contractor	14	54
Vendor licensing fees	10	38
Supporting technology costs	10	38
e-Ticketing technology devices	9	35
IT staff and IT network-level support costs	3	12
Others (please specify)	4	15

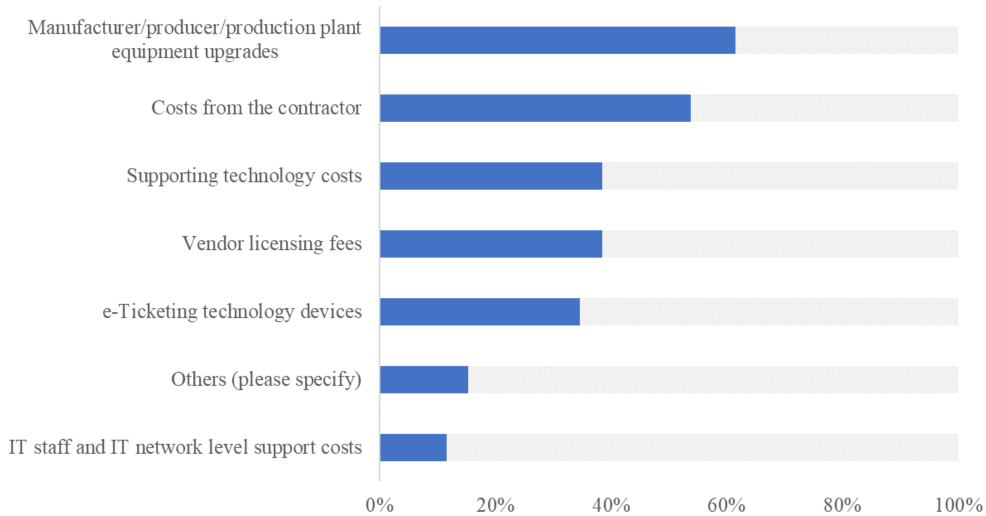


Figure 8. Chart. AASHTO survey: Percentage of agencies identifying cost factors.

Table 10. Cost items identified as deterrents to e-Ticketing.

Cost Items	Responding Agencies (No. Out of 26)	Agencies (Percent)
Manufacturer/producer/production plant equipment upgrades	8	31
Vendor licensing fees	6	23
e-Ticketing technology devices	5	19
Costs from the contractor	5	19
Supporting technology costs	5	19
IT staff and IT network-level support costs	2	8

Implementation Approaches

Procurement

Survey results showed the STAs generally procured e-Ticketing services on construction projects in three ways:

- Including e-Ticketing as a bid item in the base contract for contractors. The bid item allows the contractors to cover the costs related to proving the e-Ticketing system.
- Including e-Ticketing as incidental to another item of work, such as asphalt, aggregates, and concrete in the base contract.
- Procuring e-Ticketing through a modification to a bid item in the base contract that allows the contractor to revise the price of the bid item.

To implement e-Ticketing on projects, the STAs also made the following changes to their business processes:

- Including e-Ticketing as an agenda item in preconstruction meetings.
- Making changes to project documentation requirements.
- Making changes to retention requirements of final construction records.
- Making changes to construction specifications and procurement, such as special provisions and contract modifications.
- Providing training to DOT staff.

Table 11 and table 12 present a breakdown of STAs' procurement approaches and changes in business processes, respectively.

Table 11. e-Ticketing procurement.

Procurement Approach	Responding Agencies (No. Out of 26)	Agencies (Percent)
Included in contract as a bid item	7	27
Included in RFP as incidental to another item of work	4	15
Added as a contract modification	6	23

RFP = Request for Proposals.

Table 12. Changes in business processes.

Business Process	Responding Agencies (No. Out of 26)	Agencies (Percent)
Construction procurement/letting	3	12
Preconstruction meetings	4	15
Project closeouts	4	15
As-built documentation/project documentation	9	35
Legal/compliance	4	15
Asset management/maintenance	1	4

Validation

Similar to paper tickets, e-Tickets must be validated by the agency using established QA and verification procedures. Table 13 presents the breakdown of STAs' responses on verification procedures. Many responding STAs indicated the verification procedures for e-Tickets are similar to those of paper tickets, and no changes to existing procedures had been put in place. Only Minnesota and Washington DOTs identified documented procedures and process for verification of e-Tickets.

Table 13. Validation of e-Tickets.

Answer Choices	Responses (No.)	Responses (Percent)
Yes, we have implemented procedures for verification.	5	19
Yes, we are still getting cohort paper tickets.	7	27
No, but we have plans or are working on developing verification procedures for e-Ticketing.	1	4
No, we do not have plans to verify e-Tickets.	1	4

Because these STAs are in the piloting phase, many of them are still collecting both paper and e-Tickets. Collecting cohort tickets enables the STAs to compare e-Tickets with paper tickets for verification. The verification process included checkpoints at the production plant, during transmittal, and at the point of delivery. This process also typically includes certification of weigh scales and the presence of DOT inspectors at the production plants and quarry; the DOT inspectors checked delivery, vehicle identification (ID), time stamp, and location, and they conducted visual inspections of loads at the delivery points. Some STAs reported random inspections of loads and tracking of yield rates. To verify the on-time arrival of vehicles to jobsites against unauthorized stops or delays, the STAs typically used time stamps of vehicle departures at the production plant and arrivals at the jobsite. Some STAs required Global Positioning System (GPS) or geofencing data.[1]

Furthermore, as a part of daily summary reports, respondents indicated that both the agency and contractors compare their daily data summaries to check if their quantities match.

Data security risks are inherent to electronic data. The e-Tickets are prone to security risks, such as data tampering, loss, or breach. Almost all respondents are aware of the need to put data security requirements in place for e-Ticketing. Twelve States indicated they have plans for implementing security standards/policies. Some STAs, including Pennsylvania and Tennessee, have included clauses in their specifications to protect automatic recording and electronic transmittal of weigh scale data against potential alterations by contractors and STAs. In addition, the vendor solutions have implemented security features in their products against potential tampering.

[1]A geofence is a virtual geographic boundary around a specific location defined by mobile devices or software apps, such as GPS and radiofrequency ID tags, which are programmed to trigger an action when a device enters a set location.

Data Management

Data Attributes

In addition to fundamental data items on paper tickets, such as material quantities, project and supplier description, and location, the STAs capture a variety of data attributes. Table 14 summarizes the additional data attributes captured on e-Tickets. The commonly collected data items include mix type and design; inspector notes; mix properties, such as temperature, water content, etc.; and admixtures and modifiers. As presented in table 15, only four STAs—Alabama, Minnesota, Missouri, and Maine—indicated the collection of GPS breadcrumbing data, while most STAs captured the locations of specific points or deliveries appended by field staff.[2]

Table 14. Additional collected data attributes on e-Tickets.

Data Attributes	Responding Agencies (No. Out of 26)	Agencies (Percent)
Mix type and design	20	77
Inspector notes	20	77
Mix properties (before placement)	10	38
Admixtures and modifiers used	9	35
Temperature readings or thermal coverage from paver mounted infrared system	4	15
Material sampling locations	4	15
Dielectric profiling system (DPS) readings	2	8
Mat properties (after placement)	2	8
Roller coverage and/or stiffness using IC	1	4

Table 15. Location information on e-Tickets.

Location Information	Responding Agencies (No. Out of 26)	Agencies (Percent)
Yes, at all points along the delivery vehicle route with GPS connection	4	15
Yes, but only at specific locations (quarry, production plant, project, paver and geofence tripping points)	4	15
No, but delivery/dump location is noted/appended by field staff	10	38
No, the delivery vehicles are not tracked nor is location recorded	7	27

[2]Breadcrumbing refers to the tracking history of latitude and longitude coordinates captured at every instance of a mobile device's location.

Use of e-Ticket Data

Of the 26 STAs using e-Ticketing, 10 STAs were storing ticket data internally in their information systems for archiving and documentation, and three STAs were storing ticket data for calculating pay quantities.

Data Standardization

National efforts are currently underway to standardize data attributes on e-Tickets. Only STAs in Minnesota and Missouri identified their partnerships with AASHTO, whereas Vermont and Connecticut indicated regional cooperation in the northeast on data standardization.

Procurement Language for Data Management

Fourteen of the 26 STAs using e-Ticketing indicated they included contract clauses on the handling of e-Ticketing data. Of those 14 STAs, many included requirements on file formats, data transfer, and the extent of access to electronic data. Five STAs included language on the ownership of ticket data. Table 16 breakdowns the STAs' data management clauses in the contract documents.

Table 16. Contract language for data management.

Requirement	Responding Agencies (Out of 14)	Agencies (Percent)
File formats for e-Tickets (PDF/CSV)	11	79
Data transfer policy from vendor/contractor to agency	9	64
Extent of stakeholder access to e-Tickets	7	50
Timing of ownership of ticket data	5	36
Process for archiving ticket data	2	14
Degree of security for ticket data	2	14
Extent of liability for the accuracy of e-Tickets	1	7

Stakeholder Receptivity

Table 17 and figure 9 summarize how various stakeholder groups perceive e-Ticketing as measures on a five-point Likert scale from extremely positive to extremely negative. The receptivity among the DOT staff, midsize and large contractors, and suppliers is high; however, both small suppliers and third-party delivery truck companies do not have the same positive reception to e-Ticketing as other stakeholders. The low receptivity of small suppliers and trucking companies is reflected in the implementation challenges outlined in table 18.

Table 17. Stakeholder receptivity.

Stakeholder Groups	Extremely Positive Responses (No.)	Positive Responses (No.)	Neutral Reponses (No.)	Negative Responses (No.)	Extremely Negative Responses (No.)
DOT staff and CEI	7	22	6	0	0
Small contractors and suppliers	0	4	16	9	0
Midsize and large contractors	4	21	6	3	0
Material suppliers	2	13	11	2	0
Trucking/delivery companies	1	3	17	5	0

CEI = construction engineering inspection.

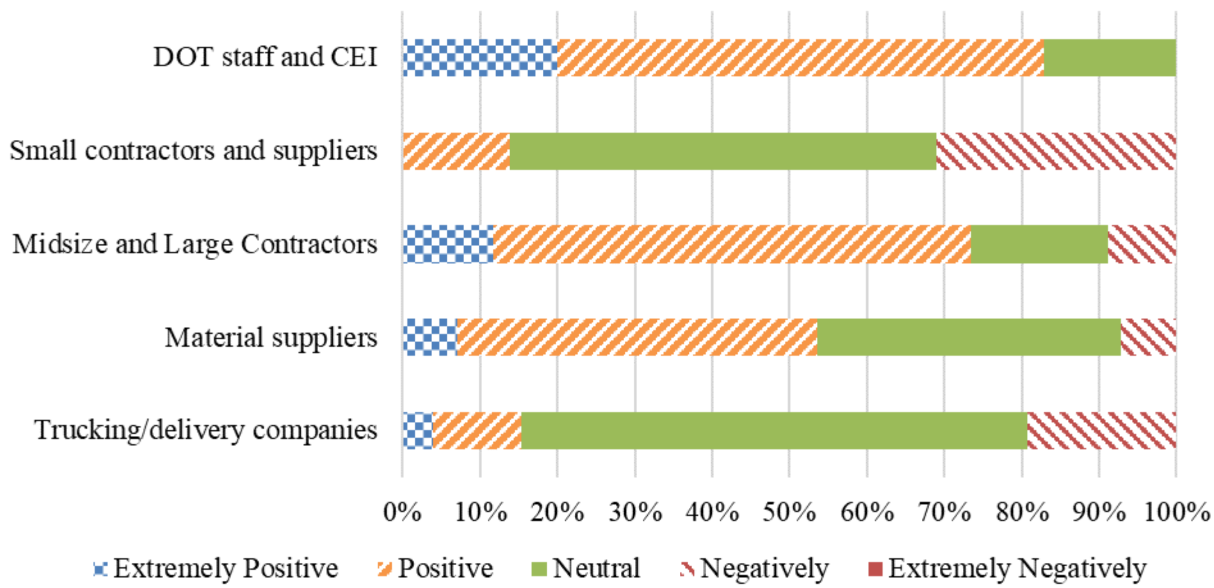


Figure 9. Chart. AASHTO survey: Percent receptivity of various stakeholder groups.

Table 18. e-Ticketing implementation challenges.

Challenges	Agencies Using e-Ticketing (No.)	Agencies Not Using e-Ticketing (No.)	Total (No.)
Internet connectivity concerns	9	10	19
Receptivity of small suppliers	5	10	15
Access, privacy, or security concerns	4	10	14
Manufacturer/producer/production plant equipment upgrades	4	10	14

Challenges	Agencies Using e-Ticketing (No.)	Agencies Not Using e-Ticketing (No.)	Total (No.)
Inadequacy of IT infrastructure/Internet connectivity	4	10	14
More education or training is needed for the field staff	4	9	13
Limited use of mobile devices for field inspection	4	8	12
Contractors have not requested	5	6	11
Receptivity of trucking/delivery operators	5	6	11
Receptivity of DOT staff	2	8	10
Receptivity of midsize and large contractors	4	6	10
More education or training is needed for the trucking/delivery operators	2	8	10
Lack of standard contract language/specifications	1	8	9
More education or training is needed for office staff	3	5	8
Legal and/or liability concerns	3	4	7
High costs associated with software or hardware	1	5	6
Benefits of using e-Ticketing are unknown	2	2	4
Executive-level management is not aware of the benefits of e-Ticketing	1	2	3
High IT staff and IT network-level support costs	0	3	3
High vendor licensing fees	1	2	3
Incompatibility with (or restricted by) legal, regulatory, or policy requirements	0	3	3
ROI is not unproven	1	1	2
Processes do not exist to ensure security or accuracy is adequate for construction	1	1	2
Unsuccessful efforts have been attempted in the past	1	0	1
Executive-level management is aware of the benefits but not chose to support	0	0	0

Implementation Challenges

AASHTO's nationwide survey also captured the challenges and deterrents that STAs face in implementing e-Ticketing. Table 18 presents the challenges STAs identified by their implementation statuses. STAs piloting e-Ticketing reported facing the following top challenges:

- Accessing connectivity in areas of low Internet coverage or dead zones.

- Responding to receptivity of small suppliers, especially related to the use of outdated load-out systems and high costs of implementation.

- Responding to receptivity of third-party haulers.

- Handling multiple e-Ticketing systems.

STAs with no e-Ticketing piloting experience reported the following top deterrents:

- Having limited use of mobile devices for field inspection.
- Experiencing Internet connectivity challenges.
- Responding to receptivity of small suppliers and third-party haulers.
- Meeting the higher costs of production plant and equipment upgrades.
- Working with inadequate IT infrastructure.

The responding STAs indicated the following needs to enable or accelerate the deployment of e-Ticketing through pilots:

- Acquiring implementation guidance.
- Gaining access to peer support.
- Securing additional funding.
- Obtaining technical assistance for training and specifications development.

Survey of Technology Providers

e-Ticketing vendors were contacted to gather information on their products. Of the eight vendors who were identified, one was not yet commercialized, and the other seven were already in the market. The respondents included Astec Industries, Inc., Command Alkon, HaulHub Technologies, Proxet, Surface Tech, Spot-On Performance, Volvo, and XBE LLC.

Product Type and Use

Two types of vendor e-Ticketing products are available in the market:

- Supplier-centric services that can capture data from the load-out scales automatically at the production plant and transmit the data through a cloud or server in realtime. The ticket information is relayed to the DOT inspector in the field via a mobile device and vendor app. The inspector can then accept or reject the tickets and append information to the tickets.

- DOT-centric Web portal services that can receive tickets directly from suppliers or through their vendor products and then import and store them into the DOT's information systems. This information is relayed to the DOT inspector in the field. The Web portal services can receive tickets from any authenticated material supplier or vendor product, which can send e-Tickets from a load-out system in a specified data format.

Regardless of the type, the vendor products are designed to be used for a variety of materials, including asphalt mixtures, concrete mixtures, reinforcing steel, deicing salts, prefabricated elements, cement, liquid asphalt binders, millings, and emulsions. The vendor e-Ticketing products are typically agnostic of the material type and can be used for a variety of materials or assembled products.

The responses indicate the vendor solutions generally offer the following capabilities:

- Electronic transfer of ticket information and data attributes.
- Material tracking/location.
- Delivery verification.
- Inspection/field data entry.

Most vendor products are capable of automatically capturing and transmitting vehicle departure time and location stamps from the production plant and their arrival times on the jobsite. Similarly, the vendor products can calculate dashboard metrics and automatic summaries, such as real-time tracking of job progress; preparing daily summary reports, payment invoices, timecards, and shift reports; and producing a variety of custom reports. The supplier-centric products can perform fleet productivity analyses, such as producing records of a driver's duty, releasing daily vehicle inspection reports, tracking truck usage and downtimes, and recording haul loading and unloading cycles. While most vendor products can track location, one vendor product (Spot-On Performance) has made GPS tracking of trucks optional.

The electronic data reside in a cloud or the vendor server. To ensure security, the vendor products rely on user management with access control, monitoring and recording of login and logout time stamps and locations, and version controls. To prevent tampering, all amendments and additions to the source data are recorded. The vendor products that utilize APIs use bearer tokens to authenticate login requests from persons or agencies sending ticket information to the Web portals.

At the time of survey, at least one vendor (Spot-On Performance) is working on camera-based or Bluetooth® Low Energy™ (BLE)-based technologies to automatically verify the arrival of trucks at the jobsite and delivery of its product, and at least two vendors (HaulHub Technologies and Command Alkon) are piloting projects on license plate detection of trucks at the delivery point.

Data Attributes and Capabilities

Table 19 presents the breakdown of data attributes their products can capture. In addition to these data attributes, some vendor products include a safety checklist, daily reports, and acceptance and rejection fields. All vendor products allow for field entry of additional data. Most of these products are capable of allowing general notes and specific entries, whereas a few products can allow appending of pictures, videos, and forms. The e-Tickets can be transmitted as CSV or JSON files, although some vendors offer PDFs, email transmittal, and Web apps.

Table 19. Data attributes and capabilities of e-Ticketing vendor products.

Requirement	Vendors (No. Out of 7)	Agencies (Percent)
Project and contract ID	7	100
Production plant ID	7	100
Material description	7	100
Pay item	6	86
Contractor ID	7	100
Scale ID	5	71
Truck ID	6	86
Truck driver ID	6	86
Loading date and time	7	100
Truck tare weight	5	71
Source and destination locations	7	100
Time at source and destination	6	86
Source and destination geofences	3	43
Transit time	7	100
Transit routing geofences	2	29
Material temperature at source and destination	3	43
Air temperature at source and destination	3	43
Load acceptance or rejection	7	100
Split load weight	3	43
Wasted material weight	4	57
Other items, including daily summaries and safety checklists	3	43

Hardware and Software Requirements

The questionnaire focused on capturing the hardware and software requirements of vendor products for both contractors/suppliers and STAs. Contractor/suppliers have the following requirements:

- Load-out system, with software capabilities of sending ticket data to a relational database.
- Mobile devices for truck drivers.

Owners have the following requirements:

- Mobile devices for viewing tickets and appending information in the field via Internet access.

- Web browsers and apps for mobile devices that support offline functionality.

- Web browsers to ingest ticket information into a relational database or information system.

Cost Structure

The vendors (Volvo, Surface Tech LLC, Spot-On Performance, HaulHub Technologies, Astec Industries, Inc., XBE LVC) offer an annual software-as-a-service subscription for their customers. Most vendors offer services for a flat fee, while one vendor (Command Alkon) offers use-based subscriptions based on the number of tickets or project value. Most vendors offer the following add-ons as a part of their pricing structure:

- Software updates.
- Software upgrades.
- Onboarding/integration services.
- Maintenance services/support services.
- Training.
- Servers/storage.

Data Ownership

When asked about the ownership of the electronic data, the vendors indicated data ownership is tied to free onboard terms. In other words, data ownership depends on the party that owns or is liable for the material. Accordingly, the data are owned by the material supplier and contractor before and during transmittal, respectively. After the data are received by the DOT, the ownership is transferred permanently. However, the vendors may retain some ownership, contingent on the terms and conditions in their license agreements with the DOT, if the vendor enriches the electronic data.

CHAPTER 3. BUSINESS CASE FOR E-TICKETING

INTRODUCTION

A business case is useful when a new product, process, service, or change is introduced to demonstrate the value the proposed change would bring to the organization. The following business case entails a comprehensive review and analysis of evidence to provide a rationale for implementing e-Ticketing and exploring its core implementation requirements.

For an agency exploring e-Ticketing, making a business case will be useful for securing the buy-in of internal stakeholders, including senior leadership and staff, and the support of external stakeholders. The business case will also be useful for seeking more funding, resources, and support systems for e-Ticketing implementation within the agency. In addition, the business case exercise examines the qualitative and quantifiable benefits, with supporting evidence, and the risks and challenges associated with implementation.

In general, e-Ticketing users find the benefits outweigh the costs. AASHTO's nationwide survey showed the receptivity for e-Ticketing among STA and construction engineering inspection staff, and large- and medium-size suppliers is highly positive. In many instances, the contractors and suppliers expressed interest in deploying e-Ticketing technologies on their projects. However, some key stakeholders, small suppliers, and third-party haulers, in particular, did not perceive that switching to e-Ticketing would bring them net benefits. Furthermore, some STAs responded that their senior leadership was unaware of the benefits of e-Ticketing. This chapter presents information for agencies on how to prepare a business case for e-Ticketing.

BUSINESS CASE EXPLAINED

Figure 10 presents an overview of the steps involved in constructing a business case, and the sections that follow describe the four subcases that comprise the e-Ticketing business case (Metrolinx 2021):

- Strategic case—Establishes why e-Ticketing should be pursued and what problems would be resolved.
- Economic case—Documents the benefits of e-Ticketing.
- Financial case—Discusses the costs of e-Ticketing for the agency.
- Implementation case—Discusses the procurement approach for e-Ticketing, including implementation considerations.

Problem Statement
Defines the problem and the corresponding goals and objectives to be addressed.

Strategic Case
How does e-Ticketing achieve the strategic goals and objectives?

Economic Case
What is e-Ticketing's overall value to stakeholders?

Financial Case
What are the financial implications for the agency?

Implementation Case
How can e-Ticketing be procured and what risks and requirements must be met?

Figure 10. Chart. Framework of business case.

The following sections describe each of these subcases in detail.

Strategic Case

The strategic case for e-Ticketing begins with the problems associated with traditional paper tickets that the electronic process seeks to replace. The problems associated with paper tickets and the value proposition that e-Ticketing offers are as follows:

- Safety—Collecting paper tickets from delivery trucks alongside live traffic, moving construction equipment, or working on roadsides in mountainous areas with no or short shoulders create safety hazards in work zones. Contactless delivery minimizes the risk for inspectors and contractor personnel to be struck by a truck accident at the jobsite. The improved safety performance may reduce worker compensation insurance costs for construction inspectors and contractor personnel.

- Better use of inspector time—Collecting paper tickets typically requires a full-time inspector or laborer. e-Ticketing allows reassignment of the ticket taker's role to other administrative, inspection, engineering, or production activities of a higher priority than ticket taking. Repurposing inspectors' time would help agencies in managing workforce shortages and ensuring better project performance outcomes. Similarly, eliminating less productive work, such as ticket taking, allows contractors to utilize laborers for production work, which contributes to savings in project costs and scheduling.

- Streamlined reporting—Compiling paper tickets is a resource-intensive process that entails reconciling the tickets, handling damaged or illegible tickets, finding or replacing lost tickets, and manually reentering quantities into an agency's CMS. e-Ticketing eliminates these problems. The e-Ticket data can be automatically summarized and exchanged with the agency's CMS.

- Digital documentation—Capturing load deliveries with location data in e-Tickets serves the following purposes: appending additional quality measures, such as IC, dielectric profiling systems (DPS), thermal profiles, on-field measurement of mixture properties (slump, air content, temperature, etc.), and material testing data; appending material certifications, source, and production plant QC data; tracing laboratory test results to placement location; and conducting data mining and using the data for forensic purposes.

- Fleet management—Delivering material is one of the major cost items for contractors and suppliers. The fleet management aspects of e-Ticketing allow suppliers to monitor truck idle times, haul cycle times, traffic impacts, arrival times and time spent waiting at jobsites, and unauthorized stops and delays in realtime, all of which create operational efficiencies.

- Production efficiency and quality—Maintaining a consistent uniform cycle time of material delivery between the production plant and paver is essential to achieve better quality. Longer or frequent idling of vehicles and pavers causes frequent stopping and starting of paving operations, which contributes to material placement problems. Real-time monitoring of a fleet can detect vehicles waiting at the jobsite to deliver materials, which allows contractors to streamline and optimize plant production and placement rates.

- Data mining—Transmitting e-Ticketing data can be conducted in realtime directly to an agency via an API, which can be ingested into the DOT information structures, such as construction management, asset management, or financial systems. The integration of e-Ticketing with other data, such as materials source information, certifications, and test data, costs, and schedule, will result in the development of digital as-builts. This information creates a “single source of truth” that can be utilized for data mining, auditing, and forensic purposes.

These value propositions can be well supported through the lens of e-Construction technologies, BIM for infrastructure, fleet management, and safety. The benefits of e-Construction technologies and BIM are well established in the industry, and the benefits of managing material delivery fleets better are adequately documented (Dadi et al. 2020; FHWA 2021; Mallela and Bhargava 2021). However, the safety benefits of e-Ticketing are inadequately documented in the literature, as described in the next section.

Safety Benefits of e-Ticketing

The safety benefits of e-Ticketing stems from reduced exposure of ticket takers to moving traffic, vehicles, and construction equipment. Visual blind areas of vehicles and equipment operators when workers are performing tasks in their activity area is a primary cause of accidents.

Citing U.S. Bureau of Labor Statistics as the source, the National Work Zone Safety Information Clearinghouse (NWZSIC) reported that 391 workers were fatally injured at road construction sites during 2017-2019 (NWZSIC 2022). About 45 percent of the 391 fatalities reported during this period, as presented in figure 11, were attributed to workers on foot who were struck by moving vehicles. Similarly, National Institute of Occupational Safety and Health (NIOSH) reports that 123 of 577 workers fatally struck by vehicles at road construction sites are attributed to backing of construction vehicles between 2011 and 2020 (NIOSH 2022a).

NIOSH's Fatality Assessment and Control Evaluation program has published 102 investigation reports, prepared by NIOSH and State DOTs, of which 42 reports indicate the involvement of a construction vehicles in the fatal accident of construction workers between 1992 and 2020 (NIOSH 2022b). While these incidents might not be directly attributed to a ticket taker, the mode of accidents in which the construction vehicles and equipment were involved, such as a moving truck/equipment striking someone, backing up over someone, running over someone, or someone falling off a truck/equipment pose a similar likelihood of safety hazards to ticket takers.

These statistics indicate the significance of safety hazards that moving vehicles could cause in the activity sections of construction work zones.

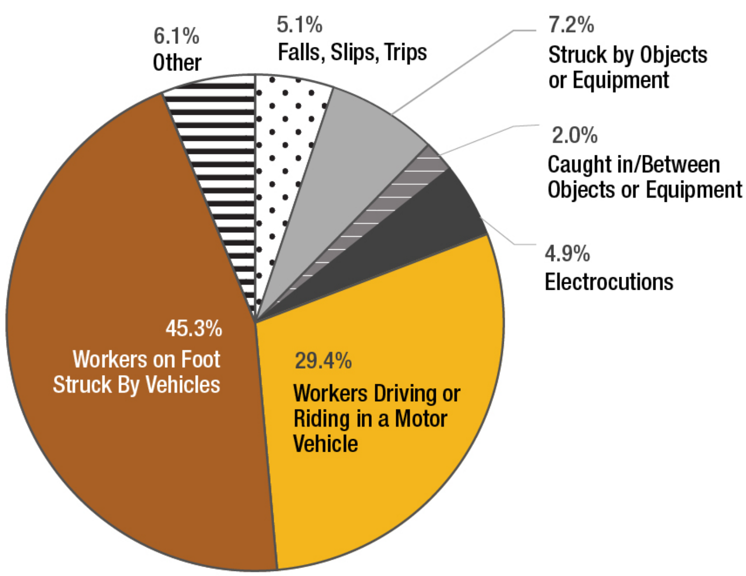
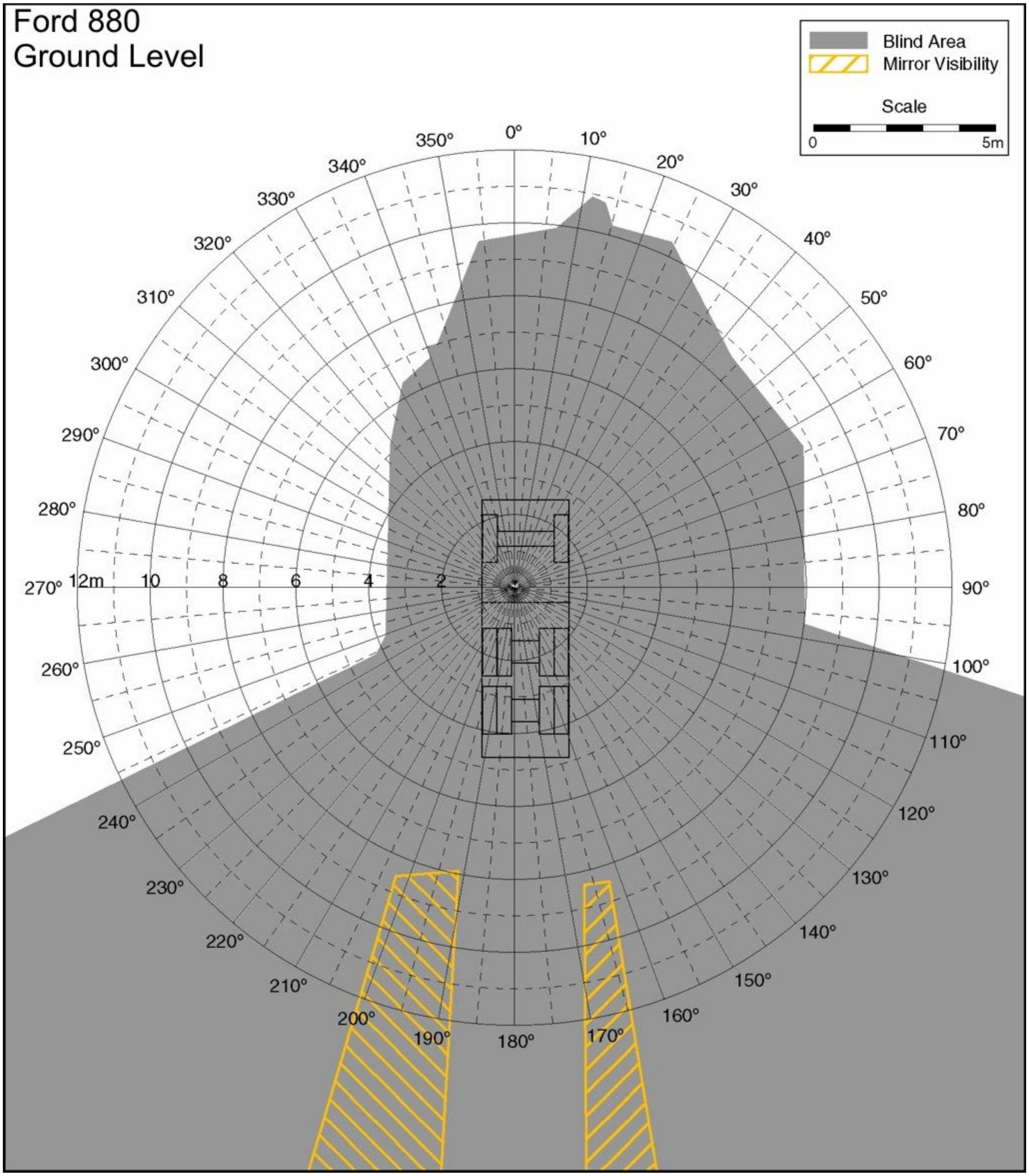


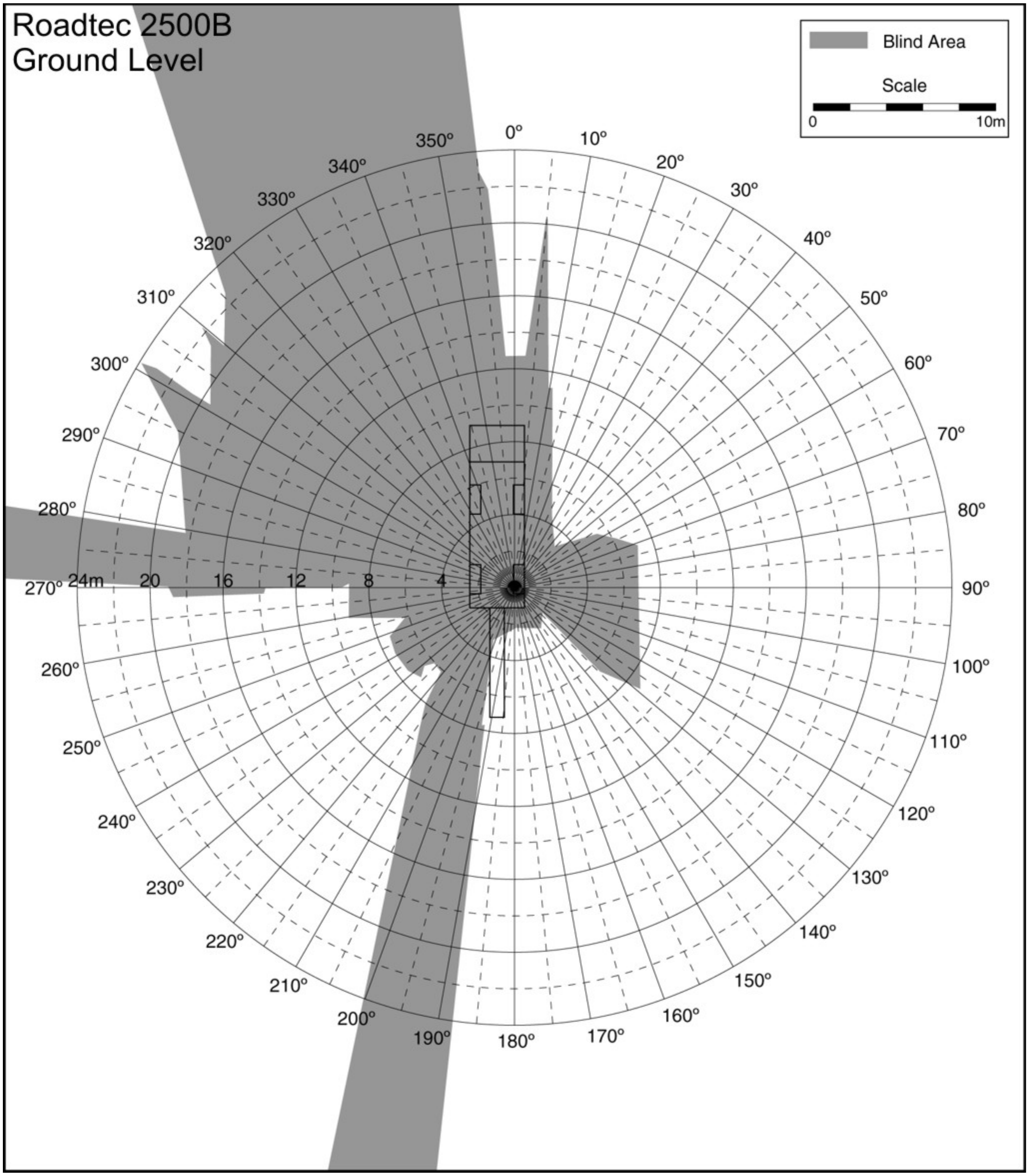
Figure 11. Graph. Types of events resulting in highway worker fatalities at road construction sites (NWZSIC 2022).

Anecdotally, the death of a construction technician who was struck by a cement truck in 2006 on the I–235 project in the Des Moines, IA, area was a significant motivation for Iowa DOT to pursue e-Ticketing (Iowa DOT 2007). Furthermore, NIOSH has developed blind area diagrams for various construction vehicles, such as dump trucks, material transfer vehicles, and rollers (Hefner and Breen 2004). The blind area diagrams were developed to educate transportation agencies and contractors on how to develop mitigation strategies and controls, such as operating procedures, training, and warning systems, to minimize accidents caused by blind areas. Figure 11 and figure 12 present the blind area diagrams of a typical dump truck and material transfer vehicle, respectively. The gray shaded areas in these diagrams are outside the line of eyesight of a truck driver or equipment operator and are indicative of safety hazards that a ticket taker might face in the vicinity.



Source: NIOSH.

Figure 12. Graph. Blind area diagram of Ford 880 dump truck (Hefner and Breen 2004).



Source: NIOSH.

Figure 13. Graph. Blind area diagram of Roadtec 2500B material transfer vehicle (Hefner and Breen 2004).

Economic Case

The economic case involves estimating the quantifiable benefits of e-Ticketing. A typical economic case entails an economic appraisal of benefits and costs by using techniques such as a benefit–cost analysis. However, owing to the challenges in estimating costs, only benefit estimates of e-Ticketing are presented in the following section.

Many benefits of e-Ticketing are derived from avoiding the costs of paper tickets. The e-Construction ROI calculator, developed by FHWA, was adapted for this purpose (Shah et al. 2017). Table 20 lists the benefit types and their calculations. The methods and formulae for most benefit types, as presented in this table, were adopted from the e-Construction ROI calculator.

Table 20. Benefit types and calculations.

Benefit Type	Calculations
Reduced use of paper, printing, mailing, faxing, scanning	Number of tickets per year × total cost per page
Time savings associated with collecting paper tickets	Estimated time savings per inspector per day × number of weeks of construction season × number of workdays per week × average hourly pay × number of inspectors
Time savings associated with creating daily summary report	Estimated data entry time savings per inspector per day × number of weeks of construction season × number of work days per week × average hourly pay × number of inspectors
Time savings associated with traveling offsite to office to submit documentation	Estimated travel time savings to submit documentation per inspector per day × number of weeks of construction season × number of work days per week × average hourly pay × number of inspectors
Time savings associated with handling errors (data entry errors, lost documentation, illegible tickets and reconciliation)	Estimated data entry time savings per inspector per day × number of weeks of construction season × number of work days per week × average hourly pay × number of inspectors
Integration efficiencies with managing contract administration, contract records, daily summary reports, contractor payments, materials management, and laboratory inventory management using the project CMS, and sending the project for final payment to financial and accounting systems	Percentage of estimated annual savings through efficiencies × annual construction program

Benefit Type	Calculations
Savings in worker compensation insurance costs because of reduced risk of work zone injuries and fatalities	Percentage of estimated savings in insurance costs × worker compensation insurance costs (1$ per every $100 of wages) for paving work × average daily work hours × number of weeks of construction season × number of work days per week × average hourly pay × number of inspectors

The key inputs required to complete the benefits calculation are:

- Annual construction program (U.S. dollar (USD)).
- Number of tickets per year.
- Total cost (paper, toner, processing, storage) per page (USD).
- Typical work hour per day (hours).
- Number of workdays per week.
- Number of weeks of construction season.
- Average hourly pay rate (USD).
- Number of inspectors collecting tickets.
- Worker compensation costs for paving work (1$ per $100 of wages).
- Time savings associated with traveling to the office to submit documentation per daily summary report (hours).
- Time savings associated with entering data on mobile device versus recording on paper and then entering on a computer (hours).
- Time savings associated with handling data entry errors, missing or illegible tickets, and reconciling quantities (hours).
- Integration efficiencies, as percent of annual construction program, associated with managing contract administration, contract records, daily summary reports, contractor payments, materials management, and laboratory inventory management using the project CMS, and sending the project for final payment to financial and accounting systems (percent).

Illustration of Benefits Estimation

The following example demonstrates the benefits of e-Ticketing for a hypothetical agency called XYDOT. The inputs and assumptions presented in the example are used for illustration purposes only. The actual inputs may vary depending on the agency's field resourcing plan, compensation costs, and benefits observed in the field. The readers are advised to use their discretion in selecting appropriate inputs for benefits estimation.

XYDOT has been piloting e-Ticketing for asphalt and concrete paving projects. This DOT has already implemented electronic plans and specifications, documentations, and signatures for its construction projects. XYDOT has gathered data on cost avoidance associated with using paperless processes, and it plans to scale up the pilots and expand e-Ticketing to full implementation in 7 yr. The following example illustrates the computation of benefits estimated for XYDOT.

Construction Program Overview. XYDOT, a hypothetical agency, delivers a construction program for $1.5 billion annually, and its construction program employs 200 full-time equivalent (FTE) employees for construction inspection. XYDOT pays an average total compensation of $55 per hour for wages and benefits and worker compensation insurance of $1.50 for every $100 of paid wages. The construction season lasts for 32 w a year. The inspectors work for 8 h per workday per week and 5 d per week.

XYDOT uses the following tonnage of materials each year for paving projects:

- Asphalt concrete (AC) = 20,000,000 tons.
- Ready-mix concrete = 1,800,000 yd^3.
- Aggregates = 3,000,000 tons.
- Reclaimed asphalt = 2,000,000 tons.

Table 21 presents the summary of XYDOT's construction program. Table 22 presents an estimated number of paper tickets that XYDOT handles for material delivery. The number of paper tickets was calculated by using the average tonnage or volume of each truck load by material type. In this example, the number of paper tickets is estimated to be 1.5 million each year.

Table 21. Illustrative example—construction program inputs of XYDOT.

Input Description	Inputs
Annual construction program (USD)	1,500,000,000
Inspectors collecting tickets (No.)	200
Average hourly pay rate (USD)	55.00
Worker compensation costs ($ per $100 of wages)	1.50
Typical work hours per day (No.)	8
Workdays per week (No.)	5
Weeks of construction season (No.)	52

Table 22. Estimated number of paper tickets.

Material Type	Annual Volume or Tonnage	Units	Tonnage or Volume of Typical Truck Load (tons or yd^3)	Tickets (No.)
AC	20,000,000	tons	20	1,000,000
Ready-mix concrete	1,800,000	yd^3	9	200,000
Aggregates	3,000,000	tons	15	200,000
Millings	2,000,000	tons	20	100,000
Estimated number of tickets	—	—	—	1,500,000

—Not applicable

XYDOT piloted e-Ticketing on 5 percent of its projects this year, and it plans to scale up the project over the next 6 yr, as illustrated in table 23.

Table 23. XYDOT piloting plan.

e-Ticketing Projects (Year)	Projects (Percent)
1	5
2	10
3	20
4	25
5	50
6	90
7	100

Estimated Percent Savings. Based on the experience derived from the earlier implementation of e-Construction technologies, XYDOT has developed estimates of cost and time savings associated with a paperless process and other e-Ticketing benefits. Table 24 summarizes XYDOT's estimates of percent savings.

Table 24. Estimated savings with paperless process and other benefits.

Estimated Savings	Inputs
Totaling cost (paper, toner, processing, storage) per page (USD)	0.25
Traveling to the office to submit documentation per daily summary report (hours)	0.5
Entering data on mobile device versus recording on paper, and then, entering data on a computer (hours)	1
Handling data entry errors and missing illegible tickets and reconciling quantities (hours)	0.5
Reducing worker compensation insurance costs of construction inspectors (percent)	25
Integrating efficiencies with managing contract administration, contract records, daily summary reports, contractor payments, materials management, and laboratory inventory management by using the project CMS, and sending the project for final payment to financial and accounting systems (percent).	0.05

Benefit Estimates. Using the guidelines presented in table 20, table 25 summarizes the benefits estimated for full implementation of e-Ticketing in this example case for XYDOT. The total amount of benefits is estimated to be $18,777,800. In proportion with the scaling up, table 26 presents the distribution of benefits over the implementation period.

Table 25. Summary of benefits.

Anticipated Benefit Stream	Anticipated Benefits (USD)
Reduced use of paper, printing, mailing, faxing, scanning	375,000
Time to collect paper tickets	14,080,000
Time to create daily summary report	1,760,000
Time to travel offsite to office to submit documentation	880,000
Time to handle errors (data entry errors, lost documentation, illegible tickets and reconciliation)	880,000
Integration efficiencies	750,000
Savings in worker compensation insurance costs because of reduced risk of work zone injuries and fatalities	52,800
Total benefits	18,777,800

Table 26. Benefits distribution over years.

Implementation Year	Projects (Percent)	Benefits (USD)
1	5	938,890
2	10	1,877,780
3	20	3,755,560
4	25	4,694,450
5	50	9,388,900
6	90	16,900,020
7	100	18,777,800

Financial Case

The financial case discusses how much e-Ticketing would cost an agency. An agency should consider the following major cost items:

- IT staff costs for software development and implementation.
- IT staff costs for maintenance and enhancements.
- Hardware and software costs for field mobile devices, if required.
- Licensing fees for procurement, implementation, and maintenance of commercial-off-the-shelf (COTS) products.
- Procurement costs.
- Training costs.
- Cost avoidance of transitioning from paper to e-Tickets.

The agencies should also consider suppliers' costs, which would reflect on their bid prices:

- Suppliers' equipment upgrades, hardware purchases, and software licensing costs.
- Suppliers' load-out upgrade costs, if applicable.

The STAs, which have completed many pilot projects to date, have procured e-Ticketing by using a separate bid item to cover e-Ticketing costs or making the costs incidental to the material bid item. Both Pennsylvania and Washington use a separate bid item for e-Ticketing. Table 27 presents a frequency distribution of bid costs of e-Ticketing, as quoted by contractors, on their DOT projects, Washington State DOT (WSDOT) and Pennsylvania DOT (PennDOT), respectively. While the bid costs exhibit a wide range of costs, the median value of e-Ticketing costs are approximately $5,000 for both agencies. The interviews with the agencies indicated that the contractor bids for e-Ticketing are typically high on their initial deployments, while the costs decrease gradually but significantly over time. The cost analysis was not performed on projects in which the deployment cost was incidental to the material type because of the challenges with capturing e-Ticketing costs.

Table 27. Summary of bid costs of e-Ticketing on WSDOT and PennDOT projects.

Bid Item Cost Range (USD)	WSDOT (No.)	PennDOT (No.)
<1,000	0	0
1,000–2,000	1	1
2,001–3,000	1	8
3,001–4,000	1	0
4,001–5,000	12	3
5,001–6,000	0	0
6,001–7,000	0	1
7,001–8,000	1	1
8,001–9,000	0	1
9,001–10,000	1	1
10,001–11,000	0	3
11,001–12,000	0	0
12,001–20,000	0	1
20,001–30,000	0	0
30,001–40,000	0	1
Total count (No.)	17	21
Minimum (USD)	1,500	2,000
Maximum (USD)	10,000	34,200
Median (USD)	5,000	4,909

Implementation Case

This subcase entails a high-level assessment of requirements and challenges to the implementation of e-Ticketing. The high-level assessment explores the technological and commercial viability of one or more options, lays out the procurement approach and specification needs, and recognizes the challenges associated with implementation.

Several technology options are available for agencies exploring e-Ticketing. Agencies should consider the following viable options:

- Capture and transmit electronic data by contractor/supplier at the load-out system to the DOT. Most suppliers either work with a vendor-based product or develop their own custom solution to integrate a load-out system for electronic capture, backup, and transmittal.

- Receive electronic data from the STA, including inspectors. The STAs use three different approaches: a vendor-based software app on a computer or mobile devices to access electronic data in near realtime via an Internet connection; an in-house Web portal using APIs to receive data from authenticated users and make the process vendor agnostic, which are then related to the inspectors in the field using a software application; or a vendor-developed solution to build a Web portal using APIs.

- Store electronic data in information systems for potential use, such as spreadsheets, document management systems, databases, and CMS.

During the piloting stage, the agencies can explore one of the following three procurement model approaches:

- Include e-Ticketing as a new bid item in the base contract.

- Make e-Ticketing incidental to a bid item in the base contract.

- Select candidate projects that are deemed favorable for e-Ticketing by using a base contract and executing a contract modification if the selected contractor and supplier is ready to do e-Ticketing on the existing project.

However, as agencies advance in the future to full implementation, the e-Ticketing is anticipated to be incidental to the material.

This subcase should also consider other considerations and challenges associated with implementation. Key challenges are summarized as follows:

- Addressing issues related to technological maturity, such as hardware requirements and data management.
- Working with multiple vendors.
- Having reliable Internet connectivity.
- Maintaining costs to small suppliers.
- Providing training and education.

Some of the key challenges mentioned in the previous bullets are discussed in detail in chapter 5.

CHAPTER 4. E-TICKETING STATE OF PRACTICE

The research team reached out to nine State DOTs to conduct interviews on experience with e-Ticketing data, benefits and costs, stakeholder coordination, data management, and verification procedures. This chapter describes the rationale behind selecting State DOTs for interviews and data requests and a summary of findings.

CANDIDATE SELECTION

The AASHTO national survey indicated that 26 STAs use e-Ticketing. Three STAs—Utah, Pennsylvania, and Nebraska—indicated the use of technologies developed in-house, whereas the remaining STAs use vendor technology solutions. To further understand the practices of these STAs, candidate selection was based on a matrix with seven factors.

1. **AASHTO geographic region**—STAs were selected to ensure geographic representation and regional affiliation across the country.

2. **Rural versus urban lane miles**—Internet coverage limitation, particularly in rural areas, is one of the most cited implementation barriers. The number of urban and rural lane miles as reported in the FHWA Highway Statistics 2019 was used to categorize agencies into three groups (FHWA 2020):

   - Mostly rural—more than 80 percent of the lane miles in rural areas (19 States).

   - Moderately rural and urban—The national average of lane miles is 71.8 percent rural and 28.2 percent urban. Two categories were considered: moderately rural—STAs with rural lane miles between 60 and 80 percent and mostly urban—STAs with rural lane miles less than 60 percent. Of the 12 mostly urban agencies, only Connecticut, Florida, and Georgia have implemented e-Ticketing. However, based on the considerations of e-Ticketing technologies, the inclusion of the "mostly urban" category does not bring significance other than representation. Therefore, these two categories were combined.

3. **Material types**—STAs were selected to capture representation of all three material types (asphalt, ready-mix concrete, and aggregates).

4. **Technology solutions**—STAs were selected to include both in-house and vendor-developed solutions.

5. **Implementation status**—STAs were selected to include agencies that implemented e-Ticketing before and after the 2020 pandemic.

6. **Integration with material/CMS**—STAs were selected to represent various CMS.

7. **Integration of other technologies**—STAs were selected to include agencies that have integrated information from other technologies, such as thermal paver.

Based on the selection criteria information, as summarized in table 28, the following State DOTs were selected for questionnaire interviews and data collection (AASHTO n.d.a):

- Pennsylvania and Delaware in AASHTO Region 1.
- Alabama and Tennessee in AASHTO Region 2.
- Iowa, Nebraska, and Minnesota in AASHTO Region 3.
- Utah and Washington in AASHTO Region 4.

Table 28. Selection of STAs for questionnaire interviews.

Criteria	MN	IA	UT	PA	WA	DE	NE	TN	AL
AASHTO geographic Region 1	—	—	—	X	—	X	—	—	—
AASHTO geographic Region 2	—	—	—	—	—	—	—	X	X
AASHTO geographic Region 3	X	X	—	—	—	—	—	—	—
AASHTO geographic Region 4	—	—	X	—	X	X	—	—	—
Mostly rural—80 percent lane miles and higher	X	X	—	—	—	—	X	—	—
Moderately rural and urban <80 percent lane miles	—	—	X	X	X	X	—	X	X
Asphalt pavement	—	X	—	X	X	X	X	X	X
Ready-mix concrete	—	X	—	—	X	X	—	—	—
Aggregates	—	X	—		X	—	—	—	—
In-house developed	—	—	X	X	—	—	X	—	—
Vendor developed	X	X	—	X	X	X	—	X	X
Piloted before 2020	X	X	X	X	—	—	—	—	—
Piloted in 2020 or later	—	—	—	—	X	—	X	X	—
Pilot planning currently underway	—	—	—	—	—	X	—	—	—
Benefit–cost quantification	—	—	—	—	—	—	X	—	—

—Not applicable.

SUMMARY OF PENNSYLVANIA DOT PRACTICE

Introduction

PennDOT runs a large, $7.3-billion construction program. PennDOT is organized as 11 districts, and, on average, it administers approximately 1,100 to 1,200 construction projects annually. PennDOT employs more than 500 DOT construction inspectors to support its construction program and supplements with about 1,800 consultant inspectors. For nearly a decade, PennDOT has been working on e-Construction efforts with the goals to provide productivity for field staff, gain efficiencies through paperless processes and technology use, and digitalize information for best use.

PennDOT was one of the early adopters of e-Ticketing, and piloted its first e-Ticketing projects in 2017 on four hot-mix asphalt (HMA)/warm-mix asphalt (WMA) and milling projects in District 11, Allegheny County. These four projects used two vendor products: Earthwave's®

FleetWatcher™ and Libra™ systems. In 2018 and 2019, PennDOT continued to pilot with 10 additional projects. As of 2021, PennDOT has used e-Ticketing on more than 50 projects.

The pilot projects predominantly included asphalt mixtures and millings; however, the agency has expanded e-Ticketing to include aggregates and concrete. PennDOT is currently expanding e-Ticketing pilots to its remaining districts with three projects per district for the three predominant material types. The goal of the agency is to fully roll out e-Ticketing by 2024 on its projects. In the future, the agency plans to include liquid asphalt and deicing salt and chemicals.

PennDOT's primary motivation for implementing e-Ticketing is focused on e-Construction and safety. PennDOT's e-Ticketing initiative evolved naturally as a part of its larger ongoing e-Construction initiative.

The construction program inherently entails volumes of paper and paper-based business processes. A typical construction project may generate about 100 to 5,000 pages of paper for plans, shop drawings, requests for information, emails, and associated documents. These volumes of paper must be processed, stored, and retained for a specific period. The transition to e-Tickets provides the following opportunities:

- Overcoming the challenges associated with handling paper tickets, such as printing and paper costs, recovering lost tickets, and ticket sorting.
- Creating daily summaries and streamlining payment processes to contractors.
- Providing material and tonnage verifications.

For PennDOT, reducing work zone hazards was a key goal for e-Ticketing to ensure the safety of construction inspectors working in live traffic, on night jobs, and on worksites with narrow shoulders. The agency intends to leverage e-Tickets to automate payroll processes for future projects and for delivery cycle and production rate monitoring.

e-Ticketing Tools

In the initial phases of piloting, PennDOT has allowed vendor solutions, such as CONNEX by Command Alkon, DOTslip, FleetWatcher, and Libra Sentinel, as well as contractor-developed solutions, such those developed by Lindy Paving.

PennDOT has developed an e-Ticketing solution called User Acceptance Testing (UAT), which works for any potential vendor solution or suppliers that would entail a Web-based, industry-standard API. The API is a set of software instructions that enable communication between two software programs. Using the APIs, an agency can receive electronic data from any vendor or supplier, in predefined file formats with authentication credentials, and post the same data in the agency's software systems. The e-Ticket will use the JSON format and must adhere to the data fields and format requirements set by PennDOT. PennDOT will provide the software vendors and suppliers with specific authentication credentials and an app key. They can then use them to call the API services and send the ticket data. The e-Tickets are posted on Azure™, a cloud computing service operated by Microsoft® (Microsoft 2023a).

The development of the UAT portal is complete. The APIs are currently working, and at least five vendors, to date, have been sending tickets using their credentials. The API puts the ticket data into the agency's database, which, in turn, relays the information to the mobile app that PennDOT's inspectors use in the field to view e-Tickets. The inspectors have the functionality within the mobile application to accept, reject, or void the ticket and add comments.

The UAT application provides an agency view of the tickets. The vendors can query the agency systems on the status of the tickets by using this app. A unique ticket ID is created when a ticket is submitted. The submitter can use this ticket ID to obtain the status or see what information has been amended or added on the e-Ticket.

Benefits and Costs

Although PennDOT recognizes specific trends with the benefits and costs associated with e-Ticketing, it has yet to capture, review, and document them.

PennDOT allows contractors to bid e-Ticketing as a lump sum using its bid item 9000-0100 Electronic Delivery Management System. Using a lump sum bid item enables the agency to absorb the contractor costs of e-Ticketing, while tracking the cost trends over time. The agency plans to phase out the use of a separate bid item over time. In the future, the agency anticipates making the contractors' e-Ticketing costs incidental to the work items, most likely after full implementation when most or all suppliers would be up and running with e-Ticketing solutions and communicating with PennDOT's software apps.

Based on the past bids to date, the bid prices for e-Ticketing appear to be varying widely between $1 and $34,200, with an average around $5,000. This variability could be attributed to three reasons:

- Inconsistency among contractors in how they spread the costs among the projects.
- High bidding prices for contractors to cover the upgrade and implementation costs of e-Ticketing, although multiple projects will ultimately reduce bid costs. Over time, the agency surmises that the bid price will reduce and stabilize to reflect only the maintenance costs on subsequent projects.
- Removal of GPS requirement, which could have resulted in lower bid prices.

Implementation Experience

Stakeholder Outreach

PennDOT has been partnering with the industry since initiating the pilots. The receptivity for e-Ticketing among Pennsylvania's midsize and large contractors, material suppliers, and DOT staff is positive; however, small suppliers have been less receptive. Although the small suppliers are incentivized to use the lump sum bid item to cover their upgrade costs, they still have practical challenges, such as obtaining Internet coverage for their production plants. PennDOT is working to have a better understanding of their concerns.

Special Provisions and Specifications

PennDOT developed a special provision to facilitate the piloting of e-Ticketing for HMA/WMA and asphalt millings: 9000-0100 Electronic Delivery Management System. These special provisions included the following requirements:

- Incorporating GPS/Global Navigation Satellite System (GNSS) tracking on all dump trucks, belly dumps, side-load dumps, pavers, materials transfer vehicles, or any other vehicles.
- Establishing full integration with the production plant load-out system.
- Tracking materials during the construction processes from the production plant load-out point to the final delivery and placement location.

Since the initial pilots, PennDOT has removed the GPS/GNSS tracking requirement from the special provision because of the pushback from the industry. Working with the industry, PennDOT developed two specifications: e-Ticketing construction and maintenance specifications (PennDOT 2020a, PennDOT 2020b). The agency received comments from the industry and is in the process of revising them, along with developing special provisions for batch mixture slips, concrete, and aggregate.

Preconstruction Meetings

e-Ticketing is an agenda item on current PennDOT preconstruction meetings. e-Ticketing was added as an agenda item for all construction projects piloted in 2021. The preconstruction meeting allows the project stakeholders to acknowledge and discuss the plan for e-Ticketing. The preconstruction meeting discussions address issues, including contingency plans to manage loss of Internet connectivity in the field and power outages at production plants.

QA

To verify the quantities on e-Tickets, PennDOT still collects both electronic and paper tickets, allowing it to compare and ensure accuracy of information. The agency will eventually stop collecting the cohort tickets. The agency plans to create an agency view of the tickets that allows it to design and implement agency-specific forms. The agency still follows the inspection process associated with paper tickets. The construction inspectors perform inspections at the plant facilities to ensure the weigh scales are reading accurately and the tickets are produced correctly. The production plants are required to keep a material logbook. The inspectors can review the record of the materials in the logbook to verify the production quantities of the plant.

GPS Requirement and Internet Coverage

Pennsylvania discontinued the requirement that the contractor must provide GPS/GNSS data because of industry pushback. Citing privacy concerns, the private sector was hesitant to share the route, location, and vehicle speed information of haul vehicles and drivers with the agency. The private sector was concerned that sharing the GPS information would allow agencies to monitor their movements during operations. In PennDOT’s view, leaving the GPS/GNSS requirement in place would have hampered implementation. Furthermore, handling GPS/GNSS equipment on every truck would be challenging. The agency anticipates that some form of verification of vehicle routing will be back eventually.

Handling Internet coverage issues is a matter that was often raised during the preconstruction meetings. The UAT app has the ability to work in an offline mode, so when the inspection team receives a signal, the app will sync back to update the ticket data.

PennDOT requires its contractors to provide Internet connectivity at the jobsite. The specification states that for project locations with limited Internet service, the contractor should provide an alternative that is acceptable to the agency. Some production plants are exploring the use of alternative ways, such as low Earth orbit satellite Internet or cell signal boosters. However, the cost of these alternatives is a deterrent. As part of the current pilots, the STA will need to update the specification to addresses this issue further in the future. PennDOT wants to ensure that the specification is not precluding anyone from bidding on a project because of Internet connection issues.

Stakeholder Outreach and Training

PennDOT has formed a steering committee with the industry to facilitate the implementation of e-Ticketing comprising representatives from the Pennsylvania Asphalt Pavement Association, the Pennsylvania Aggregates and Concrete Association, Pennsylvania chapters of American Concrete Pavement Association, Associated Pennsylvania Constructors (APC), American Council of Engineering Companies, the Pennsylvania Motor Truck Association, FHWA, contractors, and consultants. The committee has four subteams: specifications, construction QA, IT, and law enforcement. PennDOT is also exploring the potential expansion of e-Ticketing to maintenance projects. This partnership has helped PennDOT establish robust communication with the industry on e-Ticketing initiatives. Through its monthly meetings, PennDOT communicates with the industry on the progress of pilot projects; discusses implementation challenges, stakeholder needs, and national trends; and solicits feedback.

On training, PennDOT is currently training its internal teams for the pilot projects on a project-by-project basis. PennDOT is developing a training video and a PDF user guide, which will be available on demand in the future.

Data Management

PennDOT has been working on implementing and centralizing various information systems to streamline the flow of information, enhance business processes, and gain efficiencies. PennDOT's e-Construction efforts include the following information systems:

- Engineering and Construction Management System (ECMS), which handles bids, awards, payments to contractors and consultants, supplier certifications, and project site activities reports. Project Site Activity (PSA) reports, a component of ECMS that allows construction inspectors to document daily field activities and summary reports, such as actual location and quantities.

- Electronic Construction and Materials Management System (eCAMMS), a material management system with Web access that stores job mix formulas, sampling of materials, test results and deviations, material certifications, and new products evaluation (PennDOT 2021).

- PennDOT Project Collaboration Center, a Microsoft® SharePoint®-based document management solution that allows contractors to submit documents electronically (Microsoft 2023b).

These systems are designed to interact with each other. In the future, the data from e-Tickets will flow into ECMS and other the information systems. The ticket data will report contract- and material-related information to ECMS and eCAMMS, respectively; however, PennDOT has yet to build the app that pushes electronic data into eCAMMS systems. PennDOT envisions that the e-Ticket data will be populated automatically into the systems in the future and used for various purposes. For example, autosummarizing ticket quantities in PSAs will help automate payments to contractors, and correlating placement location from tickets with sampling and testing data will help with forensic investigations. On data security, PennDOT has no additional requirements for e-Ticketing. The standard policies and procedures used for the enterprise software apps are being used.

Future Plans

PennDOT's future plans include the following activities:

- Expand the deployment of pilots to newer material types, and maintenance projects.

- Integrate e-Ticketing data with ECMS and eCAMMS.

- Leverage best practices and lessons learned to continually improve the practices for full deployment by 2024.

SUMMARY OF IOWA DOT PRACTICE

Introduction

Iowa DOT is the pioneer in e-Ticketing, and the agency conducted the first proof-of-concept pilot with asphalt mixtures in 2015. After initiating the 2015 pilot project, Iowa DOT launched additional asphalt projects. The first pilot with PCC was completed in 2017, and a pilot with aggregates was completed in 2020. In 2021, Iowa DOT completed more than 100 pilot projects. In 2019, Iowa DOT used about 10,000 e-Tickets to deliver more than 100,000 yd^3 of concrete on a single construction project on I–74 that replaced an aging bridge over the Mississippi River.

Iowa DOT's e-Ticketing efforts are still in the pilot phase. The agency plans to expand the number of pilots to 100 projects in 2022, 400 projects in 2023, and 800 projects the year after. Between 2015 and 2021, Iowa DOT accepted any ticketing solution from the vendors. The costs of e-Ticketing were paid through contract modifications outside the competitive bidding to partner with interested contractors and vendors. Over time, the agency realized the difficulties associated with handling many vendor products, such as issues related to setting up the projects and training the inspectors on different vendor products.

Approaches Used

Iowa DOT has developed a Web portal. The agency hired InfoTech® and Command Alkon to build the portal. The tickets can be submitted electronically at https://iowa.ticketing.gov (Iowa DOT 2021). A customer or vendor can log into the system with an authentication key and send data via HTTPS POST, which is a method for sending data that is supported by the World Wide Web and JSON formats. The agency is paying a license fee for all the e-Ticketing apps. The suppliers can choose their preferred solution. Fleet management is at their discretion, although the suppliers will be required to submit the ticket data in a prescribed format. The ticket can include pictures, Microsoft® Excel® files, videos, and PDF files (Microsoft 2023c). The agency will have a prequalified list of vendors on the portal to enable testing.

Benefits and Costs

The primary motivation for e-Ticketing was the safety of construction inspectors after the fatal incident involving a construction technician who was struck by a cement concrete truck in 2006. Beyond safety, Iowa DOT saw many benefits associated with digitalizing tickets, including reducing paper use; avoiding issues with paper tickets, such as lost and illegible tickets, manual entry of data, consolidation, and reconciliation of daily totals; and having a readily available quantity of information. Iowa's STA did not have to make a business case because the industry was interested in using e-Ticketing on paving projects. The agency recognizes the value of e-Ticketing, but it has not yet quantified the cost, time, and safety benefits associated with implementing the process.

Implementation Experience

GPS Requirement

In the earlier phase of piloting, Iowa DOT required GPS/GNSS tracking and breadcrumbing of material delivery in its developmental specifications. The GPS/GNSS locations and associated time stamps from Internet-connected devices in delivery vehicles and the paver was captured every 60 s and 30 s, respectively. However, owing to the challenges in capturing the GPS/GNSS location, Iowa DOT eliminated the GPS/GNSS requirement in its developmental specifications. Although the agency believed the GPS/GNSS requirement was an obstacle to the widespread adoption of e-Ticketing, the GPS/GNSS requirement is likely to be reinstated in future requirements and specifications.

Verification

Iowa is awaiting to see what other States are doing to authenticate the electronic procedure. The verification process would not differ greatly because the electronic version would not be any different, in terms of information contained therein, than paper tickets. However, the agency noticed a few inconsistencies between the two versions, possibly due to faulty setup procedures and challenges in amending errors on the electronic versions.

Visual Proof of Delivery

Iowa DOT has been piloting the concept of electronic visual proof of delivery by using camera-based automatic detection of license plates as an alternative to using GPS/GNSS locations. Under this concept, the cameras would be automatically triggered to capture the information on the license plates of the trucks at the production plant and at the construction sites. The photos of the trucks loading at the plant and delivering at the jobsite would then be added to the ticket and matched with the corresponding geocoordinates and time stamps. These images would provide visual proof that a truck with this ticket has left the production plant and show when the truck has delivered the materials onsite.

The IOWA DOT completed a pilot in 2021, and the agency continues to conduct more pilots. The proof of concept is 78 percent successful because the detection software was unable to match the trucks with the photo images in a few instances. Some real-world issues, such as dirty and missing license plates, different camera angles and zooms, nighttime paving, and camera quality, contributed to mismatches. The agency is still learning from them and refining the concept through multiple pilots.

Stakeholder Engagement

Iowa DOT has been partnering with the Iowa Associated General Contractors (AGC) and the Iowa Concrete Pavement Association. The agency has shared its developmental specifications with the industry. The aggregate industry is interested in e-Ticketing; however, a better understanding is necessary for the industry before Iowa DOT can move forward with further pilots. Iowa DOT has also reached out to its small suppliers to understand their concerns.

Internet Connectivity

Iowa DOT has been exploring alternatives to overcome the challenge of weak cellular signal strength in project locations. The agency has worked with the districts to screen for areas with weak or no cellular signal strengths on upcoming construction projects. The locations with poor Internet connectivity are then shared with cellular service providers for potential service needs improvements.

Iowa DOT has also been piloting the use of cellular signal boosters in construction projects. The signal boosters are typically used to amplify a weak cellular signal or extend an existing cellular signals to areas with weak signal strengths. Iowa DOT purchased cellular signal boosters in November 2022 using the funds granted under a FHWA State Transportation Innovation Council Incentive Program award (Iowa DOT n.d.). The agency has since deployed the signal boosters in the construction projects.

Training

Iowa DOT has been conducting training across the State for contractors, suppliers, and State inspectors to instruct them on the system use. The agency has developed an updated developmental specification and is also working on a construction memorandum for e-Ticketing.

The agency has recently hired an e-Construction coordinator to provide a dedicated resource for e-Ticketing related activities, including training. The agency provides both virtual and in-person training to inspectors and offers technical support through email and telephone. The agency has created on-demand how-to-do videos and quick reference guides to support training.

Data Management

Iowa DOT has been using an Excel-based solution to extract data from e-Tickets. The Excel spreadsheet, created in-house, includes user-entered, autocalculated and autofilled data fields with sorting and filtering capabilities.

Iowa DOT uses InfoTech® Doc Express® and the AASHTOWare® Project™ (AWP) for document management and CMS, although the process has not yet been integrated (InfoTech 2023; AASHTO n.d.b.). Meanwhile, Iowa DOT has been working with InfoTech to create an agency view for e-Tickets and production plant reports in the AWP, which will be added to the inspectors' daily work report (DWR). In addition, Iowa DOT is working toward streamlining the e-Ticketing handling system into the document management system Doc Express, but it has not yet been implemented.

Future Plans

Iowa DOT's future plans include the following activities:

- Developing the e-Ticketing handling system, as illustrated in figure 14.
- Creating an agency view with Doc Express.
- Integrating document management and CMS with AWP.
- Exploring the expansion of e-Ticketing to steel products and inbound materials.
- Completing the pilots on camera-based visual proof of delivery for verification.
- Adopting business process changes to enable the implementation of e-Ticketing.

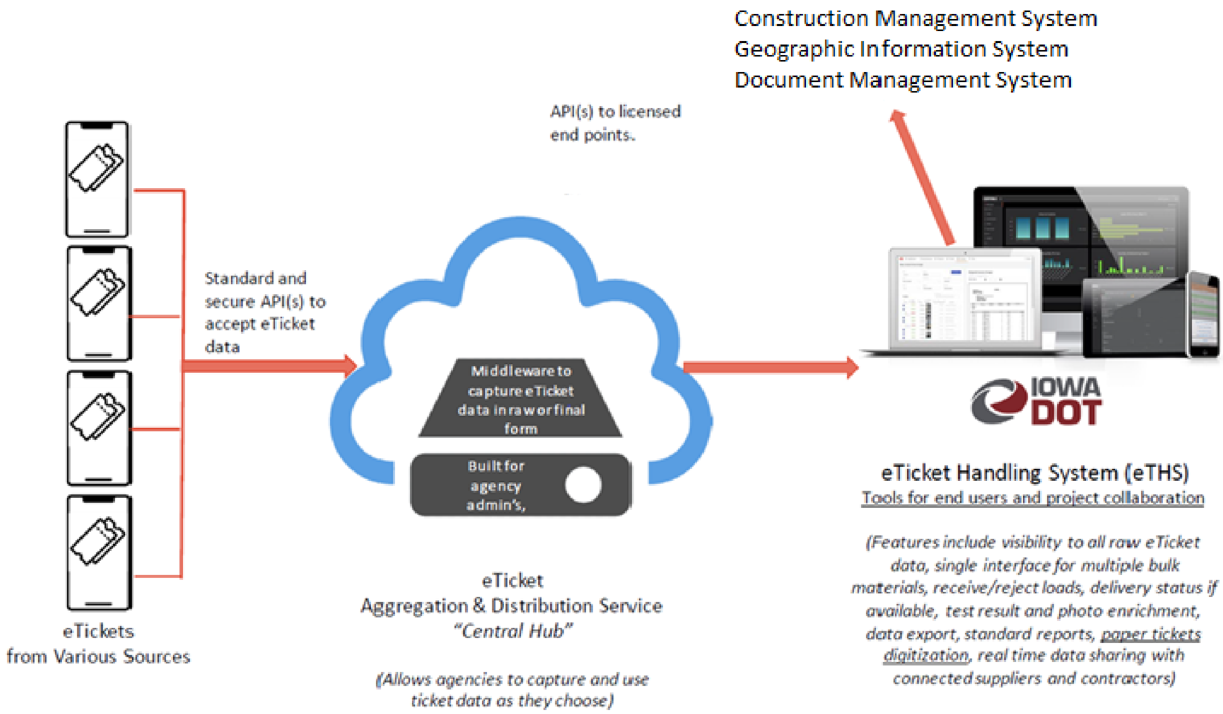


Figure 14. Diagram. Iowa DOT's future e-Ticketing handling system (Iowa DOT 2021).

SUMMARY OF DELAWARE DOT PRACTICE

Introduction

Between 2016 and 2017, the Delaware DOT (DelDOT) began planning for an e-Ticketing pilot on an asphalt paving project. The STA discussed piloting a COTS product on a paving project with a vendor. Although the planning phase for the pilot was 90 percent complete, DelDOT had to drop the project due to a lack of funds. After a 4-yr wait, a few developments culminated in renewing the implementation planning for a pilot in 2021:

- Internal conversations on electronic documentation in the context of e-Construction.
- A need to implement contactless technologies in light of the COVID pandemic and inspector safety in 2020.
- A change in the receptivity of the industry in favor of paperless technologies.
- An awareness created by the Minnesota DOT (MnDOT)-led AASHTO Material Delivery Management System (MDMS) specification efforts (Embacher 2021).

DelDOT is currently exploring the use of e-Ticketing beyond asphalt to include concrete, aggregates, and other materials. DelDOT rolled out e-Ticketing for all new HMA projects in spring 2022 and plans a statewide rollout for concrete in 2023. DelDOT is open to the possibility of using e-Ticketing for any material types that are delivered by the truck to the site, such as precast elements, guardrails, etc.

In Delaware, six suppliers deliver asphalt mixtures to paving projects. Five of the six asphalt mixture suppliers' systems were connected with the portal within 90 d after the first discussion. DelDOT began receiving tickets between February and June of 2021. To date, DelDOT has been receiving e-Tickets on 32 projects for asphalt, concrete, soils, and aggregates.

Approach Used

Leveraging the information compiled by MnDOT on MDMS, DelDOT decided to implement a Web portal approach for e-Ticketing. DelDOT's vision for the Web portal was to have full control of the agency's own view, control of the information the agency has access to, and full control of the supplier-produced data.

DelDOT decided to install a Web portal with the support of a vendor, and contracted with HaulHub to build the Web portal (Delaware DOT n.d.). After the initial buy-in from the Delaware Pavement Association, DelDOT offered three incentives to suppliers:

- Suppliers may select and use a vendor of preference, but they must report electronic data in a required format to DelDOT.
- DelDOT's vendor will provide some IT assistance to support the integration with the supplier's load-out system.
- DelDOT's vendor will provide technical assistance to suppliers for the integration with the load-out system at the production plant.
- DelDOT will pay for the technical assistance if a supplier does not prefer to use a vendor of preference on its own.

Benefits and Costs

DelDOT recognized the standard benefits of e-Ticketing but has not quantified them. DelDOT attributed difficulties in sharing the cost of building the Web portal to contractual issues. DelDOT pays an annual subscription fee to the vendor for using the portal.

Implementation Experience

GPS/GNSS Requirements and Internet Connectivity

GPS/GNSS is not a priority for DelDOT because of its smaller geographical footprint. In addition, DelDOT prefers not to receive GPS/GNSS data because the location of a delivery truck is not the responsibility of the agency. However, for verification purposes, DelDOT is looking into capturing the locations of inspections and materials deliveries on the jobsite.

Internet connectivity is a significant issue of interest to DelDOT. The STA is in contact with mobile and satellite service providers to discover alternatives for use in areas that have inadequate connectivity.

Stakeholder Outreach

DelDOT has been working with the Delaware Asphalt Pavement Association. The agency is also working to coordinate with the State chapters of concrete and aggregate industries. The agency has been keeping the industry informed on the pilots, successes, and challenges associated with e-Ticketing. DelDOT's goal is to ensure that e-Ticketing works for the suppliers.

Specifications

DelDOT has been using a special provision for e-Ticketing on every project. To phase out paper tickets, the agency is currently not accepting any paper tickets for an asphalt paving project unless an emergency occurs. The STA has included a section on e-Ticketing in the 2022 version of its e-Construction manual (DelDOT 2022).

Data Management

DelDOT's Web portal can be accessed at https://tickets.deldot.gov (DelDOT n.d.). Each authorized supplier will receive an authentication key to send tickets in the JSON format. The Web portal is connected with a cloud through Boomi™, which connects the cloud with on-premises apps and data (Dell 2023). If the supplier has an API established by the supplier's vendor, the supplier can send data to the portal directly. In absence of an API at the supplier's end, the supplier can use Boomi, as customized by the vendor, to send the ticket to the portal. The data can be downloaded in a PDF and CSV format from the database. DelDOT exercises the full ownership of the data. Once received, the e-Ticketing data will be subject to the same retention policies as paper tickets.

DelDOT has been making progress on the integration of the e-Ticketing data collected through the portal with the Oracle® Primavera Unifier™ system. Unifer™ serves as the Web-based project lifecycle management app for the agency (Oracle 2023). DelDOT uses Unifier for digital construction administration processes, including electronic submittal and storing of documents, electronic recording of Inspector's Daily Reports (IDR), bidding, and contractor payments. Unifier serves as the central hub for storing, utilizing, and archiving e-Ticket data.

The field inspectors review e-Tickets received through the Web portal. The inspector-reviewed tickets have a "delivered" mark on them. The inspector-reviewed tickets are gathered to create packages by material types, inspector names, and dates. The data packages have general information, such as bid item or nonbid item and dates. The inspector daily summaries are used to create progress payments on each project. The inspectors review the data packages and approve them for progress payments. The Unifier runs Web services every 4 h while the data packages are imported from the e-Ticketing cloud into the Unifier system.

DelDOT has created a business process to automate the payment to contractors based on quantity calculations. All e-Tickets, which are marked as delivered to the portal, are gathered by the project and imported into the Unifier. The inspectors then create ticket packages for specific dates by material type and bid pay item. The ticket packages are populated into the Unifier environment, which are then reviewed for split loads, summarized automatically, and marked for payment upon the approval of IDR. Beyond the automation of payments, DelDOT plans to keep all material testing data in the Unifier system. In the future, DelDOT also wants to use the e-Ticketing integration with Unifier for calculating production rates and assigning resources to projects.

Future Plans

DelDOT's planned enhancements to the e-Ticketing mobile application include enabling an audit review of ticket data, allowing the DOT plant inspectors to view and add notes to the tickets, and adding the field inspector's GPS location and station to the ticket. DelDOT also plans to automate project initiation and assign users with access credentials for use in the e-Ticketing applications. Future integrations will address situations such as the acceptance of tickets with spilt loads and waste and overweight trucks.

SUMMARY OF UTAH DOT PRACTICE

Introduction

Approaches Considered

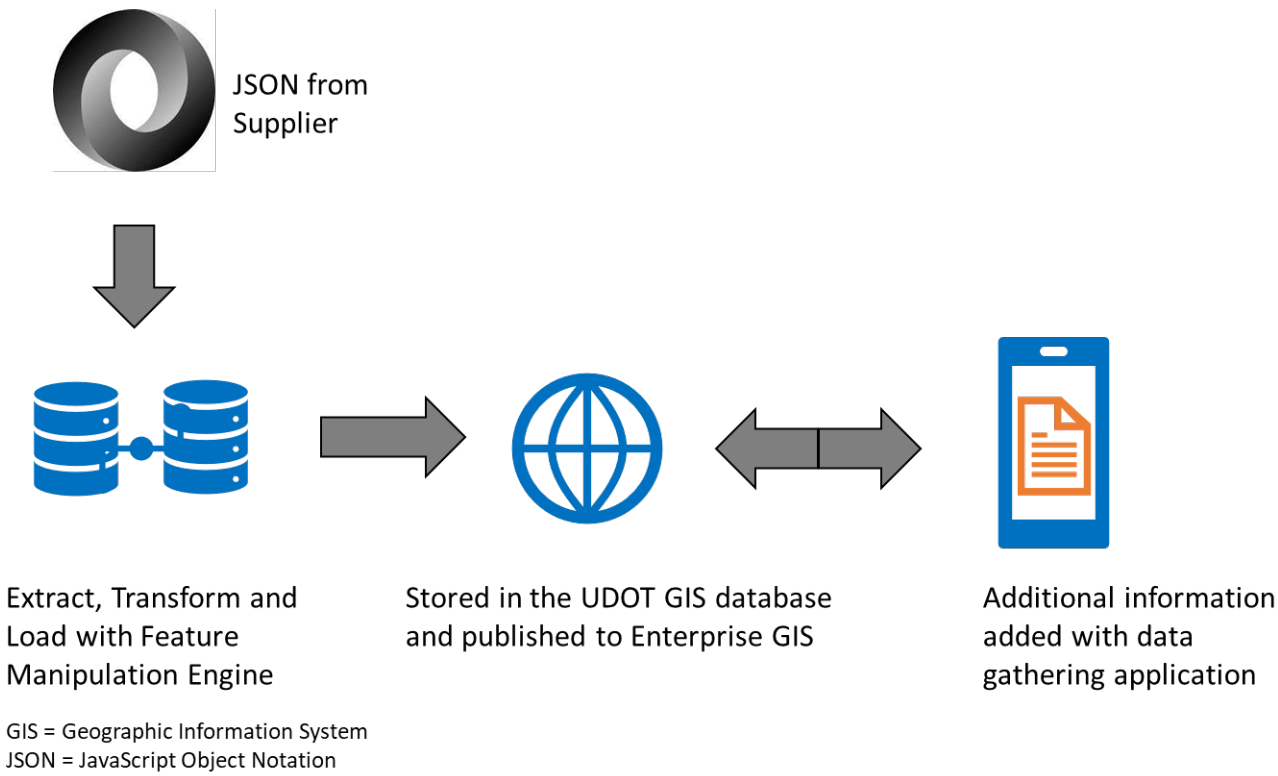
Initially, the Utah DOT (UDOT) considered an e-Ticketing pilot for concrete, but the agency experienced difficulty with procuring a software solution and incurred resistance from the contracting and supplier industry. Given that a majority of UDOT's pavements are asphalt, the agency determined that an asphalt pilot was the best approach. Still facing software procurement challenges, UDOT, with input from its GIS business unit, determined that an internally developed solution was feasible, although the solution lacked the ability to track the haul vehicles. The Utah contracting industry voiced concerns about tracking trucks, while UDOT was concerned that it would need to purchase the required GPS/GNSS units and be exposed to potential liability from knowing if a truck was operating illegally. The in-house approach was preferred for this reason and because the commercial solution would cost more, require inspectors to be familiar with multiple apps, and require data storage development. With a single, in-house system, inspectors only need training on the use of one e-Ticketing approach.

Solution Implementation

UDOT received an FHWA State Transportation Innovation Council grant to implement its in-house approach. The STA launched an initial pilot in spring 2019, and subsequent pilots continue to refine UDOT's approach and scale up the extent of its app. Between the initial pilot and early 2021, the State used e-Ticketing for several dozen projects. Presently, UDOT has implemented e-Ticketing for three of its four major asphalt suppliers, as well as one PCC supplier, despite initial pushback from the concrete industry. UDOT received more than 19,000 e-Tickets in 2020, accounting for more than 663,000 tons of asphalt products, and the STA plans to apply e-Ticketing further to aggregates and prefabricated elements.

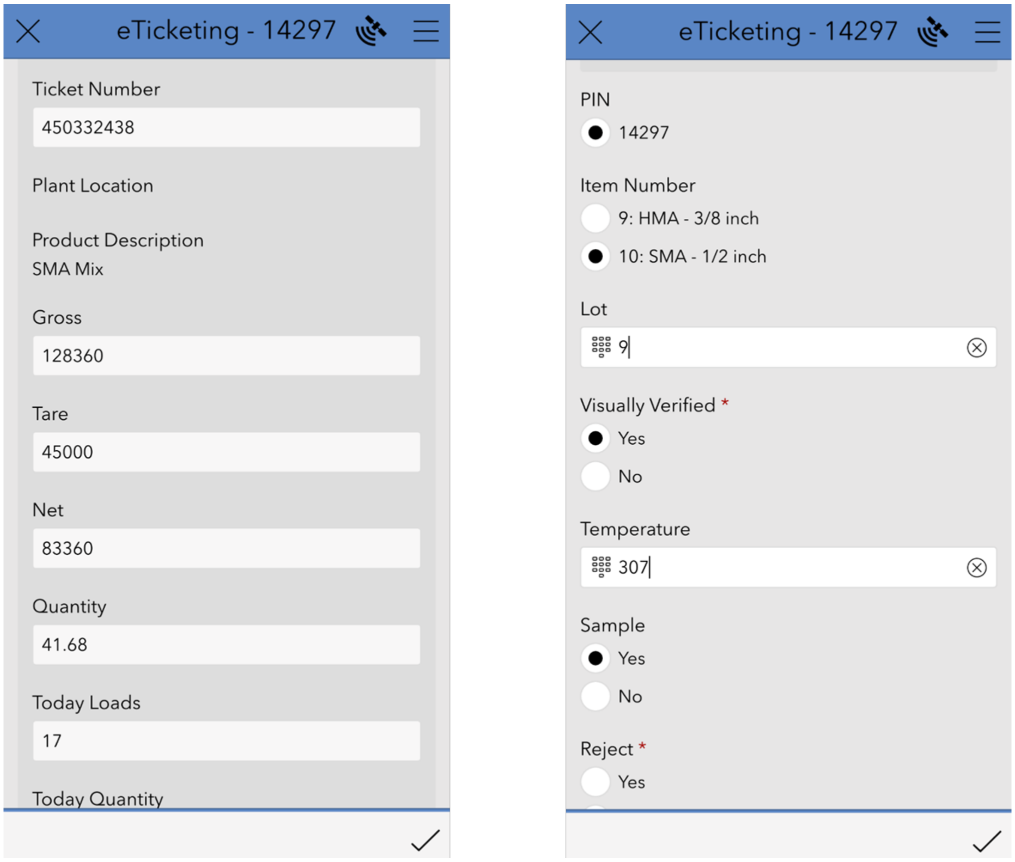
UDOT's in-house solution (figure 15) consists of a Web portal that receives the e-Tickets from the suppliers in JSON format. The electronic data are extracted, transformed, loaded, stored in an

Esri Enterprise Geodatabase with the aid of a feature manipulation engine (FME) (Esri n.d.a.; Safe Software® 2023). The FME is a data integration tool that transforms datasets from multiple sources to a destination to ensure interoperability. UDOT uses the FME to filter, process, and merge data attributes from e-Ticketing into the enterprise geodatabase. The electronic data are then served to inspectors using the Esri Survey123 mobile app (figure 16). Inspectors can view the ticket information (e.g., mix type and design, mix properties, and material sampling locations) conduct the inspection, and add information and notes (e.g., temperature) using the Survey123 app on their mobile devices (Esri n.d.b). Inspectors accept the loads based on the truck DOT ID number. Load acceptance logs a latitude and longitude near the delivery site. Data are shared and downloaded using an operations dashboard (figure 17). Inspection results are returned to the material supplier, and the e-Ticket data are associated with a line item for payment.



© 2020 UDOT. Recreated by WSP.

Figure 15. Diagram. UDOT e-Ticket workflow (Talbot and Sellars 2020).



* = required fields; SMA = stone matrix asphalt.

Figure 16. Screenshot. Example UDOT e-Ticket view on the inspector's mobile app.

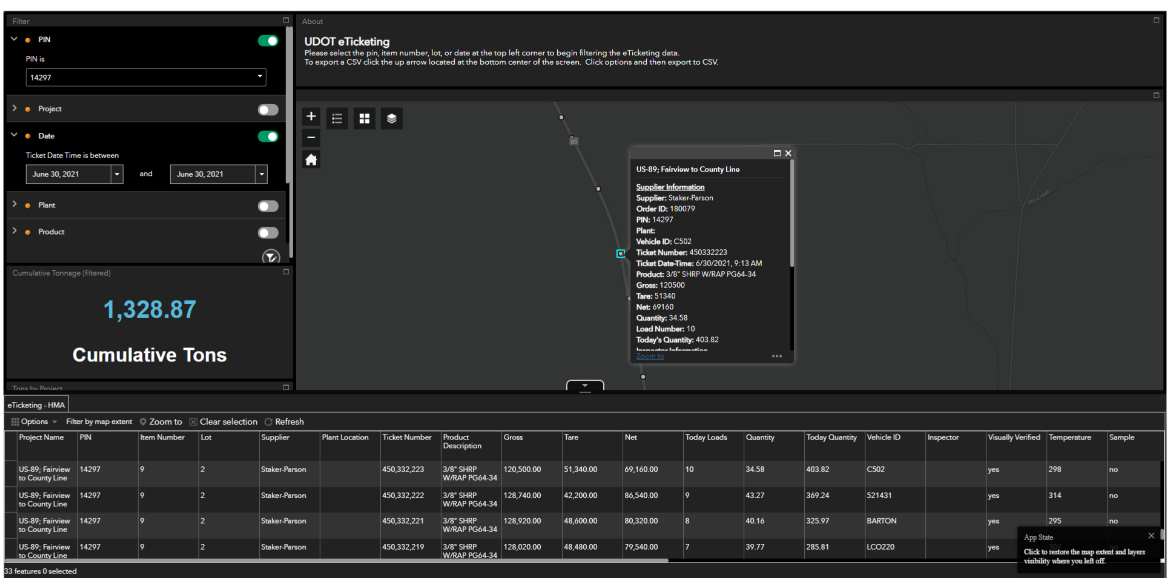


Figure 17. Screenshot. UDOT e-Ticketing operations dashboard.

Benefits and Costs

UDOT recognized the following benefits to the agency, which are yet to be quantified: reduced paper documentation, time savings in review and consolidation of material quantities, readily available material quantity information, archived material placement location, safety benefits, and real-time material tracking.

The benefits to the contractors include near real-time quantities, itemized delivery information, verification and reconciliation of delivery tickets, data analytics for better understanding of cycle times, and fleet management.

UDOT expressed difficulties in quantifying the costs of its in-house solution because of the indirect costs involved with in-house staffing and enterprise-wide licensing of FME and GIS software used in the development.

Implementation Experience

Stakeholder Receptivity and Outreach

UDOT's e-Ticketing pilot projects have garnered positive reception from midsize and large contractors, as well as from inspectors and other agency staff. Suppliers have also viewed e-Ticketing favorably, although greater support from them would help advance e-Ticketing technologies further. Small contractors and third-party trucking companies have been more neutral toward the e-Ticketing process.

Other concerns include loss of Internet coverage and use of the mobile app, as well as the ability to sort and navigate the vast number of tickets expected from full-scale implementation.

QA

UDOT does not currently, and is not planning to, verify the accuracy of the e-Ticket information generated at the production plant. Upon delivery, the truck numbers and time of departure are used to verify that the correct load is received.

An office technician performs further verification of the e-Ticket information when data are queried from the operations dashboard and exported to CSV. Production totals are summed, and results compared with inspector notes to identify anomalies. The technician creates a PDF copy of the data for exporting and posting in Aurgio® Masterworks™, their CMS, for submission for payment (Aurigo n.d.).

Data Management

No procurement language was used to outline the data management practices. Some effort has been made to integrate ticket data with CMS. UDOT has been preparing a data standardization plan, but the agency does not have plans to implement security standards or policies for e-Ticketing data or mobile devices.

Future Plans

UDOT plans to continue expanding its use of e-Tickets. Ongoing and planned improvements include integration of the e-Ticket data in GIS with UDOT's CMS (Masterworks), using webhooks to generate a POST API request populating parts of the PCC testing form, and researching integration with smaller suppliers using third-party e-Ticketing providers. UDOT would also like to establish standard operating procedures and document best practices.

UDOT notes several issues to overcome as e-Ticketing implementation expands:

- Applying the process when the prime contractor is not also the material supplier.
- Bypassing Utah ports of entry, which still require a paper ticket.
- Addressing server capacity if all UDOT projects use e-Ticketing.
- Establishing data governance.

SUMMARY OF NEBRASKA DOT PRACTICE

Introduction

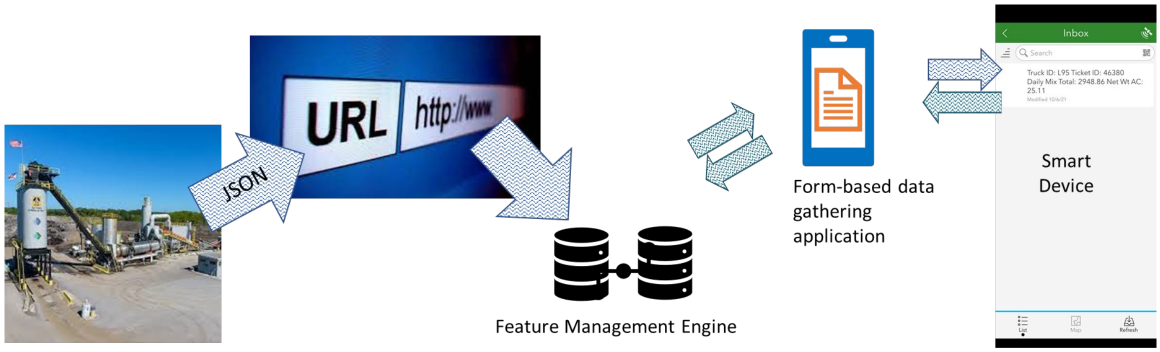
Approaches Considered

Nebraska DOT (NDOT) has piloted e-Ticketing for a small number of projects since 2021. The STA reviewed COTS solutions and in-house customized solutions and worked with the Nebraska AGC through an e-Ticketing task force to select a customized solution, weighing the pros and cons of each option. Although a COTS solution is generally easier and quicker to implement and requires little maintenance, it is more expensive, requires more training, and presents a sole-source problem for procurement. NDOT's customized solution correlates with its existing processes and apps, is more flexible, and requires staff to learn only one system. However, this solution needs collaboration from IT, must go through beta testing, and has higher maintenance requirements.

Solution Implementation

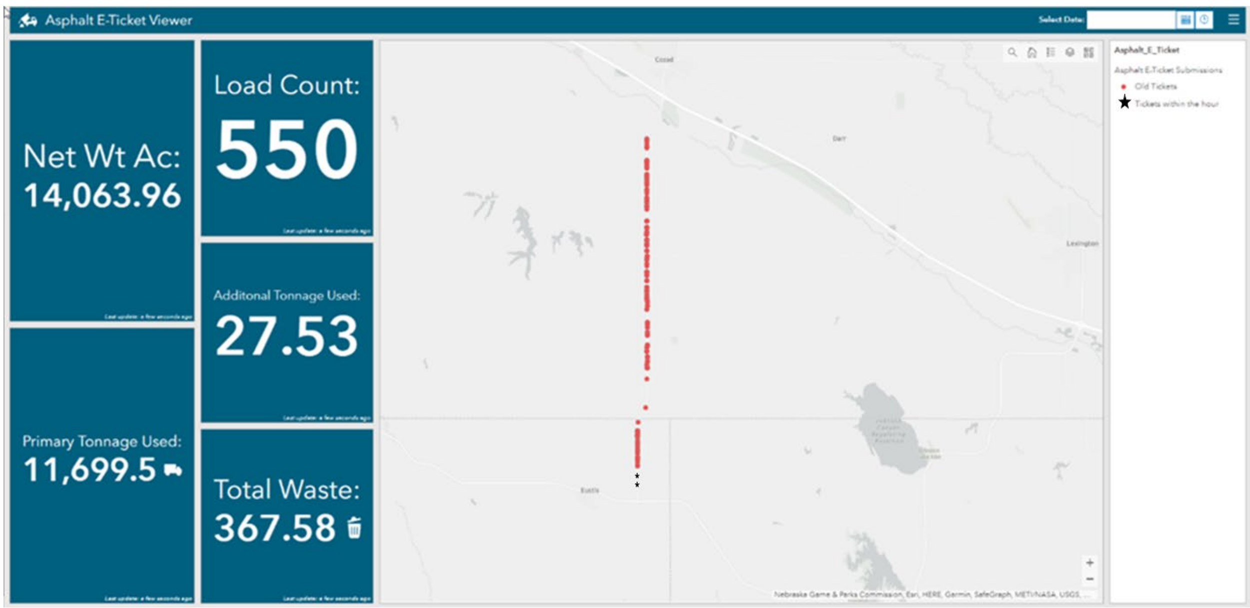
NDOT modeled its customized solution after UDOT's (figure 15) and developed it in-house using their Business Technology Support Division (figure 18). The process begins when a production plant's load-out software generates an e-Ticket in JSON file format that is then sent to a project-specific Web portal with restricted access. The JSON file is fed into an FME software package that extracts, transforms, and loads into the ArcGIS Survey123 mobile app used by inspectors (Esri n.d.b). Inspectors can add notes to the e-Ticket, including delivery location, which is not recorded automatically, as well as mix type and design and overrun or underrun tonnage checks. An e-Ticketing dashboard (figure 19) allows others to track daily progress in material delivery.

Data are stored in the FME and accessible only to NDOT (Safe 2023). NDOT is developing a daily asphalt summary report that can be provided and/or accessed by the supplier/contractor.



© 2022 NDOT. Modified by WSP.

Figure 18. Diagram. NDOT e-Ticket workflow.



© 2022 NDOT. Modified by WSP.

Figure 19. Screenshot. NDOT e-Ticketing dashboard.

Benefits and Costs

NDOT recognized the standard benefits of e-Ticketing, and, in terms of inspection time, it realized the savings of a 1.0 to 1.5 FTE employee cost for a construction inspector. Similar to UDOT, however, NDOT also faced challenges in quantifying the development and maintenance costs of its in-house solution because of the use of in-house personnel for development and licensing costs of software apps procured for enterprise-wide use.

Implementation Experience

Stakeholder Receptivity and Outreach

NDOT recognized that e-Ticketing promotes safety and efficiency, and during the pandemic, the STA facilitated social distancing and contactless activities.

NDOT determined the solution was reliable enough to allow the paper tickets (which have remained the document of record) to accumulate daily at the production plant, and then have the tickets collected and summarized at the end of each day's production.

Internet connectivity challenges remain. Only 40 percent of rural Nebraska has reliable and cost-effective Internet options. Most rural areas have poor cellular connectivity and inadequate broadband coverage. Satellite Internet is a viable option but could be more expensive. Identifying haul vehicles is also a challenge, which may be mitigated by requiring use of vehicle ID plaques.

Midsize and large contractors have been neutral toward the e-Ticketing solution, while small contractors have not been in favor of the process because of the higher plant upgrade costs. Leveraging its longstanding relationship with AGC, NDOT has been meeting with a task force bimonthly to facilitate implementation of e-Ticketing. The task force includes representatives from both the AC and PCC industries. In the bimonthly meetings, NDOT provides updates on pilots; shares lessons learned; discusses challenges, such as Internet connectivity and resistance from third-party haulers; and solicits feedback.

QA

NDOT's e-Tickets include project identification, plant identification, truck identification, load type, weight, and time. The accuracy of e-Ticket data is verified by geofencing around the paver for placement location.

The inspector mobile app includes a "tonnage check" feature that tracks the quantities of each load delivered at the jobsite to detect possible over or under running of material.

The availability of real-time data has allowed inspectors to efficiently track the truck carrying the "random-sample-ton" required for testing by the QA program.

Data Management

NDOT is working on a data standardization plan and intends to implement security standards or policies.

Future Plans

Data sharing with suppliers and contractors is expected to occur via the daily asphalt summary reports. NDOT is also investigating other ways e-Ticket data can be used (e.g., data collection automation, hauling statistics) as identified by the e-Ticketing Task Force.

NDOT is also exploring the deployment of Long Range (LoRa®) Wide Area Network (LoRaWAN®) technologies, which are used by Nebraska's agriculture industry, to overcome Internet connectivity issues. Led by a private sector initiative, Nebraska built its public statewide network of LoRaWAN to facilitate data transfer for in-field crop monitoring on farms in rural areas. LoRa devices are low cost, low power sensors that can handle small packets of data over long distances. These devices are connected to a gateway, which in turn, routes the communication nearby wireless networks located within a range of approximately 10 mi.

SUMMARY OF MINNESOTA DOT PRACTICE

Introduction

MnDOT uses an estimated 3 million tons of asphalt mixtures annually and typically handles 200,000 paper tickets each year. MnDOT started piloting e-Ticketing with two projects in 2018 and has completed more than 83 projects as of October 2022. Presently, MnDOT has been conducting pilots only with asphalt. The agency plans to move forward with ready-mix concrete and aggregates in the future. MnDOT plans to fully implement e-Ticketing in 2025.

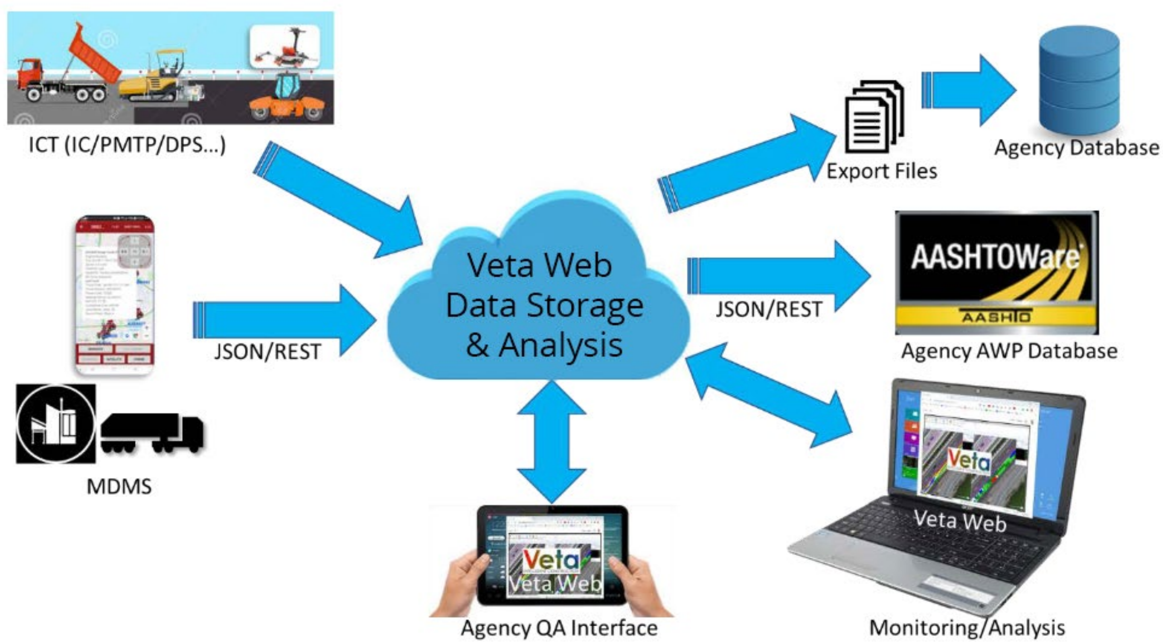
Approaches Implemented

MnDOT's e-Ticketing practice is called MDMS. In the early stages of the pilot, the agency pursued the digitalization of the data typically printed on the paper tickets. However, the agency realized the need for additional data to support the reconciling of daily quantities. Besides the data attributes recorded by the supplier, new data attributes were deemed necessary to support automatic reconciling of quantities. Additional information requirements included those data recorded in the field by the DOT inspector, such as split, waste, or rejected load quantities as well as fleet data, such as time stamps, geocoordinates of point of delivery, and geofence names. Furthermore, the contractors were interested in capturing prevailing wage data digitally for tracking their trucking expenses. In light of additional information needs, and upon consultation with the industry, MnDOT created its MDMS, which captures various types of data to support reconciliation of quantities, determination of truck cycle times and flow rates, compliance checks, and audits (Embacher 2021).

In an effort to fully automate construction inspection, MnDOT has fully deployed IC and paver-mounted thermal profiling along with e-Ticketing. Furthermore, MNDOT requires GPS/GNSS units at the source, on haul vehicles, and on the paver. With e-Ticketing, MnDOT captures e-Tickets to track tonnage of materials deliveries and automate daily reports for measurement and payment. The GPS/GNSS units on trucks are being used to capture the time stamps at the source, entry and exit of trucks at the source, and arrival time at the jobsite. The GPS/GNSS units on pavers track when the paver is stationary (forward motion stops and starts). The time stamps will help track the arrival times of deliveries, waiting times of trucks at the production plant or the jobsite, and stopping times of pavers waiting for loads, which can impact pavement quality.

e-Tickets include temperature measurements collected at the source, truck bed, and jobsite. MnDOT uses a paver-mounted thermal profiler (PMTP) to monitor temperature behind the paver and hopper. This technology uses infrared sensors to produce a thermal profile of the asphalt mat after placement. The IC is an improved compaction process that uses rollers equipped with intelligent construction technologies (ICT), including GPS/GNSS, accelerometers, PMTP, and DPS. The IC enables the real-time monitoring of location, temperature, and stiffness of the underlying asphalt, aggregate base, and subgrade layers of pavements during the compaction process. The stiffness index captured from the IC is an indicator of the densification of the pavement layer. Together, the vertical integration of e-Ticketing with the IC allows for capturing quantities of materials placed along with the placement location mat temperature and compaction stiffness.

MnDOT is making enhancements to Veta, a geospatially enabled intelligent construction data management system, as a secured Web platform to host, analyze, and visualize e-Ticketing and ICT data (MnDOT n.d.). Veta is currently serving to store, map, monitor, and analyze IC, PMPT, DPS, and spot QA test data in near realtime. Figure 20 shows the conceptual architecture of the proposed enhancements to Veta. With the proposed enhancements, the Web-based Veta will serve to receive e-Tickets in standardized file formats and save them in a cloud server, map the locations of trucks serving the paving job for real-time monitoring, estimate arrival and wait times, and calculate material flow rates from plant to jobsite. Furthermore, in conjunction with the e-Ticketing data, the material dump locations will be overlaid on the ICT measurements and other QA data. The agency is currently planning to integrate Veta into AWP. The integration will allow the STA to export e-Ticketing and ICT data from the Veta cloud server to the AWP using APIs and standard file formats. MnDOT plans to complete the integration in 2023.



© 2021 MnDOT. Modified by WSP.
QA = quality assurance; REST = representational state transfer.

Figure 20. Diagram. Conceptual architecture of proposed enhancements to Veta software.

Benefits and Costs

The primary motivations for MnDOT to pursue e-Ticketing were to increase safety for inspectors in the activity areas, improve the logistics performance of delivery vehicles, gain efficiencies from avoiding manual handling of paper tickets, improve the ease of reconciling quantities, and eventually digitalize construction documents.

MnDOT incentivizes the contractor with a single lump-sum payment of $5,000 for collecting, storing, and exporting MDMS data into Veta (MnDOT n.d.).

Implementation Experience and Data Management

MnDOT does not require any specific vendor; however, the agency has had experience with four different vendor-developed options and one supplier-built solution.

MnDOT has established a partnership with the industry on MDMS implementation. The agency conducts regular technology meetings to discuss the status of pilots, contract modifications on projects, and future plans. About one-fifth of contractors have purchased the MDMS systems and are exposed to the technologies. Presently, MNDOT has been selecting projects that have good Internet access. The State's industry representatives have expressed interest in exploring satellite Internet for potential pilots in 2023.

MnDOT has developed a special provision "Quality Management—E-Ticketing (Material Delivery Management System)" for use with MnDOT 2360 plant-mixed asphalt pavement, 2363 permeable asphalt stabilized base, and 2365 stone matrix asphalt. The use of special provisions is not mandatory until the full deployment (MnDOT 2022).

To aid with the MDMS implementation, MnDOT has developed detailed workflows of the MDMS process from the preconstruction setup to the back-office functions. This detailed workflow is a culmination of lessons learned from pilots and extensive outreach with contractors and vendors. The workflows provide detailed descriptions of steps involved in the following phases of the MDMS delivery process (Embacher 2021):

- **Preconstruction process.** The work activities include tasks to be undertaken by the agency and contractors during the STA's preconstruction phase its training for MnDOT personnel. The agency tasks typically include setting up Veta for the project, ensuring that pay items will be imported correctly, and creating geofences. The contractor tasks include setting up the load-out software at the production plant to facilitate data transmittal; installing and ensuring Internet connectivity; establishing truck IDs; entering plant information in the MDMS; and setting up geofences at the source, transmittal, and project locations and establishing their naming conventions.

- **Process at source.** The work activities at the source or production plant include entering hauler data, capturing data on truck entries and exits into the geofence of the plant location, loading trucks, and issuing tickets, and importing data into the contractor MDMS by using the Veta user interface.

- **Material delivery process.** The work activities during the delivery process include capturing data on trucks entering and exiting the project geofence and materials deliveries and conducting independent field verifications. Independent field verification must be performed for the first 10 loads and material and for each 1,000-ton lots thereafter. The MnDOT inspectors should review the source data on the MDMS ticket and verify that all required data attributes are complete and accurate. The inspector will compare the estimated quantity of material delivered by truck to the quantity entered into the MDMS.

- **Data transmittal.** The MDMS data are transmitted to Veta through an API in JSON format or exported into Veta in other formats. The inspectors can also download data in dbase ASCII, CSV, Excel spreadsheet files, or text from the proprietary software and exported into the Veta platform. Some inspectors are still using their own spreadsheets to handle the tickets.

- **Back-office activities.** At the end of the workday, MnDOT personnel will undertake activities, including comparing independent field verification data with those data contained within the final MDMS data export; reconciling quantities using source-, fleet-, agency-, and contractor-related data attributes; and conducting labor compliance and civil rights audit reviews.

Future Plans

MnDOT is targeting for full MDMS deployment by 2025 or 2026. The agency plans to conduct pilots with ready-mix concrete in 2023 and with paving concrete and aggregates in the future. The agency also plans to develop draft specifications for ready-mix concrete and aggregates in future.

MnDOT plans to create spreadsheets to assist with digital reconciliation of quantities using MDMS data in 2024 and automate this process in AWP in 2027 or later. The agency is also exploring the development of a Web version of Veta to integrate all MDMS-related data in a standardized format. In addition, the STA is also planning to integrate MDMS data and analysis to its AWP and other information systems.

MnDOT has also been leading the development of the AASHTO provisional standards for AASHTO. More information on data standardization and MnDOT's efforts are presented in chapter 5.

SUMMARY OF ALABAMA DOT PRACTICE

Introduction

The Alabama DOT (ALDOT) has implemented e-Ticketing pilot projects because of a growing demand for materials inspection with fewer staff members, along with a desire to improve the safety of its construction inspection operations. ALDOT has also equipped field staff with mobile devices (iPads). In 2018, the STA duplicated the typical paper ticket with an electronic version in an initial set of pilots for asphalt delivery. ALDOT has also piloted e-Ticketing for PCC. Through contract modifications, the agency added an e-Ticketing special note to projects so that ALDOT could be sure the contractor and material supplier were well-equipped to handle the new approach using e-Ticketing.

In its initial pilot, ALDOT implemented a COTS solution (FleetWatcher by Earthwave) selected by the contractor. Earthwave provided the software setup and training for all parties and conducted additional training and field support, as needed. Other projects have used Command Alkon and HaulHub as the vendor Web portals and DOTSlip as the mobile app.

As of spring 2022, ALDOT is developing a Web portal and API, with the support of HaulHub, to receive tickets electronically from any supplier or supplier's vendor solutions. The suppliers have the flexibility to select an e-Ticketing product of their choice to meet their needs. ALDOT is only interested in receiving the ticket information through its own portal.

The required data should include the following elements:

- Name of the contractor and material producer.
- Project number and county.
- Truck number.
- Contract item number and item name.
- Date and time of loading.
- Gross, tare, and net weights.
- Weighmaster's signature (can be electronic).
- Any additional information as required of the contractor or material producer for participation as a qualified source as given in the department's "materials, sources and devices with special acceptance requirements" manual unless furnished on a separate applicable bituminous material certificate of compliance.

e-Ticket data are stored locally on a personal computer, and e-Tickets are not geolocated in GIS.

Benefits and Costs

ALDOT identified the following benefits, although it has not yet quantified them:

- Reduced paper documentation.
- Time savings in review and consolidation of material quantities.
- Readily available material quantity information.
- Safety benefits.
- Real-time material tracking.
- Production tracking.

No cost data were available because ALDOT makes e-Ticketing incidental to the bid items.

Implementation Experience

Stakeholder Receptivity and Outreach

For the ALDOT case study, inspectors were pleased with the improved safety of their work environment from e-Ticketing because they can conduct their work while being protected from traffic and backing vehicles (traveling in reverse gear) to unload mixtures at the pavers. By being situated behind the paver and overseeing the asphalt mat, they can better inspect the supplied and placed material. Worksite efficiency also increased by eliminating the need for manual ticket taking in areas where inspectors frequently had to navigate around vehicles and equipment and climb up to the drivers. ALDOT management appreciates having access to data not normally collected on paving projects from paper tickets.

Although a few contractors had some initial reservations because of preferences for existing methods and data use, overall, the pilots were well received, and contractors have welcomed the ability to track deliveries and optimize hauling. There was also some initial pushback from material haulers and internal staff member, in part from concerns over connectivity at production plants where load-out systems may not be easily connected to the Internet.

Specifications

ALDOT would like to net economies of scale by applying a single e-Ticketing solution and does not want to train inspectors in multiple software platforms serving the same purpose. However, without specifying a sole-source product, achieving a single approach and not repeatedly paying for a solution is challenging. Simultaneously, costs are associated with to getting a production plant online and implementing a software solution, so it seems appropriate for the contractor to share in the expense. Nonetheless, ALDOT is investigating the steps necessary for moving from a special note approach to a standard specification.

QA

ALDOT collected both e-Tickets and paper tickets during their pilot projects. A comparison of e-Tickets with cohort paper tickets indicated that e-Ticketing has resulted in fewer data inaccuracies and calculation errors.

Data Management

e-Ticket information and some location data are downloadable as a CSV file. ALDOT has concerns about the security of CSV files, however, and whether that file type or the data altogether would satisfy records or source documentation and retention policies. Potentially not complying with a policy or standard that specifically references paper tickets is also a challenge. ALDOT currently requires weighmaster seals and stamped documentation of aggregate sources, so the full transition to an e-Ticket-only system would have to include a solution for this requirement. The agency has no plans for implementing security standards/policies for e-Ticketing data.

Future Plans

ALDOT is investigating how to integrate e-Ticket data into its construction administration system seamlessly to improve the contractor payment process and to use the data to understand and improve pavement performance. Although the focus will remain on asphalt until a more standardized approach can be applied, ALDOT is considering applying the e-Ticketing approach to aggregates and concrete.

SUMMARY OF TENNESSEE DOT PRACTICE

Introduction

Tennessee DOT (TDOT) has been using e-Ticketing on its interstate pavement resurfacing projects (approximately 20 projects in 2021) by using a combination of in-house and vendor-developed solutions. The solutions provide either a digital photograph or a scan of the ticket, or they generate a standalone e-Ticket transmitted to a cloud and shared with TDOT. e-Ticket data are stored in TDOT's CMS, AASHTOWare® Site Manager™ (AASHTO n.d.).

TDOT maintains a list of Qualified e-Ticketing Software Products (Tennessee State Government 2022). Providers on the list are asked to provide a demonstration of their e-Ticketing platform. TDOT ensures that it meets all specifications outlined in Special Provision 109ETAS *Electronic Ticket Delivery System for Asphalt* (Tennessee State Government 2021). This requirement has been included in the Request for Proposals (RFP) as an incidental item. The cost is built into the unit price of asphalt tonnage. Cohort paper tickets are not required by the specification.

Inspectors can handle technology solutions from multiple vendors through technology solution-specific training provided at a preconstruction meeting. Inspectors are given individual log-in criteria at that time. An inspector must be familiar with multiple systems if contractors choose to use different platforms within the inspector's area.

The e-Ticket process records location information at specific points and includes the following information:

- Mix type and design.
- Mix properties (before placement).
- Admixtures and modifiers used.
- Inspector notes.

e-Tickets are used to verify materials delivered to the project, and TDOT pays the contractor based on the documented weights submitted.

Benefits and Costs

TDOT does not collect data on the e-Ticketing costs to the contractor nor the costs that are passed to TDOT. The STA has not quantified any time-saving options for the work of inspectors.

Implementation Experience

Stakeholder Receptivity and Outreach

TDOT had to overcome some stakeholder pushback, Internet connectivity issues, and data privacy concerns. Nonetheless, midsize and large contractors and TDOT staff members have viewed e-Ticketing extremely positively. Material suppliers are also in favor, despite concerns from those who rely on third-party haulers who might not be receptive to using GPS/GNSS-based technologies.

Specifications

TDOT maintains an e-Ticketing committee. The committee developed the SP109ETAS specification for asphalt and is developing e-Ticketing specifications for other materials (concrete, aggregates, etc.) (Tennessee State Government 2022). The committee members also review the products for inclusion on TDOT's qualified e-Ticketing software products list (Tennessee State Government 2022).

QA

Verification of quantities within the e-Ticketing system has not changed from the process applied to paper tickets. TDOT requires routine proof-of-scale calibration, and all weights must be certified by a Tennessee-certified public weigher. All quantities must also be verified by actual spread rates and planned quantities. Mix designs are confirmed by comparing the expected mix design associated with the project in Site Manager with a sample. Project offices receive notifications from Site Manager when a mix design has been approved and is associated with a contract.

Data Management

Data management procurement language that outlines the extent of stakeholder (i.e., TDOT inspections staff, contractors, suppliers) access to the e-Tickets is included in the RFP. TDOT's specification requires tamper proofing of the e-Ticketing system to prevent unauthorized altering of loadout scale data (Tennessee State Government 2021). System users are required to have a unique login and password.

Future Plans

TDOT would like to expand e-Ticketing requirements to non-interstate projects. The agency has been considering applying e-Ticketing to aggregates, millings, and concrete.

SUMMARY OF WASHINGTON STATE DOT PRACTICE

Introduction

WSDOT uses the contractors' solutions for e-Ticketing. Contractors are permitted to use whatever vendor they determine can provide the required information per Section 1-09.2 (1) of WSDOT's 2022 standard specifications (WSDOT 2022). Prior to mid-2020, contractors used e-Ticketing on a voluntary basis. Contracts let since January 2021 require e-Ticketing. WSDOT requires e-Ticketing for asphalt (all projects regardless of tonnage), concrete (for project less than 500 yd^3), and aggregates. e-Ticketing is procured by including it as a contract bid item or incorporating it into other bid items as incidental.

WSDOT does not actually receive digitalized data; instead, the agency receives a PDF report with the required ticket information or it accepts a PDF scan of the actual paper ticket. However, WSDOT is currently planning to procure a COTS product to receive e-Tickets through an API-enabled Web portal.

The specifications require the contractor to develop a plan detailing their e-Ticketing system. The plan must be submitted to WSDOT for review and approval. The plan identifies alternative methods for manually capturing and electronically delivering data if Internet service is unavailable. WSDOT continues to have a project engineer designated as the “receiver” on the construction site to log deliveries on a weight ticket log that can be used to reconcile daily summary reports.

The specifications also require the contractor to provide onsite technical assistance and training during setup to all parties requiring access to the e-Ticket information.

Benefits and Costs

WSDOT has identified the following benefits from e-Ticketing: reduced paper documentation, time savings in review and consolidation of material quantities, readily available material quantity information, and safety benefits. However, a return on investment (ROI) has not been calculated.

Implementation Experience

Stakeholder Receptivity and Outreach

WSDOT staff members and inspectors view e-Ticketing favorably. While midsize and large contractors have been positive about using e-Ticketing, small contractors have reacted negatively. Similarly, large suppliers have embraced e-Ticketing, while small suppliers have been resistant. WSDOT participates in industry partner teams (e.g., American Concrete Pavement Association, AGC of Washington, Washington Asphalt Pavement Association) meetings during which e-Ticketing is discussed. This participation effort has contributed to industry buy-in.

There were some initial concerns from smaller suppliers about additional costs associated with implementation. When WSDOT began applying e-Ticketing by special provision, the provision included a lump sum pay item for e-Ticketing. When the specifications were incorporated into the 2022 standard specifications, no pay item was included, requiring costs to be absorbed into the item being ticketed as an incidental cost.

Specifications

WSDOT’s 2023 standard specifications address e-Ticketing in section 1-09.2(1) (WSDOT 2023). The e-Ticket requires the following information as a minimum:

- Data of haul.
- Contract number.
- Contract unit bid item.
- Unit of measure.
- Identification number of hauling vehicle.

- Weight delivered:
  - Net weight in the case of batch and hopper scales.
  - Gross weight, tare (a.m. and p.m. minimum) and net weight in the case of platform scales (tare may be omitted if a tare beam is used).
  - Approximate load out weight in the case of belt conveyor scales.

The location of material delivery will be appended by field staff. The specification also includes additional requirements for the contractors:

- Internet connectivity at the material source.
- Developing a contingency plan when Internet connectivity is lost at the construction jobsites.
- On-site technical assistance and training during the initial setup.
- Verification checks of loading scales.
- Description of how partial loads will be tracked.

QA

Procedures for e-Ticketing verification include scale certification and scale verification checks. Loads received are reconciled daily with loads delivered. The inspector documents and verifies materials deliveries by vehicle number, time, and location.

Data Management

Currently, WSDOT stores e-Ticketing data predominantly in local project files. The agency has not yet established an interface to the Materials Tracking Program, Electronic Content Management Portal, or SharePoint (Microsoft 2023b). This lack of integration can be attributed to receiving only PDFs with the required information rather than actual electronic data from the e-Tickets. Nonetheless, WSDOT is planning to procure an e-Ticketing portal system to receive e-Tickets from suppliers' plant loadout systems.

Since April 2020, WSDOT began the implementation of Oracle Primavera Unifier to enable the enterprise-wide management of contract administration, construction documentation and related workflows (Oracle 2023). WSDOT has developed multi-year work plans to complete the full-scale migration from the legacy system to the Unifier environment.

Future Plans

WSDOT is currently planning to procure a COTS product for an API-enabled Web portal in 2023 and 2024, while the suppliers would be allowed to use an e-Ticketing solution of their choice. The Web portal will allow WSDOT to receive e-Ticket data in digitalized format, which in turn, will be integrated into the Unifier workflows to automate payment processing. WSDOT plans to implement the portal solution to asphalt mixtures, concrete, and aggregates. WSDOT hopes to apply e-Ticketing to other bulk items such as water, steel, and emulsion.

CHAPTER 5. E-TICKETING IMPLEMENTATION

INTRODUCTION

The number of STAs implementing e-Ticketing has been steadily rising since the first pilot in 2015. Both the adoption of e-Construction technologies and the need for contactless delivery have arguably contributed to the increased interest in e-Ticketing among the STAs. Transitioning toward paperless delivery in highway construction has enabled the STAs to recognize the benefits that their e-Construction initiatives have delivered and harness the advancements in their IT infrastructure.

Many STAs, with no past e-Ticketing experience, are increasingly exploring or planning for piloting such systems, whereas those STAs with previous piloting experience are restrategizing their e-Ticketing programs. Multiple pilot projects have allowed these STAs to verify the proof of concept, recognize benefits, discover best practices, and identify risks and challenges related to the deployment of these tickets.

The initial sets of pilot projects have largely relied on the vendor products that were primarily designed for contractor fleet management. However, in part because of the proliferation and dependence on vendor products, the lessons learned from the pilots have encouraged some STAs to rethink their e-Ticketing strategies toward a more vendor-neutral approach. In this context, this chapter presents a discussion on various implementation aspects of e-Ticketing. This discussion is based on the analysis of the case study interviews, an assessment of practice landscape, and a review of emerging technological opportunities.

IMPLEMENTATION PLANNING

Implementation planning is useful for STAs to outline the high-level requirements, make actionable decisions, and progress toward the adoption of e-Ticketing. As with any new program or adoption, the planning process should focus on the key four critical success factors: strategy, people, technology, and processes. The implementation plan, which entails the following requirements, should address these critical success factors for e-Ticketing:

- **Formulate a Strategy.** The STAs should begin by strategically thinking about the alignment between the outcomes of e-Ticketing and the overall business objectives of the agency. The STAs should establish a targeted end state for e-Ticketing. In other words, gaining a good understanding of what the agency wants to do with e-Ticketing data and how e-Ticketing will align with the organization's digital strategy would help establish the target end state. This thinking process begins by recognizing the business problems that e-Ticketing offers to solve in both near term and long term. Chapter 3 presents a detailed discussion on the strategic value of e-Ticketing.

- **Decide What to Do**. To achieve the targeted end state, an STA can adopt an incremental approach to gradually advance from piloting through full deployment or "leapfrog" through concurrent or bypassing developmental stages of the implementation path.

The STAs with previous e-Ticketing experience have adopted an incremental approach to advance through the stages. These STAs have generally started with a few pilots per year with one material type, typically asphalt or ready-mix concrete, few geographical locations or districts, and a vendor product. Leveraging their pilot experience, these agencies have gradually scaled up to expand the number of pilot demonstrations, material types, and geographic coverage. For instance, Iowa DOT, which conducted its first e-Ticketing pilot in 2015 for asphalt and in 2018 for concrete, plans to deploy e-Ticketing on 400 projects in 2023. PennDOT, which conducted its first pilot in 2017, plans to fully deploy e-Ticketing on all its projects by 2024. Alternatively, an STA can also start concurrent pilots, such as pilots with more than one material type and multiple districts, to expedite the time to full deployment.

An agency seeking to begin its pilot should start by defining the scope of the pilot by asking the following questions:

- For what material types should e-Ticketing be used?
- What is the current process with paper tickets? How would e-Ticketing impact this process? What process steps would require a business process review or change?
- How should the pilots be procured?
- What technology should be considered? What technological features are required?
- Do the pilot locations have adequate internet coverage?
- What are the common implementation needs, risks and challenges?
- What are the stakeholder needs? How should their expectations be managed?

Although the pilot projects allow for case-based assessments for fine-tuning their approach, the STAs should also think about aligning their capabilities with their vision and plan for advancing toward the envisioned end state. On the pathway to mainstreaming e-Ticketing, the STAs could evaluate their piloting plans with respect to various dimensions:

- Horizontal integration, which entails expanding the scope of e-Ticketing to other material types and geographic regions or districts, location types (e.g., areas with good versus poor Internet coverage).
- Technological maturity, which includes the type of e-Ticketing technology, data integration, policies and procedures for data management, application of e-Ticketing data beyond simply capturing quantities or weights, and Internet coverage.
- Process maturity, which includes the development of specifications and validation procedures, for e-Ticketing.

- Process chain integration, which includes other upstream and downstream processes along the supply chain from material source certification to acceptance of material placement. e-Ticketing focuses on a single function of the supply chain, which is to digitalize the data associated with material hauling and delivery. Similar opportunities are available to digitalize upstream processes leading up to the storage of materials and vehicle loading at the plant. The information exchanged between the supply chain stakeholders can be aggregated through digitalization. Examples of such information from upstream processes for digitalization include bills of lading; source certifications of materials, such as liquid asphalt, steel, and cement, at a raw material source or an intermediate supply chain point; statements and proof of compliance; sampling; and testing data and inspection reports. Regarding paving materials placement, the following information can also be digitalized:
    - Inspection, sampling, and testing.
    - Supplementary technologies such as IC, smoothness, and densities.
    - Geotagging of QA sampling and testing results.

Table 29 presents a maturity matrix of implementation dimensions that STAs could use in evaluating their pilot plans.

Table 29. Maturity levels of implementation dimensions.

Dimension	Starting	Developing	Advancing
Material types	One material type	Three material types (asphalt mixtures, aggregates, and concrete)	Most material types
Number of projects	Preselected projects	Multiple pilots in all districts and location types	All districts and location types
e-Ticketing technology	e-Tickets	Digitalized tickets	Object-based tickets
Data integration	e-Ticketing data are stored electronically	e-Ticketing data are integrated with DOT information systems	e-Ticketing data are transmitted between the DOT and supplier information systems
Use cases	Only daily summaries are calculated	Automation for limited use cases	Automation for many use cases
Data management	Standard policies and procedures are followed	Ad hoc policies and procedures are established for e-Ticketing	Policies and procedures are established for e-Ticketing
Internet coverage	Dependence on offline capabilities or paper tickets	Piloting of alternative technologies	Mainstreaming of alternative technologies

Dimension	Starting	Developing	Advancing
Specifications	Use of special provisions or developmental specifications	Draft specifications under review and revisions	Adoption in standard specification books
Verification	Follows the processes developed for paper tickets. Cohort tickets may be collected	Process is modified for e-Ticketing with or without technology	Process is validated for e-Ticketing
Process chain integration	Focus is only on material quantities	e-Ticketing is integrated with other tasks in the process chain	Full integration of all tasks in the process chain

Making a Business Case

Chapter 3 presents a business case for e-Ticketing. Both the strategic value and benefits of e-Ticketing are discussed in detail.

Acquiring Stakeholder Support

Both the AASHTO nationwide survey and follow-up interviews indicate a high level of receptivity among contractors and suppliers, with the exception of small suppliers. Timely and proactive stakeholder engagement is imperative to obtain buy-in and support. To obtain internal buy-in, the STAs conducted periodic meetings with construction staff from districts or regions to communicate the agency's goals. With external stakeholders, the STAs have conducted regular outreach to the industry before and during the pilots.

Many STAs have joint committees with the members in industry groups, including AGC and American Road and Transportation Builders Association (ARTBA), with whom the STAs meet periodically to discuss the critical issues and future plans relating to the highway construction industry. The STAs have successfully used this forum to communicate the agency's plan and connect with the industry, educate them, discuss timelines, and address key challenges. Some agencies have established a task force to support e-Ticketing implementation.

Assessing Field and Technology Readiness

The STA should have a plan to conduct a readiness assessment for the deployment of e-Ticketing in pilot projects. The field and technology readiness assessment should focus on the following needs:

- Use of mobile devices, such as tablets and smart phones, by construction inspectors. Contingency plans are needed to address issues relating to short battery life, sun glare, offline data entry, and data synchronization issues.

- Adequate Internet coverage in the project work areas. Contingency plans are needed to address issues relating to poor connectivity and intermittent coverage such as Wi-Fi hotspots, cellular boosters, and satellite providers.
- Verification procedures to assure accurate determination of quantities on e-Tickets for source documentation and payment.
- Training for construction inspectors and contractor field personnel, including QC technicians.

The STAs also should plan for how to receive the electronic data, store them, and integrate the data with information systems for future use.

Implementation Barriers

The STAs should be cognizant of the challenges relating to the following implementation steps:

- Selecting an e-Ticketing approach and acquiring solutions.
- Coordinating stakeholders, including small suppliers.
- Establishing a piloting plan, including project selection, procurement approach, and standards and specifications.
- Ensuring field and technology readiness, including hardware and software requirements, and internet connectivity.
- Managing data, including selecting data attributes and receiving, storing, and using data.

Using the commonly recognized challenges, summarized in table 18, as a starting point, the STAs can assess gaps in their capabilities, screen for potential barriers and risks, and identify mitigation measures and contingency plans. The STAs can also consider devising a knowledge capture plan to document best practices and lessons learned from their pilots and transfer them to their future efforts to build maturity.

IMPLEMENTATION CONSIDERATIONS

Stakeholder Outreach

Three types of nongovernmental stakeholders were contacted to solicit their perspectives on e-Ticketing implementation landscape, benefits, and challenges.

National e-Ticketing Task Force

The National e-Ticketing Task Force is an industry group composed of STA representatives, producers, suppliers, and contractors (National e-Ticketing Task Force 2022). The goals of the task force are to promote the deployment of e-Ticketing technologies, champion change, and facilitate standards. The salient points of the interview the research team conducted with this task force are as follows:

- The transition from paper tickets to e-Tickets is about efficiency, transparency, reduction in errors, and better utilization of the workforce.

- The ROI in e-Ticketing depends on the extent of the paperless process. Many tangible benefits are associated with e-Ticketing; however, the benefits will continue to evolve over time as digitalization generates newer and greater benefits with expanding use cases.

- The key success factors for implementation include:

    - Spread general awareness.
    - Share the success stories.
    - Start slowly with pilots, progressively expand, and sustain the success.
    - Partner with the industry.
    - Learn from the failures and recalibrate the implementation approach.

- The construction industry supports the replacement of paper tickets with e-Tickets. In addition, the industry believes that the key stakeholders will benefit from getting e-Ticketing information back from the STAs.

- Given the diversity of STA practices, the standards for e-Ticketing are necessary. The AASHTO Provisional MDMS standards (Embacher 2021), which are currently adopted by MnDOT, offer a pathway for standardizing data requirements at the national level.

e-Ticketing Vendors

The research team interviewed three vendors to understand the evolving technological landscape of e-Ticketing. The interviews confirmed the findings presented in chapter 2, and the vendors shared the information on the STAs with which they worked. The conversations with the vendors are summarized as follows:

- The business model of e-Ticketing vendors is evolving and diverging into two approaches:

    - STA-focused—Some vendors focus on providing technological solutions to assist STAs with achieving their e-Ticketing requirements, including receipt, storage, and archiving of e-Tickets.

    - Contractor/supplier-focused—Some vendors focus on serving contractors and suppliers to assist with their functions, such as backend integration, trucking company and fleet management, and payroll and accounting automation.

    - Many vendors, according to the vendor interviewee(s), are obligated to select between these two business models.

- The diversity of STA special provisions and vendor products has created inconsistencies. For example, when neighboring STAs have different requirements, the suppliers doing business in multiple States face challenges in understanding and meeting their diverse requirements satisfactorily.
- The industry needs consistency, and, therefore, will greatly benefit from the data standards that AASHTO's provisional MDMS standards have developed (AASHTO Forthcoming).

Suppliers

The research team conducted interviews with four suppliers to capture their experience, perspectives on benefits and challenges, and expectations. Three of the four suppliers run small production plants, while the fourth supplier runs noncomputerized mobile plants.

Supplier 1. The production plant operator supplies asphalt and aggregates to commercial and government projects in Kentucky. The firm handles about 50,000 tickets per year. The STA projects account for one-half of the supplier's business. The supplier has had an e-Ticketing project since 2020. To date, the supplier has observed small wins with e-Ticketing but recognized that the benefits will accrue once the firm stops printing paper tickets. The biggest challenges for this supplier are the lack of clarity on the data requirements, complexity with the setup, and difficulty with transferring tickets to the STA on time. The supplier recognized the challenges during the transition phase.

Supplier 2. The supplier operates a drum plant and a batch plant in central Tennessee. The batch plant is run occasionally on an as-need basis. The supplier produces an estimated 100,000–200,000 tons of asphalt mixture per year. The STA's paving projects account for 90 percent of the supplier's business. The supplier is in the process of integrating the load-out systems for e-Ticketing. The supplier selected a vendor that focused only on the e-Ticketing aspects, not fleet management. The cost is estimated to be $10,000–$15,000 annually. The supplier recognized the costs of doing e-Ticketing are generally high but noted that costs for other vendor solutions were higher.

The supplier was apprehensive about how the State DOT will use electronic data and whether the DOT would be committed to doing e-Ticketing in the long run. In other words, the supplier expressed concerns that the investments made in the e-Ticketing solution should not be futile. Connectivity could be an issue when TDOT goes with full implementation of e-Ticketing. TDOT requires automatic capturing of the time stamp at the delivery location. However, the rural areas in Tennessee have poor Internet connectivity. With e-Ticketing, the supplier can invoice and bill TDOT quicker. However, in the supplier's opinion, the benefits of e-Ticketing for a small company operating 20–30 trucks will be minimal compared with large companies. The supplier recognized that safety is a significant benefit with nighttime paving and high-volume roadways but noted the safety benefits might not be significant for rural projects.

Supplier 3. The supplier operates five asphalt mixture plants of varying ages in Alabama. They did not have an issue with their newest plant. However, the supplier's other three plants went through an update of loadout systems. Upgrading the supplier's oldest plant would cost

$25,000–$30,000. The supplier is yet to decide on when to upgrade it. The supplier also operates quarries. The STA's projects account for 50 to 60 percent of the supplier's total business. The supplier currently supplies asphalt for nine jobs, including three active ALDOT projects.

The supplier was one of the first companies to do e-Ticketing for ALDOT in the initial phase of piloting. To date, the supplier has completed 25–30 e-Ticketing projects. The supplier is working with ALDOT to integrate their systems with ALDOT's e-Ticketing portal. Issues with Internet connectivity and areas with no cellular signal or dead zones made it challenging to access data in realtime, but the suppliers managed it with the offline mode. Initial concerns about how the data would be used were resolved through communications with the STA.

Overall, e-Ticketing has been advantageous for the supplier, with the benefits outweighing the costs. The ease of access to information was helpful for field personnel and plant operators. The supplier had to upgrade the outdated plant loadout systems, but such upgrades were necessary regardless of e-Ticketing. The investments made in tracking devices have been useful to the construction company. However, the supplier noted that the concerns of small suppliers should be considered in light of the expenses for plant upgrades, the share of STA projects, and licensing costs.

Supplier 4. The production plant operator supplies concrete in Iowa. The supplier operates 39 mobile concrete plants in rural locations, of which 4 are not computerized. Some of their plants are not operated throughout the year, but occasionally on an as-need basis. The STA projects represent less than 5 percent of their total business. The supplier does not yet use e-Tickets, but a single project is currently underway.

The high cost of production plant upgrades is a deterrent to small suppliers. The investments required for (noncomputerized) plant upgrades are estimated to range between $300,000 and $400,000. The cost burden for plant upgrades is not justifiable, particularly, if the share of STA projects is a tiny fraction of the total business portfolio. Furthermore, the expenses associated with satellite-based Internet connection solutions, as an alternative to lack of Internet connectivity, adds significantly to the cost burden. The supplier feels that a Federal assistance program to assist small suppliers would be helpful to cover the investment costs for upgrades and Internet solutions.

Internet Connectivity

Inadequate or lack of Internet connectivity is a significant implementation issue for e-Ticketing. In the AASHTO survey, both groups of STAs, with and without e-Ticketing experience, identified this issue as the foremost technical challenge. Although the amount of data to be received is small, the construction inspectors cannot receive e-Tickets in realtime in areas with intermittent, poor, or no Internet connectivity.

To date, most STAs have managed this issue by selecting projects in areas where Internet connectivity is adequate. Some STAs required offline capabilities for e-Ticketing solutions in areas with intermittent Internet connectivity. This option is more suitable for projects where the coverage is adequate for most of the work areas. In areas with connectivity limitations, inspectors can opt for the offline mode, use paper tickets for verification, and sync the tickets when Internet connectivity is available.

The North Carolina DOT (NCDOT) has adopted an alternative, using quick response (QR) codes, to manage Internet connectivity issues. First, NCDOT developed an in-house Web portal that accepts e-Tickets from suppliers through an API. The e-Ticket data are stored in the STA's in-house CMS called Highway Construction and Materials System (HiCAMS). The electronic data are then relayed from HiCAMS to DOT inspectors in the field with the aid of mobile devices and software apps. The field notes recorded by the DOT inspectors are sent back to HiCAMS (NCDOT n.d.). This process flow works seamlessly in areas where Internet connectivity is adequate. In addition, NCDOT developed QR codes to enable information exchange in areas with poor Internet connectivity. The QR codes, which are embedded with ticket data in an electronic format, are printed on suppliers' paper tickets. The QR codes are then scanned by STA inspectors using the mobile app in the field. Figure 21 presents a sample paper ticket with a printed QR code used on an NCDOT paving project. The STA has also developed a software app that captures the data stored in the QR code and transmits them to the SharePoint site for document management.

WARNING: SEE BACK OF TICKET FOR SPECIFIC PRODUCT WARNINGS.

Murphy, NC

TICKET # 38275

Date: 6/16/21 Time: 10:30 am Plant:

Customer: **Job:** 1902 **Phase:** 1

Carrier: 999 None- Pickups **PO #:** **Zone:** 0

Truck ID: 55 **Axles:** **Product:** 49886 NC S9.5C With Rap

License: **JMF:** 18-0797-151 **Temp:**

*** Simulated Delivery ***

		Max Legal Gross	Gross	Tare	Net
1 /LDS Today	15 /LDS To Date	56,500 Lb	40000*lb	20900 lb	19100 lb
9.55 Tn	138.43 Tn		20.00*Tn	10.45 Tn	9.55 Tn
8.66 Mg	125.58 Mg	* = Manual Weight	18.14*Mg	9.48 Mg	8.66 Mg

Weighmaster:

Lab: 06/30/2021

Weighmaster:

Received By:

LDS = loads delivered to site; Rap = reclaimed asphalt pavement; Tn = tons; Mg = megagram; JMF = job mix formula.

Figure 21. Screenshot. QR codes on a sample NCDOT ticket.

Several existing and emerging technology alternatives, which have the potential to overcome Internet connectivity limitations, are available on the market:

- Geosynchronous equatorial orbit satellite Internet is available in rural areas. However, the latency rate is relatively high, around 600 ms, and the connectivity could be spotty in densely wooded areas.

- Low Earth orbit satellite Internet is an emerging alternative. Because of its proximity to Earth, Internet signals are faster and have latency rates as low as 40 ms. Montana DOT demonstrated the feasibility of using low Earth orbit satellite Internet in project locations with poor or no cellular coverage with limited pilots.

- Signal boosters could be a workable alternative in areas with weak cellular fourth-generation technology (4G), 5G, and long-term evolution signals. Signal boosters, which use an external antenna and amplifier unit installed on a vehicle or office, receive weak signals from a base station and amplify them to improve connectivity. Signal boosters cannot work in areas with no signals.

- The combination of BLE and LoRaWAN devices is emerging as a choice for Internet of Things. LoRaWAN is suitable for low bandwidth, LoRa communications with low power requirements. In comparison, cellular and wireless networks require high power requirements despite their high bandwidth and long-range communication capabilities. BLE technology, which is commonly used in personal area networks, such as wearable devices, is suitable for short-range transmittals of data to mobile phones at approximately 1 MB/s. With their low power requirements, the combination of BLE and LoRa make them ideal for e-Ticketing apps (Tinella 2021).

- Wi-Fi towers entail a series of towers that extends Internet service received from a wired connection over a LoRa wirelessly. One of the towers receives Internet service through a wired connection, which then relays Internet data over radio airwaves to an adjacent Wi-Fi tower. In this sequence, a Wi-Fi tower receiving Internet data transmits the same data to the next receiver Wi-Fi tower wirelessly until the destination location is reached. Wi-Fi towers are capable of transmitting data up to 60 mi. However, the paired Wi-Fi towers must have an unobstructed view to enable wireless transfer.

Federal Aid Requirements

The STAs have been using the same verification process for both paper tickets and e-Tickets. Most agencies have been collecting both types of tickets to establish reasonable confidence in the accuracy of e-Tickets.

The verification procedures for e-Tickets should conform to the following Federal regulations and directives, as a minimum:

- "Determination and Documentation of Pay Quantities" (CFR 2013a). This regulation requires STAs to have procedures in place to ensure that the quantities of completed work are determined accurately and on a uniform basis. In accordance with this clause, the source documents, including receipts or tickets of delivered materials, used in the determination of quantities for measurement and payment would serve as records.

- FHWA Technical Memos "Computerization of Construction Record" and "Electronic Security" (Van Ness 1989; Weseman 1993). The collection and retention of construction records electronically must be acceptable and trustworthy from an engineering, audit, and legal standpoint. These records must allow for verification of pay quantities. These records should enable the reconstruction of the chain of events that occur on a project.

- "Retention Requirements for Records" (CFR 2013b). The initial source documents should be retained for a specific period in accordance with Federal and State requirements.

The STAs use the following procedures to verify e-Tickets:

- Confirm that the e-Tickets contain the actual quantities of materials delivered, used, and rejected by the inspectors.

- Ensure data reliability at the production plant by using approaches such as plant inspection, certified weigh masters, load scale calibrations, and cameras.

- Establish that the comparison of time stamps at origin and destination for the fleet have been included during transmittal to ensure reasonableness of cycle times and detect unauthorized delays. Some agencies require GPS data and geofences for this purpose.

- Verify the delivery of a truck load at the delivery point as printed on an e-Ticket and track yield rates. Iowa DOT has been recently piloting the use of paver-installed cameras for automatic detection of truck license tags. Some vendors are developing BLE-based technologies to enable automatic verification of truck loads at the jobsite; however, these solutions are under development or deemed experimental.

In addition, the e-Tickets require the implementation of adequate data security measures during generation, transmittal, and receipt to ensure trustworthiness from engineering, audit, and legal standpoints. The e-Tickets must ensure security (protection against breach), integrity (protection against tampering), accessibility (audit trails and protection against unauthorized access), reliability (completeness, accuracy, and protection against equipment malfunction) and storage (data retrieval and protection against data losses).

Data Management

According to the *Data Management Book of Knowledge,* data management is "the business function that develops and executes plans, policies, practices, and projects that acquire, control, protect, deliver, and enhance the value of data and information" (Dama International 2017). Four functions of e-Ticketing are discussed in this section: ingestion and storage, integration, standards, and security.

Data Ingestion and Storage

In the earlier phases of e-Ticketing, the STAs received e-Tickets through the contractors' vendor solutions. In light of the challenges associated with multiple vendor products, the STAs have increasingly opted for receiving electronic data directly using a Web portal. The Web portal receive data, via a REST API, either from the contractor's vendor cloud or directly from the supplier loadout systems. The API enables secure transmittal of e-Ticketing data between the two systems. JSON and CSV are the commonly used file formats for data transmittal. Figure 22 shows the schematic of data transmittal between the supplier loadout systems and the Web portal. In the current practice, the data flow has been one way from the supplier loadout systems and the Web portal. However, the APIs also enable two-way communication between the suppliers and the DOT.

When the electronic data are received directly from a Web portal using an API, the STAs use different approaches to ingest the data. Some agencies directly download e-Ticketing data and daily summaries from the vendor cloud in their preferred file formats. The STAs use a temporary solution, such as an Excel spreadsheet or CSV files, to extract data from the vendor cloud or mobile app. For instance, Iowa DOT uses a spreadsheet to extract data fields, such as quantities, latitude and longitude, slumps, etc., from the e-Tickets for further processing and use.

The STAs export data into a document management system, such as InfoTech Doc Express or SharePoint, or place the data in the cloud. For instance, DelDOT receives electronic data through the Boomi translation API, which is hosted by a vendor, exports the data to the Oracle Unifier system. The STAs, such as Massachusetts, may also store the data in an enterprise geodatabase. UDOT uses an FME to streamline the ingestion of nonspatial (e.g., quantities) and spatial data into the agency's enterprise geodatabase.

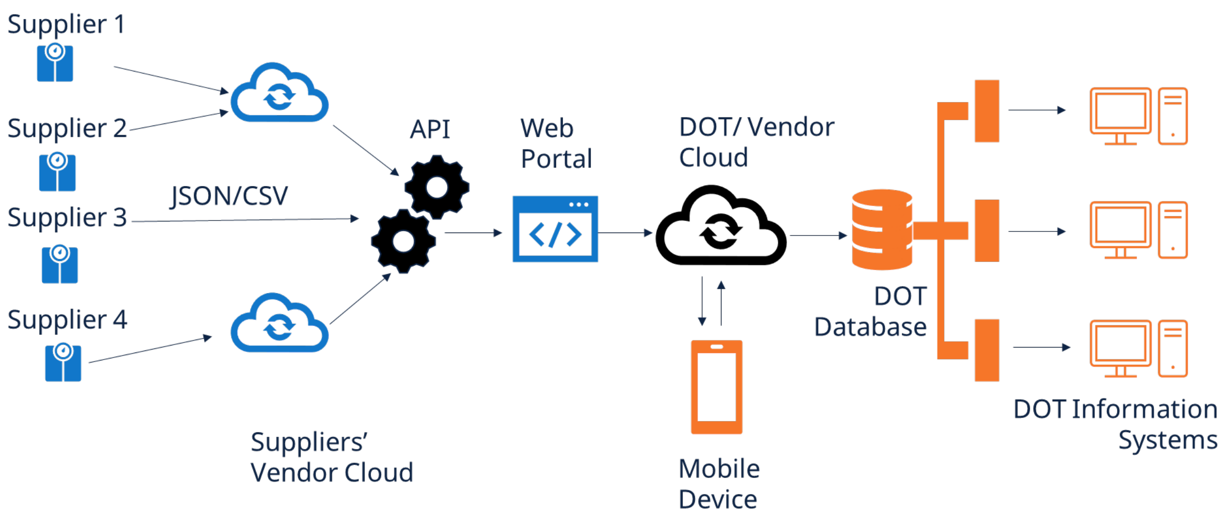


Figure 22. Diagram. Schematic of data transmittal from supplier loadout systems to DOT Web portal.

Data Use Cases and Integration

Most STAs, as indicated by the AASHTO survey and interviews, are yet to integrate e-Ticketing data into their CMS. However, these agencies have future plans to integrate data in their information systems and use them for various applications. To date, only DelDOT has integrated e-Tickets into the Unifier system for automating payment processing. As described in chapter 4, DelDOT creates ticket packages using e-Tickets in the Unifier system to streamline the process of paying contractors for approved quantities of materials.

In the absence of real-world examples, table 30 presents a list of use cases for possible future integration with the DOT information systems. These use cases, which are based on the business functions of an agency, will create value for various internal organizational units by satisfying their information requirements at project, asset, or organizational levels. Currently, this information resides in paper forms across multiple documents, digitized forms as PDFs and scans in document management systems, or digitalized formats in data siloes. The integration of e-Ticketing data with other information systems, such as CMS, construction materials management systems (CMMS), laboratory information management systems (LIMS), pavement management systems (PMS), and bridge management systems (BMS), is necessary to unlock them for wider use. Furthermore, by mapping business functions with information requirements, the use cases provide a basis for specifying data attributes that need to be collected through e-Tickets and processed, stored, analyzed, and exchanged with internal DOT information systems.

Table 30. e-Ticketing use cases and integration opportunities.

Data Exchange Types	Use Cases
e-Tickets to CMS	Creating daily work reports
e-Tickets to CMS	Automating payment processing
e-Tickets to CMS	Automating price adjustments of liquid asphalt and other materials

Data Exchange Types	Use Cases
e-Tickets to CMS	Reconciling actual quantities with contract quantities
e-Tickets to CMS	Auditing payments made to subcontractors and disadvantaged business enterprises
e-Tickets to CMMS/LIMS/ PMS/BMS	Conducting forensic analysis of asset failure
e-Tickets to PMS/BMS	Developing better asset condition forecasting models
e-Tickets to CMMS/LIMS	Conducting performance evaluation of mix designs and material sources
e-Tickets to CMS	Calculating paving flow rates to manage paving operations
e-Tickets to CMS	Auditing prevailing wages
e-Tickets to CMMS/LIMS	Calculating the statewide usage of recycled materials
e-Tickets to CMS	Linking placement and quantities data to optimize production and construction schedules
e-Tickets to CMS	Supplementing QA programs
e-Tickets to CMS/CMMS/ LIMS/PMS/BMS	Evaluating contractor performance based on asset performance
e-Tickets to CMS	Reporting construction progress
e-Tickets to CMS	Creating an electronic proof of work

Three opportunities are further illustrated in this section using AWP construction management as an example. The AWP includes a suite of software products that tracks, reports, and analyzes information throughout the contract and construction phases of a project. Site Manager and Construction & Materials™ are the client/server-based and Web-based apps of the AWP software, respectively.

Opportunity 1—DWRs and Quantities

This opportunity includes four use cases:

- Creating daily work reports
- Reconciling actual quantities with contract quantities.
- Automating payment processing
- Automating price adjustments of liquid asphalt and other materials

The e-Ticketing data can be fed into the AWP to enable automated reporting of DWR summaries in the construction module of the software. The e-Ticketing can push location and quantities information to the “DwrWorkItem” table of the DWR. The completed, in-placed, and approved quantities can be further used to automate the generation and processing of invoices. These quantities can also be used to automatically calculate price adjustments to liquid asphalt, fuel, and other materials.

The integration would allow the ingestion of data inputs from the supplier using e-Tickets. The integration could also allow for automatic validation of inputs on the e-Tickets because such inputs can be directly imported from the AWP. Table 31 presents the list of data attributes that can be ingested into the AWP from the suppliers and those attributes that can be validated by suppliers for data consistency purposes.

Table 31. Data attributes for DWRs.

Data Attributes From Plant/Supplier to AWP	Data Attributes That Must be Consistent With AWP
• Production plant number/plant name/GPSLat and GPSLong • Hauler name • Truck/vehicle ID • Gross/net/tare weights • AC mix temperatures • Concrete slump and water	• Job number/project number • Project name • Source/material/mix design ID • Plant/supplier/hauler ID • Unit price • Ticket acceptance/rejection • Quantities—daily running • Quantities—posted to date • Price adjustments • Current payment made to date

GPSLat = GPS latitude; GPSLong = GPS longitude.

In addition to the "DwrWorkItem," other opportunities for integrating the electronic data with other tables in the AWP to facilitate updating, reporting, and validating stored data are listed in table 32.

Table 32. Additional opportunities for integration with AWP for daily reporting.

AWP Module	AWP Table	Description
CIVILRIGHTSANDLABOR, CONSTRUCTION	CONTRACT	Contract
CIVILRIGHTSANDLABOR, CONSTRUCTION	CONTRACTOR	Contractor
PRECONSTRUCTION	REFPRICEINDEX	Reference price index
PRECONSTRUCTION	REFPRICEINDEXADJUSTMENT	Reference price index adjustments
PRECONSTRUCTION	REFPRICEINDEXHISTORY	Reference price index history
CONSTRUCTION	MIXDESIGN	Mix design
CONSTRUCTION	MIXDESIGNSMFMI	• Mix design source • Material facility • Material ID
CONSTRUCTION	MIXDESIGNTYPE	Mix design type
CONSTRUCTION	PAYMENTESTIMATEITEM	Payment estimate item

AWP Module	AWP Table	Description
CONSTRUCTION	DWRACCEPTANCERECORD	DWR acceptance record
CONSTRUCTION	DWRITEMPOSTING	DWR item posting
CONSTRUCTION	DWRITEMPOSTINGQUANTITY	DWR item posting installed quantity

Opportunity 2—Validating Subcontract/DBE Payments

This opportunity focuses on auditing the payments made by the prime contractor to subcontractors and disadvantaged business enterprises. The information furnished in the e-Tickets can be used to automate or support the validation of payments to be made by the prime contractor to subcontractors, suppliers, truck drivers and others in the supply chain. This information can also be used to support the auditing of payments made by the prime contractor to disadvantaged business enterprises (DBEs). Table 33 and table 34 present lists of data attributes from e-Tickets that can be ingested for validating payments to supply chain entities and the corresponding tables of the AWP.

Table 33. Data attributes for supply chain payments.

Data Attributes From Production Plant/Supplier to AWP	Data Attributes That Must be Consistent With AWP
• Subcontractor/production plant/supplier name • Hauler name • Number of loads to date	• Job number/project number • Project name • Subcontractor/plant/supplier/hauler/vendor ID • DBE certified • DBE committed amount • Committed amount DBE credit • DBE good faith ID

Table 34. Opportunities for integration with AWP for supply chain payments.

AWP Module	AWP Table	Description
CIVILRIGHTSANDLABOR, PRECONSTRUCTION	DBECOMMITMENT	DBE commitment
CIVILRIGHTSANDLABOR, PRECONSTRUCTION	DBECOMMITMENTSUMMARY	DBE commitment summary
CIVILRIGHTSANDLABOR, PRECONSTRUCTION	DBECOMMITMENTWORKITEM	DBE commitment work item
CIVILRIGHTSANDLABOR, PRECONSTRUCTION	DBECOMMITMENTWORKTYPE	DBE commitment work type
CIVILRIGHTSANDLABOR, PRECONSTRUCTION	DBEGOODFAITHEFFORT	DBE good faith effort
CIVILRIGHTSANDLABOR, PRECONSTRUCTION	DBEGOODFAITHEFFORTWT	DBE good faith effort work type

AWP Module	AWP Table	Description
CIVILRIGHTSANDLABOR, CONSTRUCTION	SUBCONTRACT	Subcontract
CIVILRIGHTSANDLABOR, CONSTRUCTION	SUBCONTRACTITEM	Subcontract item
CIVILRIGHTSANDLABOR, CONSTRUCTION	TRUCKING	Trucking
CIVILRIGHTSANDLABOR, CONSTRUCTION	TRUCKINGTRUCKTYPE	Truck type

Opportunity 3—Integration with AASHTOWare Pavement ME Design and AASHTOWare Bridge Design to Create Digital As-Builts

AASHTOWare® Pavement ME Design™ and Bridge Design™ are the standard software apps used by many STAs for pavement and bridge designs, respectively (AASHTO n.d.c; AASHTO n.d.d). Both design apps use a plethora of material inputs for use in the design and analysis calculations. The e-Ticketing data can be used to conduct performance analyses of the newly constructed pavement or bridge structures using as-constructed material properties with the aid of the design programs. The as-constructed material properties that are relevant to the performance analyses of assets include actual proportions of ingredients used in the materials in place, such as asphalt binder content, cementitious materials, and amount of water in concrete; field and laboratory measurements of quality characteristics, such as temperature, strength, and density; and the as-built thickness measured or estimated using yield rates. Such performance analyses, which will be a part of digital as-builts, will help capture the effects of construction quality and techniques in asset condition forecasting. Note that the construction data are seldom incorporated into the forecasting models that predict the future condition of assets.

This opportunity is contingent on the e-Ticketing processes' ability to include or append other data captured in the process chain, including mix design properties, sampling and test results produced for source certifications, production plant and field QA, and construction or digital as-builts information and data.

The following pertinent data fields are included in the AASHTOWare Pavement and Bridge Design software:

- Unit weight, effective binder content, air voids, layer thickness, asphalt binder for characterization of asphalt layer properties.

- Unit weight, layer thickness, PCC coefficient of thermal expansion, cement type, cementitious material content, water-to-cement ratio, aggregate type, PCC strength, and modulus for characterization of PCC layer properties.

- Percent steel (or steel quantities) and bar diameter for characterizing PCC layer in continuously reinforced concrete pavement design.

- Unit weights, gradations, Atterberg limits, dry densities, moisture content, layer thickness, standard penetration testing, strength and modulus testing, and stabilizer contents for characterization of base and subgrade layers.

- Strength, grade, and other properties demonstrating adherence to material requirements for bridge design, such as timber, steel, admixtures, and elastomeric materials.

Data Standards

As presented in table 14, the AASHTO national survey captured information on the commonly collected data types on e-Tickets.

Although some commonalities among the data attributes collected by the STAs exist, no national guidelines are currently in place to standardize the data attributes on e-Tickets. National efforts are currently underway on data standardization. AASHTO has instituted an expert task group (ETG) to develop the MDMS. Led by MnDOT—with support from the AASHTO Committee on Materials and Pavements; Committee on Construction; and Data Management and Analytics Committee's Joint Subcommittee on Data Standardization—the MDMS ETG includes a vast network of 270 members from FHWA, STAs, vendors, material suppliers, universities, consulting firms, contractors, and associations (Embacher 2021).

The MDMS has provisional standards for the delivery of asphalt: AASHTO PPXX *Standard Specification for Material Delivery Management System* (AASHTO Forthcoming). The MDMS specification for asphalt mixtures, concrete, and aggregates has been approved through the balloting process and is expected to be published in 2023.

The MDMS presents a library of data attributes for asphalt mixtures, concrete, and aggregates, grouped under five phases or data categories of the material delivery process from production plant load out to delivery at the jobsite and verification:

- Source—Data generated by the load-out software at the production plant.

- Loading and delivery event—Data related to date, time stamps, and delivery locations.

- Testing and contract administration—Data recorded by the DOT and contractor on mix design ingredients, sampling and test results, acceptance/rejection of tickets, split loads, and wasted material quantities.

- Independent field verification—Data recorded by the DOT on field verification.

- Hauler—Data related to the delivery vehicle and the driver.

The complete list of data attributes is published in *Standard Specification for Material Delivery Management System* (AASHTO Forthcoming).

Further investigation was performed to compare the common data attributes currently captured on e-Tickets with MDMS data requirements. Sample e-Tickets gathered from Iowa, Utah, Pennsylvania, and Washington were used to identify the commonly captured data attributes.

Table 35 presents a comparison between MDMS data requirements and data attributes currently captured on e-Tickets. The table indicates that most MDMS data attributes of interest are currently captured, except for temperature at source and destination. However, independent field verification data are being captured indirectly because field verification provides a basis for acceptance or rejection of tickets in accordance with the STA's procedures.

Table 35. Comparison of MDMS attributes and commonly collected data attributes.

MDMS Data Attributes Currently Captured on e-Tickets	MDMS Data Attributes Yet to Be/Less Frequently Collected on e-Tickets
• Project and contract information • Production plant and supplier information • Contractor information • Date and time • Weigh master • Hauler, delivery truck, and truck driver • Source location and time • Destination location and time • Gross/tare/net weights • Total daily loads • Total daily tonnage • Material/mix type • Material properties • Ticket status • DOT inspector approval	• Scale ID • Silo ID • Truck overweight • Truck driver classification • Transit routing geofences—entry and exit • Contractor split load • Wasted material weight • Contractor field notes • Independent field verification • Material temperature at source and destination • Air temperature at source and destination

Data Security

The e-Ticketing process uses Cloud-based storage solutions, apps, and devices to create, share, track, document, and archive quantities, sources, and delivery information in electronic or digital format among multiple stakeholders. Although electronic storage and transfer of ticketing data simplifies how materials are handled in the construction process, potential security issues need to be considered when sensitive data are handled in a digital environment.

Security Risks With e-Ticketing

Potential security risks can occur at each data input and transfer point in the e-Ticketing process. These risks stem from unauthorized access—by personnel within the STA who are unauthorized to view certain items or by those individuals who breach devices or apps and are unaffiliated with the STA and its contractors—to data stored locally or in the cloud, the apps that create and process e-Tickets, and the devices that access those apps:

- **Devices.** One potential risk is unapproved persons gaining access to devices that contain apps and files with information that is sensitive. Therefore, limiting access to sensitive information to approved DOT devices and implementing proper protection to those devices is crucial. Devices used throughout the e-Ticketing process may include, but are not limited to, the following mechanisms:
    - Devices used by suppliers or producers to generate tickets via the ticketing system.
    - Devices used to track GPS/GNSS locations of vehicles and materials.
    - Devices used by DOT personnel and contractors to access ticket data.
    - Mobile devices used for ticket acceptance and electronic proof of delivery and to capture jobsite testing and inspection data.
    - Devices used to access CMS to which e-Ticket data may be shared or uploaded.
- **Apps.** Without proper password protection, unauthorized users who gain access to STA applications can view or tamper with sensitive e-Ticketing data. Protecting applications against both unauthorized access and unauthorized editing control of e-Ticketing data is important.
- **Cloud Service Providers.** Cloud service providers supply the necessary encryption, as required by industry or Federal standards, to protect sensitive e-Ticketing data stored in the cloud. However, without proper controls in place, such as password protection or ID authentication, the data may still be vulnerable to unauthorized access. Within an organization, if the levels of access are not protected, users who are only meant to view certain cloud-based information may be able to view sensitive information beyond their classification or tamper with information that was submitted by an authorized user during the e-Ticketing process. The following situations are the two main threats to cloud-based e-Ticketing data:
    - Accounts having access to data that they are not required to access (i.e., a user is given an account but should not have permissions to view certain items).
    - Cloud-based apps lacking protection due to access to the devices on which they are stored (i.e., cloud-based files are left open/logged-in on an unlocked device, and a user without authorization to view the files gains access to device).
- **Breadcrumb GPS/GNSS Tracking.** Breadcrumb tracking of vehicles used throughout a construction project helps keep track of where vehicular assets are located. This tracking can improve the efficiency of deliveries of necessary construction materials and help identify whether anything is offtrack in the delivery process. Breadcrumb tracking is optional and is usually performed with hard-wired tracking devices, cigarette lighter adapters, or in-vehicle mobile apps on smartphones. Potential risks in breadcrumb tracking include the following situations:

- Unapproved personnel viewing the vehicle, the vehicle contents, and sensitive driver information.

- The tracker storing unnecessarily sensitive driver identifiers, such as their Social Security numbers or payroll information. Asking what data are being collected, who is allowed to view which parts of the data, whether the data are encrypted or anonymized as needed, and whether the transmittal of data from the GPS/GNSS tracking device to the database is secure is important.

Security Standards in e-Ticketing

This section presents a discussion on current standards set by the Federal Government and other directly relevant stakeholders in the data and digital services industry to ensure e-Ticketing data protection. STAs may have their own policies and procedures. However, a review of the Federal standards can help STAs establish their own standards or compare their standards with the Federal standards:

- **FHWA Cybersecurity Program (CSP):** Many of the general data security standards outlined in the *FHWA CSP Handbook* can also apply to e-Ticketing contractors because they are often working in collaboration with FHWA or directly using apps created by DOT vendors to transmit sensitive information (FHWA 2017). The *FHWA CSP Handbook* outlines procedures to protect this information, which can include GPS/GNSS tracking information and even employee Social Security numbers and pay rates. In combination with general best practices in data protection, such as those outlined by cloud service providers, the FHWA CSP guidelines create a framework for ensuring a secure transition from paper to e-Ticketing in construction services.

- **Federal Information Processing Standards (FIPS)**. Developed by the National Institute of Standards and Technology (NIST) in accordance with the Federal Information Security Management Act, the FIPS standards provide guidelines for adoption and use by Federal departments and agencies (Office of the Federal Register (OFR), National Archives and Records Administration (NARA) 2002). Of the 11 FIPS standards available on the NIST website, the following three standards are considered most relevant for e-Ticketing (NIST 2022):

    - FIPS 140-2, *Security Requirements for Cryptographic Modules*—FIPS 140-2 sets the minimum or default standard for data encryption in products that are used by Federal agencies to process nonclassified information (NIST 2002). To be FIPS compliant, the security algorithms implemented in hardware or software must align with the security features described in FIPS standards.

- FIPS 199, *Standards for Security Categorization of Federal Information and Information Systems*—FIPS 199 establishes security categories for information (data) and information systems from the standpoint of security objectives: confidentiality, availability, and integrity (NIST 2004). The security categories are based on assessing potential impacts that any security-related adverse event, such as a loss of confidentiality, integrity, or availability of such information or information system, would have on individuals, assets, and operations of an organization. Table 36 summarizes the potential impact definitions for each security objective. The STAs could use these criteria to evaluate the security category for e-Ticketing data and information systems.

- FIPS 200, *Minimum Security Requirements for Federal Information and Information Systems*—FIPS 200 provides minimum requirements for protecting a federally owned information system in the event of a security breach (NIST 2006).

Table 36. FIPS 199 criteria to define impacts for security categorization (NIST 2004).

Security Objective	Low Impact	Moderate Impact	High Impact
Confidentiality: Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information (44 U.S. Code § 3542).	Unauthorized disclosure of information could be expected to have a limited adverse effect on organizational operations, organizational assets, or individuals.	Unauthorized disclosure of information could be expected to have a serious adverse effect on organizational operations, organizational assets, or individuals.	Unauthorized disclosure of information could be expected to have a severe or catastrophic adverse effect on organizational operations, organizational assets, or individuals.
Integrity: Guarding against improper information modification or destruction, including ensuring information nonrepudiation and authenticity.	Unauthorized modification or destruction of information could be expected to have a limited adverse effect on organizational operations, organizational assets, or individuals.	Unauthorized modification or destruction of information could be expected to have a serious adverse effect on organizational operations, organizational assets, or individuals.	Unauthorized modification or destruction of information could be expected to have a severe or catastrophic adverse effect on organizational operations, organizational assets, or individuals.

Security Objective	Low Impact	Moderate Impact	High Impact
Availability: Ensuring timely and reliable access to and use of information (44 U.S. Code § 3542).	Disruption of access to or use of information or an information system could be expected to have a limited adverse effect on organizational operations, organizational assets, or individuals.	Disruption of access to or use of information or an information system could be expected to have a serious adverse effect on organizational operations, organizational assets, or individuals.	Disruption of access to or use of information or an information system could be expected to have a severe or catastrophic adverse effect on organizational operations, organizational assets, or individuals.

Federal Risk and Authorization Management Program (FedRAMP®). The U.S. Government created FedRAMP under the Federal Cloud Computing Initiative to ensure adequate protection and security of Federal data in cloud systems (General Services Administration n.d.). FedRAMP provides a standardized approach to security assessment, authorization, and continuous monitoring for cloud products and services. FedRAMP applies the guidelines and procedures outlined in the NIST Special Publication (SP) 800-53, *Security and Privacy Controls for Federal Information Systems and Organizations*, as the basis to standardize security and privacy requirements for cloud systems (Ross 2013). To offer cloud-based solutions to Federal agencies, the CSPs must go through an assessment to demonstrate compliance with FedRAMP standards and requirements. Upon compliance, the CSPs can extend cloud services to multiple agencies within the Federal Government. Using this standardized approach, the individual governmental agencies do not need to perform a security assessment of every compliant CSP separately, and thus, this method facilitates a faster, cost-effective adoption of cloud-based services. Many State and local governmental agencies have based their RAMPs on the NIST SP 800-53 standards, and, therefore, these agencies may adopt the same standards into their cloud systems.

Training

The e-Ticketing practice landscape is evolving. Many vendor products are available on the market, while the STAs are customizing their Web portals to meet their needs. In this context, training is necessary to ensure that both DOT and contractor personnel are instructed adequately on the set-up tasks before progressing to the construction activities, on-field operations, and back-office functions. Contingent on the agency and contractor needs, the training can focus on the following activities, as a minimum:

- Hands-on training on the use of vendor products.
- Hands-on training on the use of mobile devices and software apps.
- Viewing data, making data entries, and making decisions in realtime about material types, including appending videos and pictures, composing inspector notes, making acceptance and rejection decisions, and recording split loads, wasted loads, etc.

- Verifying procedures by material types.
- Creating geofences and GPS data, if applicable.
- Performing back-office functions.
- Handling Internet connectivity outages.
- Addressing common problems and troubleshooting.

Many agencies offer training to the DOT personnel. These STAs have created a plethora of training products. For example, Iowa, Indiana, and Pennsylvania have created videos, instruction books, and PDF-use guides that can be available on demand. In addition, many vendors offer training on their products. Training should also be optimally timed, that is, training should not be conducted too early or too close to the construction start date. Many STAs also use pilots as a hands-on training opportunity for their inspectors.

CHAPTER 6. CONCLUSIONS AND FUTURE TRENDS

The practice of e-Ticketing has gained and continues to gain momentum among many STAs. More than two-thirds of the STAs have used e-Ticketing on their paving projects, and other STAs are exploring or planning e-Ticketing pilots. Several STAs are advancing toward full-scale implementation in the next 3–5 yr. To date, most STAs have focused on asphalt mixtures, aggregates, and concrete. In the coming years, the STAs are anticipated to expand e-Ticketing to other material types—such as liquid asphalt, asphalt millings, and deicer liquids and salts—that are delivered by a dump vehicle and paid for based on quantities.

Since the first pilot in Iowa in 2015, e-Ticketing practices have evolved considerably. The implementation landscape has become diverse, with STAs considering e-Ticketing for a variety material types, vendor products and in-house solutions, and implementation approaches. The STAs have also gained an understanding about the factors that slow down pilot programs and can identify their data needs better now. Breadcrumbing truck locations is no longer required because of the stakeholder pushback, while the STAs have found alternatives to meet their verification needs. Although digitized forms, such as photographs and digital scans, of paper tickets were widely used in early 2020s, the STAs have gained a better understanding of the source document requirements and have transitioned to digitalized forms.

In light of the challenge with handling multiple contractor-provided e-Ticketing solutions, the STAs are increasingly opting for a Web-based portal approach that accepts electronic data from authorized suppliers, regardless of which vendors they use. One key different approach is apparent between the “material delivery” and “fleet management” aspects of the practice, with the STAs focusing more on the former and the contractors and suppliers on the latter. In this context, these differences in implementation approaches emphasize the necessity to document effective e-Ticketing practices across the country.

Both the AASHTO national survey and the follow-up interviews indicate emerging trends that are common to most agencies. Presently, the STAs with no previous e-Ticketing experience are focused on starting their pilots, while those STAs that are further down the path to implementation are focused on conducting repeated demonstrations and fine-tuning their approaches for full-scale deployment. To date, the STAs have completed the pilots with willing partners through a contract modification or a separate bid item to ensure fairness among bidders and have generally selected project locations with good Internet connectivity. This progressive and selective approach has allowed the STAs to demonstrate the value of e-Ticketing and build a high level of confidence among stakeholders.

Moving forward, the STAs indicate that stakeholder receptivity, particularly for small suppliers, and Internet connectivity are critical success factors for full-scale implementation. The STA–industry partnership has been mutually beneficial, and many agencies have established a formal task force or committee on e-Ticketing to communicate goals and future plans, share experiences, and discuss challenges. Although the industry is generally receptive, the States agree that e-Ticketing should not be made mandatory on all the projects in the short term to ensure the contractors and suppliers have adequate time to complete their system integrations. Small suppliers have been less receptive to e-Ticketing because of concerns with the high cost of system upgrades, licensing costs, lack of Internet connectivity, and lower volumes of STA work. The lead adopters—including PennDOT, Iowa DOT, and DelDOT—have been proactively working to get the small suppliers with limited IT resources connected to their Web portal. However, connecting suppliers with no Internet connection and those with a small share of the DOT business is still a challenge.

The STAs are also exploring cost-effective alternatives to use in areas with poor or no Internet connectivity, such as low Earth orbit satellite, cell signal boosters, and low-power and short-range technologies. The limited pilots by the STAs have demonstrated the feasibility of low Earth orbit satellite Internet and cell signal boosters.

The STAs have made little progress on electronic data management. To date, the STAs have focused on the receipt and ingestion of electronic data for storage in a database or document management system. None of the STAs have completed the integration of ticket data into their CMS. However, the lead adopters—such as PennDOT, Iowa DOT, DelDOT, and MNDOT—plan to integrate their data in the next 2–5 yr. Currently, the States are using the electronic data for automating daily totals and preparing daily summary reports, and their planned data integrations will enable additional use cases soon. Relative to data security, most STAs have adopted their agency's enterprise-wide standards, policies, and procedures for e-Ticketing.

The specifications of the STAs are evolving for e-Ticketing. Their special provisions typically focus on general requirements for an acceptable e-Ticketing system, data transmission procedures, data requirements, Internet connectivity requirements, and payment. After GPS requirements were discontinued, many STAs began relying on time stamps and geocoordinates of source and delivery locations for verification. Alternative technologies, including Iowa DOT's electronic visual proof of delivery and BLE devices, are also on the horizon.

At the current development phase of e-Ticketing, the STAs have understandably opted for data attributes that are of most interest and use to them. The lack of commonality, consistency, and arguably, inadequacy in the data requirements among the STAs creates challenges for vendors. The MDMS presents a library of data attributes and data specifications that STAs could consider adopting to meet their information needs. However, when the STAs eventually transition to adopting the AASHTO MDMS standards, the existing challenges with verification and inconsistencies are likely to be resolved successfully (AASHTO Forthcoming). In summary, as demonstrated in this report, the practice of e-Ticketing is rapidly and continually evolving and holds great promise for continuing and achieving future successful implementation.

APPENDIX A. AASHTO NATIONWIDE E-TICKETING SURVEY

The AASHTO Committee on Construction conducted a survey in the spring of 2021 to understand the e-Ticketing state of the practice. The survey gathered information from the STAs on the status of adopting e-Ticketing technologies, costs and benefits, data management practices, QA, future plans, and perspectives on the challenges associated with implementation. This appendix presents the details of the responses provided by the individual respondent agencies in table 37 to table 76.

Table 37. Question 1: Do you currently use e-Ticketing?

State/Territory	Response
Alabama	Yes
Alaska	No
Arizona	No
Arkansas	Yes
California	No
Colorado	No
Connecticut	Yes
Delaware*	No
Florida	Yes
Georgia	Yes
Hawaii	No
Idaho	No
Illinois	Yes
Indiana	Yes
Iowa	Yes
Kansas	Yes
Kentucky	Yes
Louisiana	No
Maine	Yes
Maryland**	No
Massachusetts*	No
Michigan	No
Minnesota	Yes
Mississippi	Yes
Missouri	Yes
Montana	No
Nebraska	Yes
Nevada	No
New Hampshire	No
New Jersey	No

State/Territory	Response
New Mexico	No
New York	No
North Carolina*	No
North Dakota	No
Ohio	Yes
Oklahoma*	No
Oregon	Yes
Pennsylvania	Yes
Puerto Rico	No
Quebec, Canada	No
Rhode Island	No
South Carolina	No
South Dakota	No
Tennessee	Yes
Texas	Yes
Utah	Yes
Vermont	Yes
Virginia	Yes
Washington**	Yes
West Virginia	Yes
Wisconsin	Yes
Wyoming	No

*Delaware, North Carolina, and Oklahoma DOTs responded that e-Ticketing was not in use at the time of survey, which was conducted in the Spring of 2021; however, these States began using e-Ticketing after the survey was complete.
**Maryland DOT indicated only digital photographs and scans of a paper ticket were used. At the time of the survey, the agency did not actively pursue e-Ticketing pilot projects, although the DOT accepted some form of e-Tickets when contractors provided them voluntarily.

Table 38. Question 2: What mode(s) of e-Ticketing are you currently implementing or have already implemented?

State/Territory	Digital Photograph /Scan of a Ticket	PDF	Standalone e-Ticket Transmitted to a Cloud and Shared With DOT	e-Ticket Directly Received by a DOT Information System	Others (Please Specify)
Alabama	—	—	Yes	—	—
Arkansas	Yes	Yes	Yes	—	—
Connecticut	—	Yes	—	—	Custom Web platform developed by Tilcon Connecticut Inc.

State/Territory	Digital Photograph /Scan of a Ticket	PDF	Standalone e-Ticket Transmitted to a Cloud and Shared With DOT	e-Ticket Directly Received by a DOT Information System	Others (Please Specify)
Florida	Yes	Yes	Yes	—	We have many options, including e-Ticketing systems developed by vendors and one system developed by our turnpike office.
Georgia	—	Yes	Yes	—	—
Illinois	Yes	Yes	Yes	—	—
Indiana	Yes	Yes	Yes	—	—
Iowa	—	—	Yes	—	—
Kansas	—	Yes	Yes	—	—
Kentucky	Yes	Yes	Yes	—	—
Maine	Yes	—	Yes	—	—
Minnesota	—	—	Yes	—	—
Mississippi	—	Yes	—	—	—
Missouri	—	Yes	Yes	—	—
Nebraska	—	—	—	Yes	We are almost ready to select the first pilot project.
Ohio	Yes	Yes	Yes	—	—
Oregon	Yes	Yes	Yes	—	—
Pennsylvania	Yes	Yes	—	Yes	—
Tennessee	Yes	—	Yes	—	—
Texas	—	—	Yes	—	—
Utah	—	—	—	Yes	—
Vermont	Yes	Yes	Yes	—	—
Virginia	—	—	—	—	We currently allow the vendor to use any COTS system that incorporates geofencing into the product.
Washington	Yes	—	Yes	—	—
West Virginia	Yes	Yes	Yes	—	—
Wisconsin	Yes	Yes	—	—	—

—Not applicable.

Table 39. Question 3: Which of the following describes your e-Ticketing approach?

State/Territory	Vendor Developed	Developed In-House	Combination of In-House and Vendor Developed
Alabama	Yes	—	—
Arkansas	Yes	—	—
Connecticut	Yes	—	—
Florida	—	—	Yes
Georgia	Yes	—	—
Illinois	Yes	—	—
Indiana	—	—	Yes
Iowa	Yes	—	—
Kansas	Yes	—	—
Kentucky	Yes	—	—
Maine	Yes	—	—
Minnesota	Yes	—	—
Mississippi	Yes	—	—
Missouri	Yes	—	—
Nebraska	—	Yes	—
Ohio	Yes	—	—
Oregon	Yes	—	—
Pennsylvania	—	Yes	—
Tennessee	—	—	Yes
Texas	Yes	—	—
Utah	—	Yes	—
Vermont	Yes	—	—
Virginia	Yes	—	—
Washington	Yes	—	—
West Virginia	Yes	—	—
Wisconsin	—	—	Yes

—Not applicable.

Table 40. Question 4: Does your e-Ticketing solution(s) record location information?

State/Territory	Yes, at All Points Along the Delivery Vehicle Route With GPS Connection	Yes, But Only at Specific Points (Quarry, Plant, Project, Paver)	No, But Delivery/Dump Location is Noted/Appended by Field Staff	No, the Delivery Vehicles are Not Tracked and Location is Not Recorded
Alabama	Yes	—	—	—
Arkansas	—	—	—	Yes
Connecticut	—	—	Yes	—
Florida	—	—	—	Yes
Georgia	—	Yes	—	—
Illinois	—	—	—	Yes
Indiana	—	—	—	Yes
Iowa	—	—	Yes	—
Kansas	—	—	Yes	—

State/Territory	Yes, at All Points Along the Delivery Vehicle Route With GPS Connection	Yes, But Only at Specific Points (Quarry, Plant, Project, Paver)	No, But Delivery/Dump Location is Noted/Appended by Field Staff	No, the Delivery Vehicles are Not Tracked and Location is Not Recorded
Kentucky	—	—	—	Yes
Maine	—	—	Yes	—
Minnesota	Yes	—	—	—
Mississippi	—	Yes	—	—
Missouri	Yes	—	—	—
Nebraska	—	—	Yes	—
Ohio	—	Yes	—	—
Oregon	—	—	Yes	—
Pennsylvania	—	—	Yes	—
Tennessee	—	Yes	—	—
Texas	—	—	—	Yes
Utah	—	—	Yes	—
Vermont	—	—	Yes	—
Virginia	—	—	—	—
Washington	—	—	Yes	—
West Virginia	—	—	Yes	—
Wisconsin	—	—	—	Yes

—Not applicable.

Table 41. Question 5: What level of adoption would categorize your current e-Ticketing use?

State/Territory	Individual Pilot Projects	Repeating Pilot Projects for Gathering Information and Scaling Up Use	Extensive Use by Special Notes	Extensive Use by Standard (or Supplemental) Specification	Voluntary Statewide Data Collection and Reporting ("Information Purposes" Only)
Alabama	—	Yes	—	—	—
Arkansas	—	—	—	Yes	—
Connecticut	Yes	—	—	—	—
Florida	—	—	—	Yes	—
Georgia	—	—	—	Yes	—
Illinois	Yes	—	—	—	—
Indiana	—	—	Yes	—	—
Iowa	—	Yes	—	—	—
Kansas	Yes	—	—	—	—
Kentucky	—	Yes	—	—	—
Maine	Yes	—	—	—	—
Minnesota	—	Yes	—	—	—
Mississippi	—	—	Yes	—	—
Missouri	Yes	—	—	—	—
Nebraska	Yes	—	—	—	—
Ohio	—	Yes	—	—	—

State/Territory	Individual Pilot Projects	Repeating Pilot Projects for Gathering Information and Scaling Up Use	Extensive Use by Special Notes	Extensive Use by Standard (or Supplemental) Specification	Voluntary Statewide Data Collection and Reporting ("Information Purposes" Only)
Oregon	Yes	—	—	—	—
Pennsylvania	Yes	—	—	—	—
Tennessee	—	—	—	Yes	—
Texas	—	—	—	Yes	—
Utah	—	Yes	—	—	—
Vermont	—	Yes	—	—	—
Virginia	—	—	—	—	—
Washington	—	—	—	Yes	—
West Virginia	—	Yes	—	—	—
Wisconsin	Yes	—	—	—	—

—Not applicable.

Table 42. Question 6: Approximately what is the total number of projects that have used e-Ticketing?

State/Territory	≤5	6–10	11–25	26–50	51–100	≥101
Alabama	—	—	Yes	—	—	—
Arkansas	—	—	—	Yes	—	—
Connecticut	Yes	—	—	—	—	—
Florida	—	—	—	Yes	—	—
Georgia	—	Yes	—	—	—	—
Illinois	—	Yes	—	—	—	—
Indiana	—	—	—	—	—	Yes
Iowa	—	—	—	—	Yes	—
Kansas	Yes	—	—	—	—	—
Kentucky	—	—	—	—	Yes	—
Maine	—	Yes	—	—	—	—
Minnesota	—	—	—	Yes	—	—
Mississippi	—	—	Yes	—	—	—
Missouri	—	Yes	—	—	—	—
Nebraska	Yes	—	—	—	—	—
Ohio	—	—	—	Yes	—	—
Oregon	Yes	—	—	—	—	—
Pennsylvania	—	—	—	—	Yes	—
Tennessee	—	—	Yes	—	—	—
Texas	—	—	—	—	—	—
Utah	—	—	—	Yes	—	—
Vermont	Yes	—	—	—	—	—
Virginia	Yes	—	—	—	—	—

State/Territory	≤5	6–10	11–25	26–50	51–100	≥101
Washington	—	—	—	—	Yes	—
West Virginia	—	—	Yes	—	—	—
Wisconsin	—	—	—	—	—	—

—Not applicable.

Table 43. Question 7: For what materials are you currently using e-Ticketing?

State/Territory	Asphalt	Aggregates	Concrete
Alabama	Paid by weight	—	—
Arkansas	Paid by weight	—	—
Connecticut	Paid by weight	Paid by weight	—
Florida	Paid by weight	—	—
Georgia	Paid by weight	—	—
Illinois	Paid by weight	Paid by weight and volume	Paid by volume
Indiana	Paid by weight	Paid by weight and volume	Paid by volume
Iowa	Paid by weight	Paid by weight	Paid by volume
Kansas	Paid by weight	—	—
Kentucky	Paid by weight	Paid by weight	Paid by weight
Maine	Paid by weight	—	—
Minnesota	Paid by weight	—	—
Mississippi	Paid by weight	—	Paid by volume
Missouri	Paid by weight	—	—
Nebraska	Paid by weight	—	—
Ohio	Paid by volume	Paid by volume	Paid by volume
Oregon	Paid by weight	—	—
Pennsylvania	Paid by weight	Paid by weight	Paid by volume
Tennessee	Paid by weight	—	—
Texas	Paid by weight	—	—
Utah	Paid by weight	—	Paid by weight
Vermont	Paid by weight	—	—
Virginia	Paid by weight	Paid by weight	Paid by volume
Washington	Paid by weight	Paid by weight	Paid by volume
West Virginia	Paid by weight	—	—
Wisconsin	Paid by weight	Paid by weight	Paid by volume

—Not applicable.
Note: None of the States indicated e-Ticketing was used for millings, reinforcing steel, prefabricated elements, deicing salt/chemicals, or other bulk materials.

Table 44. Question 8: If you have selected "Asphalt" in response to the previous question, please indicate the typical project size (tonnage of asphalt mixtures used on projects) that adopted e-Ticketing.

State/Territory	<100 tons	100–500 tons	500–1,000 tons	1,000–5,000 tons	5,000–10,000 tons	10,0000–25,000 tons	>25,000 tons	Unsure
Alabama	—	—	—	—	Yes	—	—	—
Arkansas	—	—	—	Yes	Yes	Yes	Yes	—
Connecticut	—	—	—	—	—	Yes	—	—
Florida	—	—	—	—	—	—	—	Yes
Georgia	—	—	—	—	Yes	—	—	—
Illinois	—	—	—	—	—	—	—	Yes
Indiana	—	—	—	—	—	—	—	Yes
Iowa	—	—	—	—	—	Yes	—	—
Kansas	—	—	—	—	—	Yes	—	—
Kentucky	—	—	—	—	—	—	—	Yes
Maine	—	—	—	Yes	Yes	Yes	—	—
Minnesota	—	—	—	—	Yes	Yes	Yes	—
Mississippi	—	—	—	—	—	Yes	—	—
Missouri	—	—	—	—	—	—	Yes	—
Nebraska	Yes	—	—	—	—	—	—	—
Ohio	—	—	—	—	Yes	—	—	—
Oregon	—	—	—	—	—	Yes	Yes	—
Pennsylvania	—	—	—	—	—	—	—	Yes
Tennessee	—	—	—	—	—	—	—	—
Texas	—	—	—	—	—	—	—	Yes
Utah	Yes	Yes	Yes	Yes	Yes	Yes	Yes	—
Vermont	—	—	—	—	—	—	Yes	—
Virginia	—	—	—	—	—	—	—	—

State/Territory	<100 tons	100–500 tons	500–1,000 tons	1,000–5,000 tons	5,000–10,000 tons	10,0000–25,000 tons	>25,000 tons	Unsure
Washington	—	—	—	—	—	—	—	Yes
West Virginia	—	—	Yes	Yes	Yes	—	—	—
Wisconsin	—	—	—	—	—	—	—	Yes

—Not applicable.

Table 45. Question 9: If you have selected "concrete" as a material type, please indicate the typical project size (volume of concrete mixtures in cubic yards used on projects) that adopted e-Ticketing.

State/Territory	<500 yd^3	500–5,000 yd^3	5,000–25,000 yd^3	25,000–50,000 yd^3	50,000–100,000 yd^3	>100,000 yd^3	Unsure
Alabama	—	—	—	—	—	—	—
Arkansas	—	—	—	—	—	—	—
Connecticut	—	—	—	—	—	—	—
Florida	—	—	—	—	—	—	—
Georgia	—	—	—	—	—	—	—
Illinois	—	—	—	—	—	—	Yes
Indiana	—	—	—	—	—	—	Yes
Iowa	—	—	—	Yes	—	—	—
Kansas	—	—	—	—	—	—	—
Kentucky	—	—	—	—	—	—	Yes
Maine	—	—	—	—	—	—	—
Minnesota	—	—	—	—	—	—	—
Mississippi	—	—	—	—	—	—	—
Missouri	—	—	—	—	—	—	—
Nebraska	—	—	—	—	—	—	—
Ohio	—	Yes	—	—	—	—	—
Oregon	—	—	—	—	—	—	Yes
Pennsylvania	—	—	—	—	—	—	Yes

State/Territory	<500 yd^3	500–5,000 yd^3	5,000–25,000 yd^3	25,000–50,000 yd^3	50,000–100,000 yd^3	>100,000 yd^3	Unsure
Tennessee	—	—	—	—	—	—	—
Texas	—	—	—	—	—	—	—
Utah	—	—	—	—	—	—	Yes
Vermont	—	—	—	—	—	—	—
Virginia	—	—	—	—	—	—	—
Washington	Yes	—	—	—	—	—	—
West Virginia	—	—	—	—	—	—	—
Wisconsin	—	—	—	—	—	—	Yes

—Not applicable.

Table 46. Question 10: For what materials do you plan to use or hope to use e-Ticketing for in the future?

State/Territory	Asphalt	Millings	Aggregates	Concrete	Reinforcing Steel	Prefabricated Elements	Deicing Salt/Chemicals
Alabama	—	—	Within 12 mo	Within 12 mo	—	—	—
Arkansas	—	—	Unsure at this point	—	—	—	—
Connecticut	Within 12 mo	12–24 mo	Within 12 mo	12–24 mo	—	—	—
Florida	—	—	—	Unsure at this point	—	—	—
Georgia	—	—	Within 12 mo	12–24 mo	—	—	—
Illinois	Within 12 mo	Unsure at this point	Within 12 mo	Within 12 mo	Unsure at this point	Unsure at this point	Unsure at this point
Indiana	12–24 mo	—	12–24 mo	12–24 mo	—	—	—
Iowa	Within 12 mo	12–24 mo	Within 12 mo	Within 12 mo	12–24 mo	12–24 mo	Within 12 mo
Kansas	Within 12 mo	Unsure at this point	Unsure at this point	Unsure at this point	—	—	—
Kentucky	Within 12 mo	Unsure at this point	Within 12 mo	Within 12 mo	Unsure at this point	Unsure at this point	Unsure at this point
Maine	24–36 mo	—	—	Unsure at this point	—	—	—
Minnesota	—	24–36 mo	12–24 mo	12–24 mo	—	—	—
Mississippi	Within 12 mo	—	Within 12 mo	Within 12 mo	—	—	—

State/Territory	Asphalt	Millings	Aggregates	Concrete	Reinforcing Steel	Prefabricated Elements	Deicing Salt/Chemicals
Missouri	Unsure at this point	—	—	—	—	—	—
Nebraska	Within 12 mo	Unsure at this point	Unsure at this point	24–36 mo	Unsure at this point	Unsure at this point	Unsure at this point
Ohio	Within 12 mo	—	Within 12 mo	Within 12 mo	—	—	24–36 mo
Oregon	Within 12 mo	Unsure at this point	24–36 mo	24–36 mo	Unsure at this point	Unsure at this point	Unsure at this point
Pennsylvania	—	—	—	—	—	—	Within 12 mo
Tennessee	—	12–24 mo	Within 12 mo	12–24 mo	Unsure at this point	Unsure at this point	Unsure at this point
Texas	—	Unsure at this point	Unsure at this point	Unsure at this point	Unsure at this point	Unsure at this point	Unsure at this point
Utah	Within 12 mo	—	12–24 mo	Within 12 mo	Unsure at this point	12–24 mo	Unsure at this point
Vermont	—	12–24 mo	12–24 mo	Unsure at this point	Unsure at this point	Unsure at this point	Unsure at this point
Virginia	—	—	—	—	—	—	—
Washington	—	—	—	—	Within 12 mo	—	—
West Virginia	—	—	12–24 mo	12–24 mo	—	—	—
Wisconsin	Within 12 mo	Unsure at this point	12–24 mo	Within 12 mo	Unsure at this point	Unsure at this point	Unsure at this point

—Not applicable.

Table 47. Question 11: What additional information is appended with the e-Ticketing data?

State/Territory	Data Attributes	Notes
Alabama	Mix type and design	—
Arkansas	Inspector notes	Currently, we only require the specific ticket information that our specifications required pre-e-Ticketing. We do have the ability in all our approved e-Ticketing software apps for the inspectors to add any type of note that is applicable when the mix is delivered to the field, e.g., temperature, sampling information, etc.
Connecticut	• Mix type and design • Admixtures and modifiers used • Inspector notes	—
Florida	• Mix type and design • Mix properties (before placement) • Inspector notes	Regarding mix properties, only temperature of the mixture in the truck is recorded on the ticket.
Georgia	• Mix type and design • Inspector notes	Temperature readings or thermal coverage from paver-mounted infrared system.
Illinois	• Mix type and design • Admixtures and modifiers used • Mix properties (before placement) • Material sampling locations • Inspector notes • DPS readings	Load(s) rejected and reason(s) for rejection.
Indiana	• Mix type and design • Mix properties (before placement) • Inspector notes	—
Iowa	• Mix type and design • Mix properties (before placement) • Mat properties (after placement) • Material sampling locations • Inspector notes	—
Kansas	Inspector notes	Time stamp at time of acceptance or rejection, road waste quantities.

State/Territory	Data Attributes	Notes
Kentucky	• Mix type and design • Admixtures and modifiers used	—
Maine	• Mix type and design • Mix properties (before placement) • Inspector notes	—
Minnesota	• Mix type and design • Admixtures and modifiers used • Mix properties (before placement) • Mat properties (after placement) • Material sampling locations • Inspector notes • Roller coverage and/or stiffness using Intelligent Compaction • Temperature readings or thermal coverage from paver-mounted infrared system • DPS readings	Currently: Mix type and design, material sampling locations and inspector notes are currently appended to the e-Tickets. In the future, when we add concrete, we would include admixtures/modifiers and mix properties. We are currently working on obtaining funding to make Veta the standardized platform for the MDMS. After the needed MDMS enhancements are made, we plan to tie IC, PMTP, DPS, and material properties (after placement) data to the e-Ticket.
Mississippi	None of the attribute choices	—
Missouri	• Mix type and design • Inspector notes	All vehicle information.
Nebraska	• Mix type and design • Inspector notes	Overrun/underrun tonnage checks for thickness compliance.
Ohio	• Admixtures and modifiers used • Mix properties (before placement) • Inspector notes	—
Oregon	• Mix type and design • Inspector notes	Just standard specification asphalt concrete pavement ticket information at this point, with "ticket taker" notes for placement location and, sometimes, temperature and any rejected mix information.
Pennsylvania	Inspector notes	Temperature readings or thermal coverage from paver-mounted infrared system.
Tennessee	• Mix type and design • Admixtures and modifiers used • Mix properties (before placement) • Inspector notes	—
Texas	None of the attribute choices	—

State/Territory	Data Attributes	Notes
Utah	• Mix type and design • Mix properties (before placement) • Material sampling locations • Inspector notes	—
Vermont	• Mix type and design • Inspector notes	—
Virginia	Mix type and design	—
Washington	• Mix type and design • Admixtures and modifiers used • Mix properties (before placement) • Inspector notes	—
West Virginia	• Mix type and design • Inspector notes	Temperature readings or thermal coverage from paver mounted infrared system.
Wisconsin	• Mix type and design • Admixtures and modifiers used	—

—Not applicable.

.

Table 48. Question 12: What costs were considered during the implementation of e-Ticketing?

State/Territory	IT Staff and IT Network-Level Support Costs	Vendor Licensing Fees	e-Ticketing Technology Devices (GPS Units, etc.)	Manufacturer/Producer/Plant Equipment Upgrades	Costs From the Contractor	Supporting Technology Costs (Tablets, Field Devices, etc.)
Alabama	—	—	—	Yes	Yes	—
Arkansas	—	—	—	Yes	Yes	Yes
Connecticut	—	Yes	Yes	Yes	Yes	Yes
Florida	—	Yes	Yes	Yes	Yes	Yes
Georgia	—	—	Yes	—	Yes	—
Illinois	—	—	—	—	—	—
Indiana	—	Yes	—	Yes	—	—
Iowa	—	—	—	—	—	—
Kansas	—	Yes	Yes	Yes	—	Yes
Kentucky	—	—	—	—	—	—
Maine	—	—	Yes	Yes	Yes	—
Minnesota	—	—	—	—	—	—
Mississippi	—	—	Yes	—	—	Yes
Missouri	—	—	—	Yes	Yes	—
Nebraska	—	—	—	Yes	—	Yes
Ohio	Yes	Yes	—	Yes	Yes	Yes
Oregon	—	Yes	Yes	Yes	Yes	—
Pennsylvania	Yes	Yes	—	Yes	Yes	—
Tennessee	—	Yes	Yes	Yes	—	—
Texas	—	—	—	Yes	—	—
Utah	—	—	—	—	—	Yes
Vermont	—	—	—	—	Yes	—

State/Territory	IT Staff and IT Network-Level Support Costs	Vendor Licensing Fees	e-Ticketing Technology Devices (GPS Units, etc.)	Manufacturer/Producer/Plant Equipment Upgrades	Costs From the Contractor	Supporting Technology Costs (Tablets, Field Devices, etc.)
Virginia	Yes	—	Yes	Yes	Yes	—
Washington	—	—	—	—	Yes	—
West Virginia	—	Yes	—	Yes	Yes	Yes
Wisconsin	—	—	—	—	—	—

—Not applicable.

Table 49. Question 13: Which, if any, of these costs did you consider as a deterrent to the implementation of e-Ticketing?

State/Territory	Vendor Licensing Fees	e-Ticketing Technology Devices	Manufacturer/Producer/Plant Equipment Upgrades	Costs From the Contractor	Supporting Technology Costs	IT Staff and IT Network-Level Support Costs
Alabama	—	—	Yes	Yes	—	—
Arkansas	—	—	—	—	Yes	—
Connecticut	—	—	—	—	Yes	—
Florida	—	—	—	—	—	—
Georgia	—	—	—	—	—	—
Illinois	—	—	—	—	—	—
Indiana	—	—	Yes	—	—	—
Iowa	—	—	—	—	—	—
Kansas	—	—	—	—	—	—
Kentucky	—	—	—	—	—	—
Maine	—	—	Yes	Yes	—	—
Minnesota	—	—	—	—	—	—
Mississippi	Yes	—	—	—	—	—
Missouri	—	Yes	—	Yes	—	—
Nebraska	—	Yes	Yes	Yes	Yes	Yes

State/Territory	Vendor Licensing Fees	e-Ticketing Technology Devices	Manufacturer/Producer/Plant Equipment Upgrades	Costs From the Contractor	Supporting Technology Costs	IT Staff and IT Network-Level Support Costs
Ohio	Yes	—	Yes	Yes	—	Yes
Oregon	—	Yes	Yes	—	—	—
Pennsylvania	—	—	—	—	—	—
Tennessee	Yes	Yes	—	—	—	—
Texas	—	—	—	—	—	—
Utah	Yes	—	—	—	—	—
Vermont	—	—	—	—	—	—
Virginia	—	—	—	—	—	—
Washington	—	—	Yes	—	—	—
West Virginia	Yes	—	Yes	—	Yes	—
Wisconsin	—	—	—	—	—	—

—Not applicable.

Table 50. Question 14A: Which of the following outcomes were the tangible or intangible benefits you considered when choosing to use e-Ticketing?

State/Territory	Reduced Paper Documentation	Time Savings in Review and Consolidation of Material Quantities	Readily Available Material Quantity Information	Archived Material Placement Location	Safety
Alabama	Yes	Yes	Yes	—	Yes
Arkansas	Yes	—	Yes	—	Yes
Connecticut	Yes	Yes	Yes	Yes	Yes
Florida	Yes	Yes	Yes	Yes	Yes
Georgia	Yes	Yes	Yes	Yes	Yes
Illinois	Yes	Yes	Yes	—	Yes
Indiana	Yes	Yes	Yes	Yes	Yes
Iowa	—	—	—	—	—
Kansas	Yes	—	—	—	Yes
Kentucky	Yes	Yes	Yes	Yes	Yes
Maine	Yes	Yes	—	Yes	Yes

State/Territory	Reduced Paper Documentation	Time Savings in Review and Consolidation of Material Quantities	Readily Available Material Quantity Information	Archived Material Placement Location	Safety
Minnesota	Yes	Yes	Yes	Yes	Yes
Mississippi	Yes	—	—	—	Yes
Missouri	Yes	Yes	Yes	Yes	Yes
Nebraska	Yes	Yes	Yes	Yes	Yes
Ohio	Yes	Yes	Yes	—	Yes
Oregon	Yes	Yes	Yes	Yes	Yes
Pennsylvania	Yes	Yes	Yes	Yes	Yes
Tennessee	Yes	Yes	Yes	—	Yes
Texas	Yes	Yes	Yes	Yes	Yes
Utah	Yes	Yes	Yes	Yes	Yes
Vermont	Yes	Yes	Yes	Yes	Yes
Virginia	Yes	—	—	—	—
Washington	Yes	Yes	Yes	—	Yes
West Virginia	Yes	Yes	Yes	—	Yes
Wisconsin	—	—	—	—	Yes

—Not applicable.

Table 51. Question 14B: Which of the following outcomes were the tangible or intangible benefits you considered when choosing to use e-Ticketing?

State/Territory	Real-Time Material Tracking	Production Tracking	Disadvantaged Business Enterprise Requirements	Wage and Payroll Requirements	Motor Carrier Requirements
Alabama	Yes	Yes	—	—	—
Arkansas	Yes	—	—	—	—
Connecticut	Yes	Yes	—	—	—
Florida	Yes	Yes	—	—	—
Georgia	—	—	—	—	—
Illinois	Yes	—	—	—	—
Indiana	—	—	—	—	—
Iowa	—	—	—	—	—
Kansas	—	—	—	—	—

State/Territory	Real-Time Material Tracking	Production Tracking	Disadvantaged Business Enterprise Requirements	Wage and Payroll Requirements	Motor Carrier Requirements
Kentucky	Yes	Yes	—	—	—
Maine	Yes	—	—	—	—
Minnesota	Yes	Yes	Yes	Yes	Yes
Mississippi	Yes	—	—	—	—
Missouri	Yes	—	—	—	—
Nebraska	Yes	Yes	—	—	—
Ohio	Yes	—	—	—	—
Oregon	Yes	Yes	—	—	—
Pennsylvania	Yes	Yes	—	—	Yes
Tennessee	Yes	—	—	—	—
Texas	Yes	Yes	—	—	—
Utah	Yes	—	—	—	—
Vermont	Yes	Yes	—	—	—
Virginia	Yes	—	—	—	—
Washington	—	—	—	—	—
West Virginia	—	—	—	—	—
Wisconsin	—	—	—	—	—

—Not applicable.

Table 52. Question 15: Has your agency calculated the return on investment (alternatively, benefit–cost ratio or other equivalent metrics) on e-Ticketing?

State/Territory	Yes, We Have Calculated the Numbers	Not Yet, But We Have the Information to Calculate	No, We Have Challenges in Quantifying Benefits and/or Costs	Please Provide Additional Information, If Needed
Alabama	—	—	Yes	—
Arkansas	—	—	Yes	—
Connecticut	—	Yes	—	—
Florida	—	—	Yes	—
Georgia	—	—	Yes	—
Illinois	—	—	Yes	—
Indiana	—	—	—	No, we have not, because we believe that industry is moving this direction and the department must adjust and that the benefits noted in table 14 and table 15 are sufficient justification.
Iowa	—	—	—	—
Kansas	—	—	Yes	—
Kentucky	—	—	Yes	—
Maine	—	—	Yes	—
Minnesota	—	—	Yes	This will take some time to calculate and won't be evaluated until 5–10 yr from now. The technology is still rapidly changing by vendors, contractors do not know how to bid on this specification, costs will go down in the future with the increase of projects and number of systems owned/used by the contractor, future enhancements to Veta and AWP will affect prices, etc.
Mississippi	—	—	Yes	—
Missouri	—	—	Yes	—
Nebraska	Yes	—	—	—
Ohio	—	—	Yes	—

State/Territory	Yes, We Have Calculated the Numbers	Not Yet, But We Have the Information to Calculate	No, We Have Challenges in Quantifying Benefits and/or Costs	Please Provide Additional Information, If Needed
Oregon	—	—	Yes	Safety trumps the ROI, as well as the push to go paperless with InfoTech Doc Express, so calculating an ROI or benefit–cost analysis has not been considered necessary to move toward implementation, rather than it being a challenge. Contractors are largely on board and a larger paving corporation has offered the use of e-Ticketing as a relatively inexpensive add-on to their fleet management system free of charge to the agency. Data-capable devices are fairly common on project managers' crews, so no significant capital outlay has been necessary for agency implementation.
Pennsylvania	—	Yes	—	The department is expanding its pilot to a statewide pilot this construction season, as well as, expanding the applicable materials.
Tennessee	—	—	Yes	—
Texas	—	—	Yes	Required special provision, optional to contractor with an engineer's approval.
Utah	—	—	Yes	—
Vermont	—	—	Yes	—
Virginia	—	—	Yes	—
Washington	—	—	Yes	—
West Virginia	—	—	Yes	—
Wisconsin	—	—	Yes	—

—Not applicable.

Table 53. Question 16: How did you procure the e-Ticketing services?

State/Territory	Included in Contract as a Bid Item	Included in RFP as Incidental to Another Item of Work	Added as a Contract Modification	Purchased Directly by DOT	Others (Please Specify)
Alabama	—	—	—	—	Contractor provides without reimbursement currently.
Arkansas	—	—	Yes	—	We allow the contractors the choice to use e-Ticketing currently.
Connecticut	—	—	—	—	Proposed by contractor and approved on a trial basis.
Florida	—	—	Yes	—	On our two pilot projects, we added it by supplemental agreement. In April 2020, in response to COVID, we implemented contactless ticketing on all projects of which asphalt e-Ticketing is one contactless ticketing options. This process was implemented by a district construction engineers (DCE) memo, and the asphalt e-Ticketing specifications were attached.
Georgia	Yes	Yes	—	—	—
Illinois	—	—	—	—	On an individual “pilot” project basis thus far, requested by the contractor with approval by the district.
Indiana	—	—	—	—	Currently with construction memo allowing the use, in the future with specifications changes.
Iowa	—	—	—	—	—
Kansas	—	Yes	—	—	—
Kentucky	Yes	—	—	—	—
Maine	—	—	Yes	—	Voluntary usage during COVID.
Minnesota	Yes	—	Yes	—	—

State/Territory	Included in Contract as a Bid Item	Included in RFP as Incidental to Another Item of Work	Added as a Contract Modification	Purchased Directly by DOT	Others (Please Specify)
Mississippi	—	—	Yes	—	—
Missouri	Yes	—	Yes	—	—
Nebraska	—	—	—	—	Select candidate pilot projects and will add via negotiation with contractor via change order.
Ohio	—	—	—	—	Still determining.
Oregon	—	—	—	—	Allowed as an alternate under existing specifications. Draft specifications to add as a formal contract change order currently under review for 2021 season.
Pennsylvania	Yes	—	—	—	The department developed our e-Ticketing application, and there is an item in the system for our construction contractors.
Tennessee	—	Yes	—	—	—
Texas	—	—	—	—	—
Utah	—	—	—	—	Volunteer basis.
Vermont	Yes	—	Yes	—	—
Virginia	—	—	—	—	Contractor is to opt in with no additional cost to the department.
Washington	Yes	Yes	—	—	—
West Virginia	—	—	—	—	Collaborate with some contractors.
Wisconsin	—	—	—	—	No system has been procured yet.

—Not applicable.

Table 54. Question 17: What business processes have had to be modified to reach your current level of e-Ticketing use?

State/Territory	Construction Procurement/Letting	Preconstruction Meetings	Project Closeouts	As-Built Documentation/Project Documentation	Legal/Compliance	Asset Management/ Maintenance
Alabama	—	—	—	Yes	—	Yes
Arkansas	—	—	—	—	—	—
Connecticut	—	—	—	Yes	—	—
Florida	—	—	—	—	—	—
Georgia	—	Yes	—	Yes	Yes	—
Illinois	—	—	—	Yes	—	—
Indiana	—	—	Yes	Yes	—	—
Iowa	—	—	—	—	—	—
Kansas	Yes	—	—	—	—	—
Kentucky	—	—	Yes	Yes	Yes	—
Maine	—	Yes	—	—	—	—
Minnesota	—	—	—	—	—	—
Mississippi	—	—	Yes	—	—	—
Missouri	Yes	—	—	Yes	—	—
Nebraska	—	—	—	—	—	—
Ohio	—	—	—	—	—	—
Oregon	—	—	—	—	—	—
Pennsylvania	—	Yes	—	—	—	—
Tennessee	—	Yes	—	—	—	—
Texas	—	—	—	—	—	—
Utah	—	Yes	Yes	—	Yes	—
Vermont	—	—	—	Yes	—	—
Virginia	—	—	—	—	—	—
Washington	Yes	—	—	—	Yes	—
West Virginia	—	—	—	Yes	—	—
Wisconsin	—	—	—	—	—	—

—Not applicable.

Table 55. Question 18A: What e-Ticketing implementation challenges have you encountered?

State/Territory	Stakeholder Pushback	Internet Connectivity Concerns	Integrating With Current Project Administration Systems	Integrating With Plant/Supplier IT systems	Electronic Data Transfer From Third Party to DOT
Alabama	—	Yes	—	—	—
Arkansas	—	—	Yes	—	Yes
Connecticut	—	Yes	—	—	Yes
Florida	Yes	Yes	—	—	—
Georgia	—	Yes	—	—	—
Illinois	—	Yes	—	—	Yes
Indiana	Yes	Yes	Yes	Yes	Yes
Iowa	—	—	—	—	—
Kansas	—	Yes	—	—	—
Kentucky	—	—	—	—	—
Maine	Yes	Yes	—	—	—
Minnesota	—	Yes	—	Yes	—
Mississippi	—	Yes	—	—	—
Missouri	Yes	Yes	—	—	—
Nebraska	Yes	Yes	—	Yes	—
Ohio	—	Yes	—	Yes	Yes
Oregon	—	Yes	—	—	—
Pennsylvania	—	Yes	—	Yes	—
Tennessee	Yes	Yes	—	—	—
Texas	—	—	—	—	—
Utah	Yes	Yes	—	Yes	—
Vermont	Yes	Yes	—	—	—
Virginia	Yes	—	—	—	—
Washington	Yes	Yes	—	—	—
West Virginia	—	Yes	—	—	—
Wisconsin	—	—	Yes	Yes	—

—Not applicable.

Table 56. Question 18B: What e-Ticketing implementation challenges have you encountered?

State/Territory	Lack of Material Bill of Lading	Third-Party Haulers With Multiple Contractors or Multiple e-Ticketing Systems	Data Privacy Concerns	Others (Please Specify)
Alabama	—	—	—	—
Arkansas	—	Yes	—	—
Connecticut	—	—	—	—
Florida	—	—	—	—
Georgia	—	—	—	—
Illinois	—	—	—	—
Indiana	—	Yes	—	—
Iowa	—	—	—	—
Kansas	—	—	—	—
Kentucky	—	—	—	—
Maine	—	—	—	—
Minnesota	—	—	—	Issues with e-Ticketing systems, older plant loadout software platforms, yearly updates to load-out software platforms preventing pushing of data, dump locations not always accurately captured, zones with no data cellular coverage, no standardized MDMS platform for agencies to use, nonstandardized data exports, inability to automatically merge agency/contractor data, etc.
Mississippi	—	—	—	—
Missouri	—	Yes	—	Areas with no cellular service.
Nebraska	—	—	—	—
Ohio	—	Yes	Yes	—
Oregon	—	—	—	—
Pennsylvania	—	—	—	—
Tennessee	—	Yes	Yes	—
Texas	—	—	—	—
Utah	—	—	Yes	—

State/Territory	Lack of Material Bill of Lading	Third-Party Haulers With Multiple Contractors or Multiple e-Ticketing Systems	Data Privacy Concerns	Others (Please Specify)
Vermont	—	—	—	Not necessarily pushback, but contractors reluctant to integrate to e-Ticket software.
Virginia	—	—	—	—
Washington	—	Yes	—	—
West Virginia	—	—	—	Lack of mobile devices.
Wisconsin	—	—	—	—

—Not applicable.

Table 57. Question 19: Do you verify the information provided by the e-Ticketing system?

State/Territory	Responses	Others (Please Specify)
Alabama	Yes, we are still getting cohort paper tickets.	—
Arkansas	—	We verify material information in realtime by the inspection staff on the project. We then verify the daily data that are required to be uploaded by the next day after the placement of the material to complete payment documentation. Currently, we haven't seen any discrepancies that would cause alarm.
Connecticut	—	Paper tickets are available on request for spot checking or if an e-Ticket is unavailable.
Florida	—	Not sure exactly what you mean by verify the e-Ticketing system. We have project personnel fill out roadway reports that determine spread rate, they also verify the asphalt mix is correctly noted on the e-Ticketing (correct mix for the project).
Georgia	Yes, we have implemented procedures for verification for e-Ticketing.	—
Illinois	—	Since we are still in the pilot project phase, we are verifying against paper tickets on some first-time pilot contracts, plus traditional progress/final yield checks and weekly independent weight checks on all contracts.
Indiana	Yes, we are still getting cohort paper tickets.	—
Iowa	—	—
Kansas	Yes, we have implemented procedures for verification for e-Ticketing.	—
Kentucky	Yes, we are still getting cohort paper tickets.	—
Maine	Yes, we are still getting cohort paper tickets.	—
Minnesota	Yes, we have implemented procedures for verification for e-Ticketing.	—
Mississippi	Yes, we are still getting cohort paper tickets.	—
Missouri	Yes, we are still getting cohort paper tickets.	—
Nebraska	—	Not at this point.
Ohio	—	Still determining.

State/Territory	Responses	Others (Please Specify)
Oregon	—	We use our standard specification check weights on secondary certified scales to verify mass on the ticket at a specified minimum but random frequency. Nothing new with the addition of e-Ticketing. We also check quantity totals manually for each shift.
Pennsylvania	—	The e-Ticketing system will be new this season, so it will be tested during this pilot season.
Tennessee	No, we do not plan to verify e-Tickets.	—
Texas	—	Must meet all requirements of contract specifications at specified intervals or as requested.
Utah	Yes, we have implemented procedures for verification for e-Ticketing.	—
Vermont	No, but we have plans for, or are working on developing, verification procedures for e-Ticketing.	—
Virginia	—	Suppliers are inspected by department representatives as part of an independent assurance and independent verification process. Materials are visually verified when received.
Washington	Yes, we have implemented procedures for verification for e-Ticketing.	—
West Virginia	Yes, we are still getting cohort paper tickets.	—
Wisconsin	—	—

—Not applicable.

Table 58. Question 20: How do you verify (or plan to verify) the accuracy of information printed on e-Tickets at a plant or quarry?

State/Territory	Responses
Alabama	Certification of load scales at plant.
Arkansas	We have plant inspectors, and we require scale certifications for each asphalt concrete hot mix plant.
Connecticut	Currently, no additional verification procedures specific to e-Ticketing are in place.
Florida	Not quite sure what needs to be verified. How is an e-Ticket any different than a paper ticket in that regard? We check spread rate to ensure we're getting the tonnage/thickness, and the tickets are checked to ensure the correct mix is being used.
Georgia	Certified weigher, inspectors at the plant.

State/Territory	Responses
Illinois	Primarily follow existing processes, i.e., we require certified scales for weight measurement (when the pay unit of measure is weight), adhere to our current random weight check process, and verify necessary data at the point of delivery by DOT field inspectors.
Indiana	Certify scales at plants, comparison of plan quantities and yields.
Iowa	—
Kansas	Verify the calculated quantities with the delivered quantities.
Kentucky	Not sure.
Maine	Same as for paper tickets: periodic scale checks, random plant inspections.
Minnesota	We currently still use paper tickets; however, we also have an independent verification process in place to ensure that this procedure works before removing paper tickets. Our example is included in the MDMS AASHTO provisional practice.
Mississippi	—
Missouri	Random QA checks.
Nebraska	All scales are required to be certified by weights and measures. Tickets will contain project ID, plant ID, truck ID, and load specifics regarding type, weight, and time.
Ohio	—
Oregon	Certified scales are always required on our projects, e-Ticketing or not, and the same for check weights per standard specification. The e-Ticketing doesn't really change how we verify e-Tickets versus paper tickets.
Pennsylvania	Presence of inspectors at the plant/quarry; they will be verifying the plants scales and equipment to make sure the material is being produced, shipped, and documented properly.
Tennessee	—
Texas	e-Ticketing only for asphalt (hot mix) delivered to project.
Utah	We do not currently verify the accuracy of information printed on e-Tickets at the plant and do not plan to.
Vermont	Plant scales are verified annually during plant inspection. e-Ticket setup and calibration protocol is being discussed and will be included in specifications eventually. Currently, a contractor provides setup and calibration methods.
Virginia	The department inspects vendor facilities on a reoccurring basis to validate equipment and whether personnel are compliant with department requirements.
Washington	Scale certification and scale verification checks. We also reconcile loads received with loads delivered.
West Virginia	Presence of inspectors at the plant.
Wisconsin	Still in development.

—Not applicable.

Table 59. Question 21: How do you verify (or plan to verify) the accuracy of information printed on e-Tickets during transmittal from the plant/quarry to the jobsite?

State/Territory	Responses
Alabama	No plan.
Arkansas	The e-Ticketing systems we have used have a feature whereby the inspector can sign off on each ticket once the load is received for placement on the project. We do have some versions of software that use GPS location, but we don't require it at this time.
Connecticut	Currently, no additional verification procedures specific to e-Ticketing are in place.
Florida	See table 57 for response.
Georgia	Tracking data and time stamps, field verification.
Illinois	Certification of load scales at plants, comparison of tonnage against plan quantities and yield, and weekly independent weight checks (as was required for paper tickets) will continue.
Indiana	Jobsite inspector review of information in the field.
Iowa	—
Kansas	Truck number, load count, daily total tons produced, and time stamp.
Kentucky	Not sure.
Maine	—
Minnesota	See table 57 for response.
Mississippi	—
Missouri	We allow flexibility in how the contractor achieves verification. It could be with GPS or with other systems, such as vehicle recognition technology at the asphalt paver. We need proof that the truck listed on the ticket actually dumped the load in the paver.
Nebraska	Geofencing, verification by DOT inspector.
Ohio	—
Oregon	We are not requiring GPS at this time.
Pennsylvania	See table 57 for response.
Tennessee	—
Texas	We do not track this information. This information is not required.
Utah	We do not currently verify the accuracy of information printed on e-Tickets from the plant to the jobsite and do not plan to.
Vermont	Current specifications include delivery vehicle departure time from the load source and arrival time at the paver. Arrival time at the paver is currently done by an inspector authorizing the load with acceptance of the load, initials, and time stamp.
Virginia	No plans to verify route tracking. Arrival time may be spot checked by department field staff at the project site.

State/Territory	Responses
Washington	Scale certification and scale verification checks.
West Virginia	Still being worked on.
Wisconsin	Still in development.

—Not applicable.

Table 60. Question 22: How do you verify (or plan to verify) the accuracy of information printed on e-Tickets at the point of delivery?

State/Territory	Responses
Alabama	DOT inspector checks accuracy.
Arkansas	Currently, we have the inspector on the project verifying whether the loads are received.
Connecticut	Currently, no additional verification procedures specific to e-Ticketing are in place.
Florida	See table 57 for response.
Georgia	Inspectors onsite to verify truck number and vendor, verify mix with ticket description, and track within the e-Ticketing app.
Illinois	Follow processes outlined in response in table 57 and table 58
Indiana	Jobsite inspector review of information in the field.
Iowa	—
Kansas	Time stamp.
Kentucky	Not sure.
Maine	—
Minnesota	See table 57 for response.
Mississippi	—
Missouri	Random QA checks.
Nebraska	Verification by the inspector.
Ohio	—
Oregon	The truck number will be checked against the e-Ticket for quantity, with ticket taker/inspector notes on delivery location. Yield checks are also required versus tonnage delivered. Most jobs with over 15,000 tons also require blind random density testing, requiring the agency to closely monitor tonnage to identify the QC density shot locations.
Pennsylvania	See table 57 for response.
Tennessee	—
Texas	Certification of load scales at the plant, comparison of tonnage against plan quantities and yield, summary spreadsheet with total for payment, time stamp by Texas DOT when loads are accepted.
Utah	The truck number and time of departure are used to verify whether the correct load has been received at the point of delivery.
Vermont	Current process with e-Ticket vendors is DOT inspector verifying the loads onsite. Verification is by truck license plate number matching to load ticket. We would accept an automated means of point of delivery verification.

State/Territory	Responses
Virginia	Visuals inspection by department field staff.
Washington	We have a dedicated inspector onsite to document/verify delivery of material (track truck number, time, location).
West Virginia	Presence of inspectors at the project, and e-ticket will have to be accepted/approved by an inspector.
Wisconsin	Still in development.

—Not applicable.

Table 61. Question 23: What additional measures does your agency undertake to independently verify information provided by the e-Ticketing system is accurate and the material was incorporated into the project?

State/Territory	Responses
Alabama	—
Arkansas	—
Connecticut	Currently, no additional verification procedures specific to e-Ticketing are in place.
Florida	See table 57 for response.
Georgia	—
Illinois	Inspectors in the field will continue taking yield checks, conducting independent weight checks, and verifying the “one truck = one ticket” concept once on the jobsite.
Indiana	This process is still under development as we look to scale implementation.
Iowa	—
Kansas	—
Kentucky	To date, we are still ultimately getting the paper tickets to compare to the e-Tickets.
Maine	—
Minnesota	In addition to the response provided in table 57, we use asset trackers and geofences to assist with ensuring that the material was indeed delivered.
Mississippi	—
Missouri	Random QA checks.
Nebraska	Geofence around the paver for location of placement.
Ohio	—
Oregon	Same process as we use for our standard projects. Refer to responses provided in table 57 to table 60.
Pennsylvania	See table 57 for response.
Tennessee	—
Texas	A requirement that data cannot be altered, and we must meet all “paper documentation” requirements of contract specifications.
Utah	The office technician verifies the ticket information using a CSV and inspector notes before submitting the tickets for payment.

State/Territory	Responses
Vermont	Due to our standard operating procedures with e-Ticketing, our specifications do not dismiss the requirement of individual truck tickets for verification. The agency and contractor discuss daily data summaries to verify quantities and ensure the information matches.
Virginia	Procedures are in place independent of the e-Ticketing program.
Washington	WSDOT verification of delivery, scale certification, scale verification, daily reconciliation.
West Virginia	Still being worked on.
Wisconsin	Still in development.

—Not applicable.

Table 62. Question 24: Do you have a documented procedure of your agency's process for verification of e-Tickets?

State/Territory	Yes/No
Alabama	No
Arkansas	No
Connecticut	No
Florida	No
Georgia	No
Illinois	No
Indiana	No, still in development
Iowa	—
Kansas	No
Kentucky	No
Maine	No
Minnesota	Yes
Mississippi	No
Missouri	No
Nebraska	No
Ohio	No
Oregon	No
Pennsylvania	No
Tennessee	—
Texas	No
Utah	No
Vermont	No
Virginia	No
Washington	Yes
West Virginia	No
Wisconsin	No

—Not applicable.

Table 63. Question 25: Does your agency use procurement language that outlines data management practices?

State/Territory	Yes/No
Alabama	No
Arkansas	Yes
Connecticut	Yes
Florida	Yes
Georgia	Yes
Illinois	No
Indiana	Yes
Iowa	—
Kansas	Yes
Kentucky	No
Maine	No
Minnesota	Yes
Mississippi	No
Missouri	Yes
Nebraska	No
Ohio	—
Oregon	Yes
Pennsylvania	Yes
Tennessee	Yes
Texas	Yes
Utah	No
Vermont	Yes
Virginia	Yes
Washington	No
West Virginia	No
Wisconsin	No

—Not applicable.

Table 64. Question 26: If you answered yes to the previous question, what is included in the procurement language in regard to data management practices?

State/Territory	Response	Comments
Alabama	—	—
Arkansas	• File formats for e-Tickets (PDF/CSV) • Data transfer policy from vendor and/or contractor to agency	We have certain requirements for the data contained in our special provision.
Connecticut	Data transfer policy from vendor and/or contractor to agency	—

State/Territory	Response	Comments
Florida	• File formats for e-Tickets (PDF/CSV) • Data transfer policy from vendor and/or contractor to agency • Extent of stakeholder (DOT inspection staff, contractor, supplier, etc.) access to the e-Tickets	—
Georgia	• File formats for e-Tickets (PDF/CSV) • Data transfer policy from vendor and/or contractor to agency • Extent of stakeholder (DOT inspection staff, contractor, supplier, etc.) access to the e-Tickets • Timing of ownership of ticket data	—
Illinois	—	—
Indiana	• File formats for e-Tickets (PDF/CSV) • Data transfer policy from vendor and/or contractor to agency • Extent of stakeholder (DOT inspection staff, contractor, supplier, etc.) access to the e-Tickets • Process for archiving ticket data • Degree of security for ticket data • Timing of ownership of ticket data	These requirements will be defined as we look toward full-scale implementation of e-Ticketing, but we are aware of the need to include them in the procurement language.
Iowa	—	—
Kansas	• File formats for e-Tickets (PDF/CSV) • Process for archiving ticket data	—
Kentucky	—	—
Maine	—	—
Minnesota	• File formats for e-Tickets (PDF/CSV) • Data transfer policy from vendor and/or contractor to agency • Extent of stakeholder (DOT inspection staff, contractor, supplier, etc.) access to the e-Tickets • Timing of ownership of ticket data	—
Mississippi	—	—
Missouri	• File formats for e-Tickets (PDF/CSV) • Data transfer policy from vendor and/or contractor to agency • Timing of ownership of ticket data	—
Nebraska	—	—
Ohio	—	—

State/Territory	Response	Comments
Oregon	File formats for e-Tickets (PDF/CSV)	Some of this terminology is in the draft contract change order language, but in our standards, the contractor is required to provide the data in a format compatible for upload to Doc Express.
Pennsylvania	File formats for e-Tickets (PDF/CSV)	—
Tennessee	Extent of stakeholder (DOT inspection staff, contractor, supplier, etc.) access to the e-Tickets	—
Texas	• File formats for e-Tickets (PDF/CSV) • Data transfer policy from vendor and/or contractor to agency • Extent of liability for the accuracy of the e-Tickets • Extent of stakeholder (DOT inspection staff, contractor, supplier, etc.) access to the e-Tickets • Degree of security for ticket data • Timing of ownership of ticket data	—
Utah	—	—
Vermont	• Data transfer policy from vendor and/or contractor to agency • Extent of stakeholder (DOT inspection staff, contractor, supplier, etc.) access to the e-Tickets	—
Virginia	File formats for e-Tickets (PDF/CSV)	—
Washington	—	—
West Virginia	—	—
Wisconsin	—	—

—Not applicable.

Table 65. Question 27: Has your agency participated in, at a minimum, a pilot effort to integrate ticket data with existing CMS?

State/Territory	Yes/No
Alabama	Yes
Arkansas	No
Connecticut	Yes
Florida	Yes
Georgia	Yes
Illinois	Yes
Indiana	—
Iowa	—
Kansas	Yes
Kentucky	No
Maine	No
Minnesota	Yes
Mississippi	Yes
Missouri	No
Nebraska	No
Ohio	—
Oregon	Yes
Pennsylvania	—
Tennessee	—
Texas	—
Utah	Yes
Vermont	—
Virginia	Yes
Washington	Yes
West Virginia	—
Wisconsin	—

—Not applicable.

Table 66. Question 28: If you answered yes to Question 27, to what degree is the ticket data integrated into the CMS?

State/Territory	Response
Alabama	Stored to calculate pay quantities.
Arkansas	—
Connecticut	Stored internally for archiving/documentation.
Florida	Stored internally for archiving/documentation.
Georgia	Stored internally for archiving/documentation.
Illinois	Stored internally for archiving/documentation.
Indiana	—

State/Territory	Response
Iowa	—
Kansas	Stored to calculate pay quantities.
Kentucky	—
Maine	—
Minnesota	Stored internally for archiving/documentation.
Mississippi	Stored internally for archiving/documentation.
Missouri	—
Nebraska	—
Ohio	—
Oregon	Stored internally for archiving/documentation.
Pennsylvania	—
Tennessee	—
Texas	—
Utah	—
Vermont	—
Virginia	Stored to calculate pay quantities.
Washington	—
West Virginia	—
Wisconsin	—

—Not applicable.

Table 67. Question 29: What are your agency's plans for standardizing the e-Ticketing data?

State/Territory	Response
Alabama	Have no plans to standardize currently, but hoping to learn from other DOTs.
Arkansas	Have no plans to standardize currently, but hoping to learn from other DOTs.
Connecticut	Working with a regional group of other DOTs on a data standardization plan.
Florida	Working internally on a data standardization plan.
Georgia	Have no plans to standardize.
Illinois	Have no plans to standardize currently, but hoping to learn from other DOTs.
Indiana	—
Iowa	—
Kansas	Have no plans to standardize currently, but hoping to learn from other DOTs.
Kentucky	Have no plans to standardize.
Maine	Working with a national group on a data standardization plan.
Minnesota	Working with a national group on a data standardization plan.

State/Territory	Response
Mississippi	Working internally on a data standardization plan.
Missouri	Working with a national group on a data standardization plan.
Nebraska	Working internally on a data standardization plan.
Ohio	—
Oregon	Have no plans to standardize currently, but hoping to learn from other DOTs.
Pennsylvania	Working internally on a data standardization plan.
Tennessee	Have no plans to standardize currently, but hoping to learn from other DOTs.
Texas	Have no plans to standardize.
Utah	Working internally on a data standardization plan.
Vermont	Working with a regional group of other DOTs on a data standardization plan.
Virginia	Working internally on a data standardization plan.
Washington	Working internally on a data standardization plan.
West Virginia	Have no plans to standardize currently, but hoping to learn from other DOTs.
Wisconsin	—

—Not applicable.

Table 68. Question 30: Has your agency implemented (or is planning to implement) security standards or policies for e-Ticketing data, mobile devices, and vendor software applications?

State/Territory	Response
Alabama	No, but we have plans to implement security standards/policies.
Arkansas	No, but we have plans to implement security standards/policies.
Connecticut	No, but we have plans to implement security standards/policies.
Florida	Our security policies are the same for computing devices, and we abide by them.
Georgia	No, we don’t have plans to implement security standards/policies.
Illinois	No, we don’t have plans to implement security standards/policies.
Indiana	—
Iowa	—
Kansas	No, but we have plans to implement security standards/policies.
Kentucky	No, but we have plans to implement security standards/policies.
Maine	No, but we have plans to implement security standards/policies.
Minnesota	No, we don’t have plans to implement security standards/policies.
Mississippi	No, but we have plans to implement security standards/policies.
Missouri	No, but we have plans to implement security standards/policies.
Nebraska	No, but we have plans to implement security standards/policies.
Ohio	—
Oregon	No, we don’t have plans to implement security standards/policies.

State/Territory	Response
Pennsylvania	No, but we have plans to implement security standards/policies.
Tennessee	Yes, we have implemented security standards/policies.
Texas	No, we don’t have plans to implement security standards/policies.
Utah	No, we don’t have plans to implement security standards/policies.
Vermont	No, we don’t have plans to implement security standards/policies.
Virginia	No, but we have plans to implement security standards/policies.
Washington	No, but we have plans to implement security standards/policies.
West Virginia	No, but we have plans to implement security standards/policies.
Wisconsin	—

—Not applicable.

Table 69. Question 31: Do you plan to use e-Ticketing in the future?

State/Territory	Response	Comments
Alabama	Yes, currently piloting or preparing for a pilot.	—
Arkansas	Yes, currently piloting or preparing for a pilot.	—
Connecticut	Yes, currently piloting or preparing for a pilot.	Currently piloting two Connecticut DOT Projects.
Florida	—	We are using asphalt e-Ticketing on a good portion of projects (due to COVID) and plan to continue working with our asphalt contractors in moving toward making asphalt e-Ticketing a standard practice.
Georgia	—	—
Illinois	—	—
Indiana	Yes, currently piloting or preparing for a pilot.	—
Iowa	—	—
Kansas	Yes, currently piloting or preparing for a pilot.	We have only let one contract with e-Ticketing and work on the project has not started.
Kentucky	Yes, currently piloting or preparing for a pilot.	—
Maine	Yes, currently piloting or preparing for a pilot.	—
Minnesota	—	—
Mississippi	Yes, currently piloting or preparing for a pilot.	—
Missouri	Yes, currently piloting or preparing for a pilot.	—
Nebraska	Yes, currently piloting or preparing for a pilot.	Currently developing an in-house protocol that is similar to UDOT.
Ohio	—	—
Oregon	—	—
Pennsylvania	Yes, currently piloting or preparing for a pilot.	

State/Territory	Response	Comments
Tennessee	—	—
Texas	—	—
Utah	—	—
Vermont	—	—
Virginia	—	e-Ticketing is currently available.
Washington	Yes, currently piloting or preparing for a pilot.	—
West Virginia	Yes, currently piloting or preparing for a pilot.	—
Wisconsin	Yes, currently piloting or preparing for a pilot.	—

—Not applicable.

Table 70. Question 32: What is your anticipated time line for piloting?

State/Territory	Response
Alabama	Within 12 mo
Arkansas	—
Connecticut	Within 12 mo (currently piloting two active construction projects)
Florida	—
Georgia	—
Illinois	—
Indiana	—
Iowa	—
Kansas	Within 12 mo
Kentucky	Within 12 mo
Maine	Within 12 mo
Minnesota	—
Mississippi	Not sure
Missouri	Within 24 mo
Nebraska	Within 12 mo
Ohio	—
Oregon	—
Pennsylvania	Within 12 mo
Tennessee	—
Texas	—
Utah	—
Vermont	—
Virginia	—
Washington	—
West Virginia	Within 12 mo
Wisconsin	Within 12 mo

—Not applicable.

Table 71. Question 33A: What materials do you plan or hope to use e-Ticketing for in the future?

State/Territory	Asphalt	Millings	Aggregates	Concrete
Alabama	Under consideration for piloting	—	For later consideration (beyond the planned timeline)	For later consideration (beyond the planned timeline)
Arkansas	—	—	—	—
Connecticut	Under consideration for piloting	—	Under consideration for piloting	—
Florida	—	—	—	Under consideration for piloting
Georgia	—	—	—	—
Illinois	—	—	—	—
Indiana	—	—	—	—
Iowa	—	—	—	—
Kansas	Under consideration for piloting	For later consideration (beyond the planned timeline)	For later consideration (beyond the planned timeline)	For later consideration (beyond the planned timeline)
Kentucky	Under consideration for piloting	Under consideration for piloting	Under consideration for piloting	Under consideration for piloting
Maine	Under consideration for piloting	—	—	—
Minnesota	—	—	—	—
Mississippi	—	Under consideration for piloting	—	—
Missouri	Under consideration for piloting	—	—	—
Nebraska	Under consideration for piloting	Unsure at this point	Unsure at this point	For later consideration (beyond the planned timeline)
Ohio	—	—	—	—
Oregon	—	—	—	—
Pennsylvania	Under consideration for piloting	—	Under consideration for piloting	Under consideration for piloting
Tennessee	—	—	—	—
Texas	—	—	—	—
Utah	—	—	—	—
Vermont	—	—	—	—
Virginia	—	—	—	—

State/Territory	Asphalt	Millings	Aggregates	Concrete
Washington	—	—	—	—
West Virginia	Under consideration for piloting	—	For later consideration (beyond the planned timeline)	For later consideration (beyond the planned timeline)
Wisconsin	Under consideration for piloting	Unsure at this point	For later consideration (beyond the planned timeline)	Under consideration for piloting

—Not applicable.

Table 72. Question 33B: What materials do you plan or hope to use e-Ticketing for in the future?

State/Territory	Reinforcing Steel	Prefabricated Elements	Deicing Salt/Chemicals	Other Bulk Materials	Other Items	Please Specify Other Bulk Materials or Items
Alabama	—	—	—	—	—	—
Arkansas	—	—	—	—	—	—
Connecticut	—	—	—	—	—	—
Florida	—	—	—	—	—	One concrete e-Ticketing pilot was completed.
Georgia	—	—	—	—	—	—
Illinois	—	—	—	—	—	—
Indiana	—	—	—	—	—	—
Iowa	—	—	—	—	—	—
Kansas	—	—	—	—	—	—
Kentucky	Under consideration for piloting	Under consideration for piloting	Under consideration for piloting	—	—	—
Maine	—	—	—	—	—	—
Minnesota	—	—	—	—	—	—
Mississippi	—	—	—	—	—	—
Missouri	—	—	—	—	—	—
Nebraska	Unsure at this point	Unsure at this point	Unsure at this point	Unsure at this point	Unsure at this point	—
Ohio	—	—	—	—	—	—
Oregon	—	—	—	—	—	—
Pennsylvania	—	—	Under consideration for piloting	Under consideration for piloting	—	Liquid bituminous for maintenance projects
Tennessee	—	—	—	—	—	—
Texas	—	—	—	—	—	—
Utah	—	—	—	—	—	—
Vermont	—	—	—	—	—	—

State/Territory	Reinforcing Steel	Prefabricated Elements	Deicing Salt/Chemicals	Other Bulk Materials	Other Items	Please Specify Other Bulk Materials or Items
Virginia	—	—	—	—	—	—
Washington	—	—	—	—	—	—
West Virginia	—	—	—	—	—	—
Wisconsin	Unsure at this point	Unsure at this point	Unsure at this point	Unsure at this point	Unsure at this point	—

—Not applicable.

Table 73. Question 34: Which, if any, of these factors were considered a deterrent to the implementation of e-Ticketing?

State/Territory	Response
Alabama	• Receptivity of small contractors • Internet connectivity concerns • Manufacturer/producer/plant equipment upgrades
Arkansas	—
Connecticut	• Contractors have not requested • Receptivity of small contractors • Receptivity of midsize and large contractors • Receptivity of trucking/delivery operators • More education or training is needed for office staff • More education or training is needed for the field staff • More education or training is needed for the trucking/delivery operators • Access, privacy, or security concerns • Internet connectivity concerns • Limited use of mobile devices for field inspection • Manufacturer/producer/plant equipment upgrades • Lack of standard contract language/specifications
Florida	—
Georgia	—
Illinois	—
Indiana	—
Iowa	—
Kansas	• Receptivity of trucking/delivery operators • Processes do not exist to ensure security or accuracy is adequate for construction • Internet connectivity concerns • Limited use of mobile devices for field inspection
Kentucky	• Benefits of using e-Ticketing are unknown • Return on investment is not unproven • Contractors have not requested • Receptivity of DOT staff • Receptivity of small contractors • Receptivity of midsize and large contractors • Receptivity of trucking/delivery operators • More education or training is needed for office staff • More education or training is needed for the field staff • More education or training is needed for the trucking/delivery operators • Legal and/or liability concerns • Access, privacy, or security concerns • Internet connectivity concerns • Limited use of mobile devices for field inspection • High costs associated with software or hardware • Manufacturer/producer/plant equipment upgrades • Inadequacy of IT infrastructure/cellular service

State/Territory	Response
Maine	• Receptivity of small contractors • Receptivity of midsize and large contractors • Legal and/or liability concerns • Internet connectivity concerns • High vendor licensing fees • Manufacturer/producer/plant equipment upgrades • Inadequacy of IT infrastructure/cellular service
Minnesota	—
Mississippi	Contractors have not requested
Missouri	• Contractors have not requested • Receptivity of small contractors • Receptivity of midsize and large contractors • Receptivity of trucking/delivery operators • Access, privacy, or security concerns • Internet connectivity concerns
Nebraska	Internet connectivity concerns
Ohio	—
Oregon	—
Pennsylvania	—
Tennessee	—
Texas	—
Utah	—
Vermont	—
Virginia	—
Washington	—
West Virginia	• Access, privacy, or security concerns • Internet connectivity concerns • Limited use of mobile devices for field inspection • Inadequacy of IT infrastructure/cellular service
Wisconsin	• Receptivity of small contractors • Receptivity of midsize and large contractors • Receptivity of trucking/delivery operators • More education or training is needed for office staff • More education or training is needed for the field staff • Legal and/or liability concerns • Internet connectivity concerns • High vendor licensing fees • Inadequacy of IT infrastructure/cellular service

—Not applicable.

Table 74. Question 35: How have the following stakeholders reacted to your agency's use of e-Ticketing?

State/Territory	Small Contractors	Midsize and Large Contractors	DOT Staff and Construction Engineering Inspection	Material Suppliers	Trucking/Delivery Companies	Law/Vehicle Enforcement
Alabama	Neutral	Positively	Positively	Positively	Positively	Neutral
Arkansas	—	—	—	—	—	—
Connecticut*	—	Positively	Positively	—	—	—
Florida	Neutral	Neutral	Positively	—	—	—
Georgia	Neutral	Positively	Extremely positively	—	Neutral	Neutral
Illinois**	—	Positively	Positively	—	—	—
Indiana	Neutral	Positively	Neutral	Positively	Neutral	Neutral
Iowa	—	—	—	—	—	—
Kansas	—	Positively	Positively	—	—	—
Kentucky	Negatively	Neutral	Neutral	Neutral	Negatively	Neutral
Maine†	—	—	—	—	—	—
Minnesota	Negatively	Positively	Extremely positively	Positively	—	—
Mississippi	Neutral	Positively	Positively	Positively	Neutral	Neutral
Missouri	Negatively	Neutral	Positively	Neutral	Negatively	—
Nebraska	Negatively	Neutral	Positively	Neutral	Neutral	—
Ohio	—	—	—	—	—	—
Oregon	Neutral	Positively	Positively	Positively	Neutral	Neutral
Pennsylvania	Neutral	Positively	Positively	Positively	Positively	Neutral
Tennessee	Neutral	Extremely positively	Extremely positively	Positively	Neutral	—
Texas	—	—	—	—	—	—
Utah	Neutral	Positively	Positively	Positively	Neutral	Neutral
Vermont	Positively	Positively	Positively	Positively	Neutral	Neutral
Virginia	—	—	Positively	—	—	Neutral
Washington	Negatively	Extremely positively	Positively	Neutral	Neutral	Neutral
West Virginia	Neutral	Positively	Positively	Neutral	Neutral	Neutral
Wisconsin	—	—	—	—	—	—

—Not applicable.
*Comments from Connecticut: We only have data on two stakeholders as current use is limited.
**Comments from Illinois: Unknown for small contractors, material suppliers, truck and delivery companies, and law/vehicle enforcement (since still in piloting phase), so we left these fields blank.
†Comments from Maine: Difficult to answer. Not all small contractors think alike—some are very receptive, others not so much; same for other categories.

Table 75. Question 36: What will help you to consider or accelerate a pilot implementation of e-Ticketing?

State/Territory	Response	Comments
Alabama	• Leadership buy-in • Implementation guidance • Technical assistance	—
Arkansas	—	—
Connecticut	• Access to peer support • Leadership buy-in • Implementation guidance • Technical assistance	—
Florida	—	—
Georgia	—	—
Illinois	• Access to peer support • Implementation guidance • Technical assistance	—
Indiana	• Access to peer support • Implementation guidance • Technical assistance	—
Iowa	—	—
Kansas	• Access to peer support • Implementation guidance • Technical assistance	—
Kentucky	Implementation guidance	—
Maine	• Access to peer support • Leadership buy-in • Implementation guidance • Technical assistance	—
Minnesota	—	Assistance with funding for enhancement of Veta as the standardized MDMS tool. Currently trying to get some money from the National Road Research Alliance pooled fund; however, the money will not be enough to get this project done as fast as we would like. Assistance with spreading the word about the Veta Web for use in this application and for seeking support and further funding.
Mississippi	—	—
Missouri	• Access to peer support • Technical assistance	—
Nebraska	Implementation guidance	We are currently looking for a project to try our new protocol—hopefully in June or July.
Ohio	—	—

State/Territory	Response	Comments
Oregon	• Access to peer support • Implementation guidance • Technical assistance	—
Pennsylvania	—	Industry and department feedback from the first pilot season.
Tennessee	—	—
Texas	—	TxDOT/contractor joint interest for other materials.
Utah	• Leadership buy-in • Implementation guidance	—
Vermont	Implementation guidance	—
Virginia	—	—
Washington	—	Industry evolving and incorporating platforms to support e-Ticketing.
West Virginia	• Implementation guidance • Technical assistance	—
Wisconsin	Technical assistance	—

—Not applicable.

Table 76. Question 37: What would make it easier for you to advance, adopt, and use e-Ticketing technologies in your agency?

State/Territory	Responses
Alabama	—
Arkansas	—
Connecticut	A centralized platform for all suppliers, contractors, and trucking companies to use.
Florida	—
Georgia	—
Illinois	Industry's desire to implement this technology. If industry desires to use the technology, it will become the standard of practice without DOT forcing it, i.e., when technology improves efficiency (and is economically appropriate) people want to embrace it. The Illinois DOT is not ready to disallow satisfactory materials because a vendor cannot provide an e-Ticket.
Indiana	To get to full scale for HMA, concrete, and aggregates, smaller suppliers will need upgrades, cellular and wireless coverage in rural areas, and a DOT e-Ticketing system built to manage tickets from all contractor/vendor systems. Then, construction professional engineers and inspectors and the industry will need education and training.
Iowa	—
Kansas	—
Kentucky	—
Maine	—
Minnesota	Development of Veta MDMS; enhancements made to AWP to import MDMS data from Veta MDMS; and increased willingness from vendors to move toward standardized exports as outlined in the draft AASHTO provision. Smaller vendors do not appear to be as receptive to standardization.

State/Territory	Responses
Mississippi	—
Missouri	A reliable system that is not limited in rural areas with no cell service.
Nebraska	We are currently investigating the possible use of LoRaWAN technology to gain connectivity in rural areas with spotty/no cellular coverage.
Ohio	—
Oregon	Mostly coordination with our contractors: Big challenges to systemwide implementation include significant areas of the State that do not have viable access to data coverage (we likely will not require satellite data coverage).
Pennsylvania	We are in the process of piloting e-Ticketing and anticipate a full rollout by 2024.
Tennessee	—
Texas	Documented situational cost savings and efficiencies; buy-in.
Utah	More support from material suppliers.
Vermont	Contractors' buy-in and reliable forms of e-Ticketing in remote locations.
Virginia	—
Washington	Industry buy-in.
West Virginia	Experience and knowledge from other agencies that successfully adopted e-Ticketing, development of a standardized business process with e-Ticketing, and additional mobile devices with better cellphone coverage.
Wisconsin	—

—Not applicable.

ACKNOWLEDGMENTS

This report presents the results of research conducted by the authors and does not necessarily represent the views or policies of the State DOTs, vendors, or construction contractors whose policies and practices have been referenced, or who shared their insights via interviews.

This project is possible due to FHWA for funding, AASHTO for survey administration, and the State DOTs for leading efforts to implement e-Ticketing. The contribution of the following individuals and entities is also acknowledged:

- Casey Soneira AASHTO
- Alec Harris ALDOT
- Billy Sweeney DelDOT
- Craig Blowers DelDOT
- Cedric Wilkinson Iowa DOT
- Rebecca Embacher MnDOT
- Andy Dearmont NDOT
- Bryan Edwards NCDOT
- Janet Treadway Ohio DOT
- Kelly Barber PennDOT
- John Myler PennDOT
- Ken Talbot UDOT
- Adrian Sellars UDOT
- Heather Purdy Hall TDOT
- Kevin Waligorski WSDOT
- Greg Nadeau National e-Ticketing Task Force
- e-Ticketing vendors
- Suppliers

REFERENCES

AASHTO. Forthcoming. *Standard Specification for Material Delivery Management Systems*. Washington, DC: American Association of State Highway and Transportation Officials.

AASHTO. n.d.a. "Agency Administration Managing Committee" (web page). https://agencyadmin.transportation.org/aashto-regions/, last accessed January 29, 2023.

AASHTO. n.d.b. "AASHTOWare Project" (web page). https://www.aashtowareproject.org/, last accessed January 29, 2023.

AASHTO. n.d.c. "AASHTOWare Pavement M-E Design" (web page). https://www.aashtoware.org/products/pavement/pavement-overview, last accessed January 29, 2023.

AASHTO. n.d.d. "AASHTOWare Bridge" (web page). https://www.aashtoware.org/products/bridge/bridge-overview, last accessed January 29, 2023.

Aurigo. n.d. "Masterworks Cloud Platform" (web page). https://www.aurigo.com/masterworks-cloud-platform/, last accessed January 29, 2023.

CFR. 2013a. "Determination and Documentation of Pay Quantities." 23 CFR § 635.123. https://www.govinfo.gov/content/pkg/CFR-2013-title23-vol1/xml/CFR-2013-title23-vol1-sec635-123.xml, last accessed May 25, 2022.

CFR. 2013b. "Retention Requirements for Records." 2 CFR § 200.334. https://www.ecfr.gov/current/title-2/subtitle-A/chapter-II/part-200/subpart-D/subject-group-ECFR4acc10e7e3b676f/section-200.334, last accessed May 25, 2022.

Dadi, B. J., R. E. Sturgill, D. Ames, D. Patel, C. Van Dyke, and G. Mulder. 2020. *Electronic Ticketing of Materials for Construction Management*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25839, last accessed May 25, 2022.

Dama International. 2017. *DAMA-DMBOK: Data Management Body of Knowledge*. 2nd ed. Basking Ridge, NJ: Technics Publications, LLC.

DelDOT. 2022. "Part F—eConstruction. Section F3.00—Unifier Documentation" (web page). https://constructionmanual.deldot.gov/index.php/Part_F_-_eConstruction, last accessed May 25, 2022.

DelDOT. n.d. "My DOT Portal" (web page). https://tickets.deldot.gov/, last accessed January 29, 2023.

Boomi. 2023. Boomi (web page). https://boomi.com/, last accessed January 29, 2023.

Embacher, R. 2021. *Use of Material Delivery Management System (MDMS) for Asphalt Paving Applications*. Report No. MN 2021-10. Maplewood, MN: Minnesota Department of Transportation. https://mndot.gov/research/reports/2021/202110.pdf, last accessed May 25, 2022.

Esri. n.d.a. "ArcGIS Online" (web page). https://www.arcgis.com, last accessed January 29, 2023.

Esri. n.d.b. "ArcGIS Survey 123" (web page). https://www.esri.com/en-us/arcgis/products/arcgis-survey123/overview, last accessed by January 29, 2023.

FHWA. 2015. *e-Construction Peer-to-Peer Exchange Summary Report, Iowa and North Dakota Departments of Transportation*. Washington, DC: Federal Highway Administration. https://www.fhwa.dot.gov/construction/econstruction/peer_exchange/ia_nd.pdf, last accessed May 25, 2022.

FHWA. 2017. *Federal Highway Administration (FHWA) Cybersecurity Program (CSP) Handbook*. Washington, DC: Federal Highway Administration. https://www.fhwa.dot.gov/legsregs/directives/orders/csp_handbook.pdf, last accessed May 25, 2022.

FHWA. 2019. *Every Day Counts: An Innovation Partnership With States*. EDC-4 Final Report. Washington, DC: Federal Highway Administration. https://www.fhwa.dot.gov/innovation/everydaycounts/reports/edc4_finalreport.pdf, last accessed May 25, 2022.

FHWA. 2020. "Highway Statistics 2019" (web page). https://www.fhwa.dot.gov/policyinformation/statistics/2019, last accessed January 29, 2023.

FHWA. 2021. "e-Construction" (web page). https://www.fhwa.dot.gov/construction/econstruction/, last accessed May 25, 2022.

General Services Administration. n.d. "Federal Risk and Authorization Management Program (FedRAMP)" (website). https://www.fedramp.gov/, last accessed January 29, 2023.

Hefner, R. and P. J. Breen. 2004. *Construction Vehicle and Equipment Blind Area Diagrams*. Report No. 200-2002-00563. Washington, DC: Centers for Disease Control. https://www.cdc.gov/niosh/topics/highwayworkzones/bad/pdfs/catreport2.pdf, last accessed January 29, 2023.

Iowa DOT. 2007. "Employee Killed on I-235 Project." *Inside,* January 2007, p. 3. https://iowadot.gov/inside/inside_january_2007.pdf, last accessed May 25, 2022.

Iowa DOT. 2015. "eTicketing Show Promise of Speeding Process and Improving Accuracy at Asphalt Job Sites." *Transportation Matters for Iowa*, December 17, 2015. https://www.transportationmatters.iowadot.gov/2015/12/eticketing-show-promise-of-speeding-process-and-improving-accuracy-at-asphalt-job-sites.html, last accessed January 29, 2023.

Iowa DOT. 2016. "Improving Accountability in the Construction Process with eTicketing for Concrete loads." *Transportation Matters for Iowa*. , November 21, 2016. https://www.transportationmatters.iowadot.gov/2016/11/for-iowa-department-of-transportation-inspectors-tablet-computers-are-quickly-becoming-the-most-essential-tool-on-a-construc.html, last accessed January 29, 2023.

Iowa DOT. 2021. *Developmental Specifications For e-Ticketing*. Ames, IA: Iowa Department of Transportation. https://iowadot.gov/specifications/dev_specs/2015/DS-15091.pdf, last accessed May 25, 2022.

Iowa DOT. n.d. "State Transportation Innovation Council" (web page). https://iowadot.gov/research/Programs-and-Partnerships/STATE-TRANSPORTATION-INNOVATION-COUNCIL, last accessed January 29, 2023.

Mallela, J., and A. Bhargava. 2021. *Advancing BIM for Infrastructure: National Strategic Roadmap*. Report No. FHWA-HRT-21-064. Washington, DC: Federal Highway Administration. https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/21064/index.cfm, last accessed January 29, 2023.

Metrolinx. 2021. *Business Case Manual Volume 2: Guidance*. Toronto, ON, Canada: Metrolinx. https://assets.metrolinx.com/image/upload/v1663237565/Documents/Metrolinx/Metrolinx-Business-Case-Guidance-Volume-2.pdf, last accessed January 29, 2023.

Microsoft. 2023a. "Microsoft Azure: Cloud Computing Services" (web page). https://azure.microsoft.com/en-us, last accessed by January 29, 2023.

Microsoft. 2023b. "Microsoft 365 SharePoint" (web page). https://www.microsoft.com/en-us/microsoft-365/sharepoint/collaboration, last accessed by January 29, 2023.

Microsoft. 2023c. "Microsoft 365 Excel" (web page). https://www.microsoft.com/en-us/microsoft-365/excel, last accessed by January 29, 2023.

MnDOT. n.d. "Materials and Road Research: Veta" (web page). https://www.dot.state.mn.us/materials/amt/veta.html, last accessed by January 29, 2023.

MnDOT. 2022. MnDOT Standard Specifications for Construction and Supplemental Specifications. 2020 Edition. St. Paul: Minnesota Department of Transportation. https://www.dot.state.mn.us/pre-letting/spec, last accessed by January 29, 2023.

National Asphalt Pavement Association. 2020. *e-Ticketing Synopsis*. Greenbelt, MD: National Asphalt Pavement Association. https://www.asphaltpavement.org/uploads/documents/State_E_Ticketing.pdf, last accessed October 24, 2021.

National e-Ticketing Task Force. 2022. "National e-Ticketing Task Force" (website). https://e-ticketingtaskforce.org/, last accessed January 29, 2023.

NCDOT. n.d. "Connect NCDOT: Construction Project Support" (web page). https://connect.ncdot.gov/projects/construction/Pages/default.aspx, last accessed January 29, 2023.

NIOSH. 2022a. "Highway Work Zone Safety" (web page). https://www.cdc.gov/niosh/topics/highwayworkzones/, last accessed January 29, 2023.

NIOSH. 2022b. "Fatality Assessment and Control Evaluation (FACE) Program" (web page). https://www.cdc.gov/niosh/face/default.html, last accessed January 29, 2023.

NIST. 2002. *Security Requirements for Cryptographic Modules*. FIPS PUB 140-2. Gaithersburg, MD: National Institute of Standards and Technology. https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.140-2.pdf, last accessed May 25, 2022.

NIST. 2004. *Standards for Security Categorization of Federal Information and Information Systems*. FIPS PUB 199. Gaithersburg, MD: National Institute of Standards and Technology. https://nvlpubs.nist.gov/nistpubs/fips/nist.fips.199.pdf, last accessed May 25, 2022.

NIST. 2006. *Minimum Security Requirements for Federal Information and Information Systems*. FIPS PUB 200. Gaithersburg, MD: National Institute of Standards and Technology. https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.200.pdf, last accessed May 25, 2022.

NIST. 2022. "Computer Security Resource Center" (web page). https://csrc.nist.gov/publications/fips, last accessed January 29, 2023.

NWZSIC. 2022. "Worker Fatalities and Injuries at Road Construction Sites" (web page). https://workzonesafety.org/work-zone-data/worker-fatalities-and-injuries-at-road-construction-sites/, last accessed May 25, 2022.

OFR NARA. 2002. Public Law 107–347 E-Government Act of 2002. U.S. Government Printing Office. https://www.govinfo.gov/app/details/PLAW-107publ347, last accessed December 1, 2022.

OGC. 2023. "OGC LandInfra/InfraGMP*"* (web page). https://www.ogc.org/standards/infragml, last accessed January 29, 2023.

Oracle. 2023. "Capital Program Management: Project Controls and Facilities Management: Primavera Unifier" (web page). https://www.oracle.com/industries/construction-engineering/unifier-project-controls-asset-management/, last accessed by January 29, 2023.

PennDOT. 2020a. *e-Ticketing Construction Specification*. Harrisburg, PA: Associated Pennsylvania Constructors. https://www.paconstructors.org/wp-content/uploads/2020/10/Eticketing_Construction_Specification.pdf, last accessed May 25, 2022.

PennDOT. 2020b. *e-Ticketing Maintenance Specification*. Harrisburg, PA: Associated Pennsylvania Constructors. https://www.paconstructors.org/wp-content/uploads/2020/10/Eticketing_Maintenance_spec.pdf, last accessed May 25, 2022.

PennDOT. 2021. eCAMMS (web page). https://www.ecamms.pa.gov/Public/Home.aspx, last accessed January 29, 2023.

Ross, R. 2013. *Security and Privacy Controls for Federal Information Systems and Organizations*. SP 800-53 Rev. 4. Gaithersburg, MD: National Institute of Standards and Technology.

Sadasivam, S., and R. Sturgill. 2021. *e-Ticketing Handout*. TechNote No. FHWA-HRT-22-044. Washington, DC: Federal Highway Administration. https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/22044/22044.pdf, last accessed January 29, 2023.

Safe Software. 2023. "Empower Your Business With FME" (web page). https://www.safe.com/fme/, last accessed by January 29, 2023.

Shah, K., A. Mitchell, D. Lee, and J. Mallela. 2017. *Addressing Challenges and Return on Investment (ROI) for Paperless Project Delivery (e-Construction)*. Report No. FHWA-HIF-17-028. Washington, DC: Federal Highway Administration. https://www.fhwa.dot.gov/construction/econstruction/hif17028.pdf, last accessed May 25, 2022.

Momentive. n.d. "SurveyMonkey" (web page). https://www.surveymonkey.com, last accessed January 29, 2023.

Talbot, K., and A. Sellars. 2020. "Utah's Use of Existing Software for e-Ticketing." Presented at the *AASHTO Committee on Construction Virtual Annual Meeting, August 10–13, 2020*. https://construction.transportation.org/wp-content/uploads/sites/20/2020/08/Utahs-use-of-existing-software-for-e-Ticketing.pdf, last accessed March 15, 2023.

Tennessee State Government. 2021. *Special Provision Regarding Electronic Ticket Delivery System for Asphalt*. Nashville, TN: Tennessee State Government. https://www.tn.gov/content/dam/tn/tdot/construction/special-provisions/Const-109ETAS.pdf, last accessed May 25, 2022.

Tennessee State Government. 2022. *Qualified E-Ticketing Software Products.* Nashville, TN: Tennessee State Government. https://www.tn.gov/content/dam/tn/tdot/hq-materials-tests/field-operations/E-ticketing_Options.pdf, last accessed May 25, 2022.

Tinella, C. 2021. “LoRa® Combined With BLE Creates Complementary Hybrid IoT Connectivity.” *Inside Out: Semtech’s Corporate Blog*, September 8, 2021. https://blog.semtech.com/lora-combined-with-ble-creates-complementary-hybrid-iot-connectivity, last accessed May 25, 2022.

Van Ness, N. J. 1989. Norman J. Van Ness to Regional Federal Highway Administrators, Federal Lands Highway Program Administrator, memorandum, “Computerization of Construction Record,” September 21, 1989. Washington, DC: Federal Highway Administration. https://www.fhwa.dot.gov/construction/contracts/890921.cfm, last accessed May 25, 2022.

Weseman, W. A. 1993. William A. Weseman to Volmer K. Jensen, memorandum, “Electronic Security Issues,” July 7, 1993. Washington, DC: Federal Highway Administration. https://www.fhwa.dot.gov/construction/contracts/930707.pdf, last accessed May 25, 2022.

WSDOT. 2022. *Standard Specifications for Road, Bridge, and Municipal Construction. M 41-10.* Olympia, WA: Washington State Department of Transportation. https://wsdot.wa.gov/publications/manuals/fulltext/M41-10/SS2022.pdf, last accessed January 29, 2023.

WSDOT. 2023. *Standard Specifications for Road, Bridge, and Municipal Construction. M 41-10*. Olympia, WA: Washington State Department of Transportation. https://www.wsdot.wa.gov/publications/manuals/fulltext/m41-10/ss.pdf, last accessed January 29, 2023.

Recommended citation: Federal Highway Administration,
Documenting Effective e-Ticketing Implementation
(Washington, DC: 2023) https://doi.org/10.21949/1521991

HRDI-20/06-23(WEB)E