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IMPACT OF AUGMENTED DOCUMENTATION WORKFLOWS ON TRANSPORTATION AGENCY ASPHALT PAVING OPERATIONS: A QUALITATIVE AND QUANTITATIVE STUDY

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DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Engineering
at the University of Kentucky

By
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2024

ABSTRACT OF DISSERTATION

IMPACT OF AUGMENTED DOCUMENTATION WORKFLOWS ON TRANSPORTATION AGENCY ASPHALT PAVING OPERATIONS: A QUALITATIVE AND QUANTITATIVE STUDY

e-Ticketing was an intriguing technology to many state transportation agencies (STAs) pre-COVID-19 pandemic but gained significant attention upon arrival of the pandemic due to the contactless nature of the technology. Research completed prior to the pandemic into e-ticketing for asphalt paving primarily identified qualitative benefits and concerns. However, minimal academic literature exists in the post-pandemic era discussing the additional e-ticketing benefits not previously captured which resulted in increased implementation by STAs. This research seeks to address this gap by gathering information from state members of the American Association of State Highway and Transportation Officials Committee on Construction (AASHTO COC), employees of the Kentucky Transportation Cabinet (KYTC), and members of the Kentucky Association of Highway Contractors (KAHC) and the Plantmix Asphalt Industry of Kentucky (PAIKY) regarding e-ticketing practices for asphalt paving in the post-pandemic era.

The first portion of the study combines national and state-level survey responses to create a qualitative benefit-cost analysis for e-ticketing for asphalt paving operations based upon experience gained through emergency implementation during the pandemic. To reinforce the results of the qualitative analysis and increase the power of the study, the second portion of the research creates a quantitative benefit-cost analysis (BCA) from data collected from KYTC construction projects to compare the traditional weigh ticket collection process with e-ticketing processes for both project engineers and inspectors. The analysis shows a statistically significant time savings for field employees but not project management personnel. The monetary analysis for Kentucky indicates that while e-ticketing does not result in significant time savings for all employees, there is substantial monetary benefit worthy of STAs adopting e-ticketing as policy. Cluster analysis was completed for both project engineers and inspectors to group project types where e-ticketing impact was maximized, and a decision matrix was created to aid agencies in creating implementation plans.

The primary contributions to the body of knowledge include an improved BCA methodology utilizing a modified action research approach applied to a new domain of electronic bulk material tickets and an informed quantitative valuation framework useful for STAs as a proof-of-concept to champion and effectively implement e-ticketing and by transportation-focused researchers for evaluating emerging technological applications.

KEYWORDS: Asphalt Paving, Benefit-Cost Analysis, Cluster Analysis, E-Ticketing, Implementation

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04/05/2024

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CHAPTER 1. INTRODUCTION

1.1 Problem Statement

As of 2019, the centerline mileage of roadways within the United States was approximately 4.1 million (Epps, 2019). Additionally, nearly two-thirds of this roadway mileage is paved, and more specifically, asphalt accounts for nearly 94% of the paved mileage surface type (Epps, 2019). In 2017, approximately 375 million tons of traditional asphalt mixtures were produced nationally (Williams et al., 2018). Depending on the specific requirements of the asphalt mixture, the in-place price (cost of material and construction) can exceed $70-$75 per ton (Epps, 2019). Therefore, state transportation agencies (STAs) and other public owners expend a significant number of resources (human, capital, etc.) completing required operations to construct and maintain these roadways for the public use.

Typically, public construction contracts use unit-price constructs, which break the work to be completed down on a per-unit basis and require contractors to submit pricing based upon anticipated quantities in the contract documents (Gransberg and Riemer, 2009). Therefore, meticulous documentation must be retained by STAs that support payment records based upon the supplied materials and construction activities completed. Since highway and heavy civil projects are generally dependent on large quantities of materials, large amounts of data are historically kept on paper and transferred between the material supplier, the project, and an office location. However, this traditional documentation workflow has created concerns over time.

For asphalt specifically, the construction operation places STA project inspectors in hazardous scenarios due to their proximity to heavy equipment and passing traffic within the work zone. This scenario is illustrated by Figures 1.1 and 1.2 (Federal Highway Administration, 2020c). The project inspector has multiple responsibilities for a standard asphalt paving project, including weigh ticket receipt and acceptance, tracking of theoretical tonnage, asphalt material temperature monitoring, compaction operation monitoring, coordination of density measurements and material samples, and traffic control monitoring (Newcomer et al., 2019). The combination of these factors increases the potential for worker accidents on the project site. However, many of these potential injuries and fatalities are preventable and can be minimized with newer and safer project practices.

Figure 1.1 Contractor Paving Crew placing Asphalt Material (From FHWA, 2020c)

Figure 1.2 Inspection of Asphalt Material (From FHWA, 2020c)

An example of the required information to be collected on the weigh ticket is shown in Figure 1.3 (Kentucky Transportation Cabinet, 2009). This investigation into safer project practices has been aid through the Federal Highway Administration (FHWA) Every Day Counts (EDC) technology implementation initiative. The current FHWA EDC cycle specifically focuses on e-ticketing, or the provision for all project stakeholders to "produce, transmit, and share materials data and track and verify materials deliveries" electronically (Federal Highway Administration, 2021a). E-ticketing can provide benefits in terms of project personnel safety, time savings, and project quality. Electronic data collection reduces exposure of STA project inspectors to potential injury from contractor equipment or civilian traffic while attempting to retrieve a paper material ticket from the delivery driver. The elimination of this job duty for project inspectors also allows them to utilize their expertise in more critical areas, such as project material quality control and quality assurance. Access to electronic ticket information can also streamline the processing time required for material delivery verification and payment review by the STA project inspector. By keeping all files strictly electronic, payment on project estimates will not have to be postponed until paper weigh tickets that were lost or damaged in the field can be reprinted and replaced. Finally, the elimination of transferring data from a physical delivery ticket to an electronic storage system is more efficient and can be archived for future STA usage in design, construction, and maintenance of the roadway network (Federal Highway Administration, 2021a).

TRANSPORTATION CABINET
DEPARTMENT OF HIGHWAYS
DIVISION OF CONSTRUCTION

TC 63-12
Rev. 5/87

PCN: __________

DAILY REPORT OF WEIGHED MATERIALS

PROJECT NO. ______________________________ COUNTY ______________

TYPE OF MATERIAL ______________________________ DATE ______________ 19____

SCALES LOCATED AT ____

MAINT. TCT NO. ______________ ELECTRONIC SCALES (YES) (NO) SHEET ________ OF ________

TRUCK NO.	GROSS POUNDS	TARE POUNDS	NET POUNDS	TICKET NO.	REMARKS
TOTALS					

*TOTAL WEIGHED __________ TONS | | TOTAL NET PAY QUANTITY (TONS)

*I ______________________________ (Plant Manager) (KYTC Employee) DO HEREBY CERTIFY THAT THE ABOVE QUANTITY OF MATERIAL WAS FOR THE SOLE USE AND BENEFIT OF THE COMMONWEALTH OF KENTUCKY.

PAY QUAN. COMPILED BY: ______________________ CHECKED BY: ______________________

APPROVED: ______________________
PROJECT ENGINEER

White - From Weighman to Project Engineer
Canary - From Weighman to Contractor
Pink - Retained by Weighman
Goldenrod - From Weighman to Vendor

NOTE: Each kind of material must be listed on separate sheets.

Figure 1.3 Weighed Materials Daily Report Example (From KYTC Construction Guidance Manual)

1.2 Research Objectives

The first pilot project in the United States to incorporate e-ticketing was conducted by the Iowa Department of Transportation in 2015 (Dadi et al., 2020). Since 2015, several STAs have tested various e-ticketing systems as potential replacements for traditional paper ticket collection methods. This includes pilot projects in Alabama, Pennsylvania, Florida, Kentucky, Virginia, and other states (Powe, 2020). However, each STA still faces challenges, such as whether to procure an e-ticketing system from an outside vendor or create an in-house version, or how to overcome resistance to adaption from both inside and outside the agency (Dadi et al., 2020).

One of the major findings of *NCHRP Synthesis 545: Electronic Ticketing of Materials for Construction Management* was that there was still a widespread need for a deeper understanding of the value offered by e-ticketing technologies (Dadi et al., 2020). This need was identified directly from an STA survey completed as part of the research effort, and therefore could meet a major industry need in determining the value added to an STA using available innovative technologies. While many STAs agree that e-ticketing has a visible benefit, there has not been a definitive study conducted to produce finite evidence as to the exact costs saved by an agency through implementation of e-ticketing.

1.3 Research Scope

The proposed research focuses primarily upon e-ticketing, which is a subcategory of e-Construction. This research seeks to determine whether adoption and implementation of e-ticketing in STA operations is beneficial, which is a stated goal of the Federal Highway Administration under the Every Day Counts Phase 6 (EDC-6) initiative (Weisner and Torres, 2020). e-Ticketing has previously been investigated for use in combination with other e-Construction technologies such as Intelligent Compaction and Infrared Thermal Scanning for asphalt paving operations (Dadi et al., 2020). However, for the purposes of the proposed research, e-ticketing will be evaluated in a standalone environment, although there is the potential that if adopted by STAs, this technology could be combined with others for future use.

This proposed research will bridge the existing knowledge gap between estimated savings and benefits for STAs and track real costs and benefits. It will evaluate the potential benefit of an STA implementing e-ticketing systems beyond strictly a comparison of positive and negative factors while looking at whether implementation of the technology also connects with a STAs goals and stated mission.

1.4 Research Questions

Through the larger task of determining whether e-ticketing is worthy for full-scale implementation in STA operations, the research outlined later in this dissertation also lends itself to considering several foundational questions.

1. Does the use of e-ticketing align with an STA's mission statement?
2. What are project stakeholder opinions of e-ticketing technology given their current experiences? Are there existing roadblocks to stakeholder buy-in? If so, what improvements could be made?
3. Could e-ticketing implementation be a primary step to encourage greater e-construction principle use? With stakeholder support, e-ticketing could become a

foundational step to creating data-driven archives to further promote the cooperation between STA construction and maintenance activities.

1.5 Research Outline

The research presented in the following chapters has four primary objectives that are shown below.

1. Determine the progression of e-ticketing use for asphalt paving in STA policy nationally from pre-pandemic to post-pandemic operations. (Chapter 2, in Withrow, J., Dadi, G. B., and Nassereddine, H. (2024). "Progression of E-Ticketing Implementation for State Transportation Agencies for Asphalt Materials." *Journal for Road Engineering*. 4(1), 80-92. https://doi.org/10.1016/j.jreng.2023.03.003)
2. Examine potential benefits and concerns of e-ticketing adoption for asphalt paving through an in-depth analysis utilizing a case study methodology to create an updated qualitative benefit-cost analysis. (Chapter 3, in Withrow, J., Dadi, G.B., Nassereddine, H., and Sturgill, R.E. (2023). "Asphalt Material e-Ticketing Workflow: A Qualitative and Quantitative Analysis." *Journal of Construction Engineering and Management*. American Society of Civil Engineers, 150(3). DOI: 10.1061/JCEMD4.COENG-13945)
3. Develop a quantitative benefit-cost analysis using a case study methodology focused on actual STA projects including asphalt paving operations. (Chapter 3, in Withrow, J., Dadi, G.B., Nassereddine, H., and Sturgill, R.E. (2023). "Asphalt Material e-Ticketing Workflow: A Qualitative and Quantitative Analysis."

Journal of Construction Engineering and Management. American Society of Civil Engineers, 150(3). DOI: 10.1061/JCEMD4.COENG-13945)

4. Investigate the impact of e-ticketing on various project stakeholders using the case study methodology to improve recommendations for STA implementation efforts beyond the previously anecdotal process. (Chapter 4, in Withrow, J., Nassereddine, H., Dadi, G.B., and Sturgill, R.E. (under review). "A Quantitative Analysis Towards Guidance for Implementing E-Ticketing for Asphalt Paving Operations." *Transportation Research Record*)

This research will provide conclusive evidence for STAs to determine whether implementation of e-ticketing practices is a sound investment while also quantifying the potential savings that may be reallocated by various stakeholders.

CHAPTER 2. PROGRESSION FOR E-TICKETING FOR STATE TRANSPORTATION AGENCIES FOR ASPHALT MATERIALS

2.1 Introduction

Highway and infrastructure construction projects generate large amounts of data over the project lifetime (Nipa et al, 2019). Many construction contracts center around unit bid prices, and documentation must be retained through the life of a project to verify paid quantities for items measured by weight. Historically, State Transportation Agencies (STAs) have collected paper weigh tickets to verify material delivery to a project site. However, this traditional documentation methodology creates concerns regarding worker safety and workflow efficiency.

2.1.1 Concerns regarding Worker Safety and Workflow Efficiency

This practice of paper weigh ticket collection has resulted in project inspectors being placed in hazardous scenarios due to their proximity to both heavy equipment and high-speed traffic in the work zone (Embacher, 2021; Tripathi et al, 2022). Between 2005 and 2010, the primary causes of worker fatalities on roadway construction projects were runovers/backovers at 48%, vehicular collisions at 14%, and caught in between/struck by construction equipment at 14% (Federal Highway Administration, 2020b). Additionally, one work zone fatality occurs for every $112 million worth of roadway construction expenditures (Federal Highway Administration, 2021b).

In addition to the safety risks, the typical workflow of transferring data from a plant or quarry is inefficient and human-dependent, which is problematic from a material records perspective (Navon and Shpatnitsky, 2005; Kasim, 2015). Electronic data at the plant or quarry is transferred onto physical paper tickets delivered to the project by the haul vehicle driver, which is then passed along to the STA project inspector and re-scanned to an electronic storage space at the construction office at the end of a shift. Sadasivam et al. (2021) noted the considerable number of resources required by both contractors/producers and STAs to produce, record, and archive physical weigh tickets with minimal traceability and limited future use for the physical data.

2.1.2 Need for Process Digitization

These inefficiencies with collecting and using data place more emphasis on the need for innovative technologies to digitize the current process. As an additional benefit, researchers have also shown that the use of innovative technologies can help counteract decreasing in-house staffing levels that many STAs have to address (Taylor and Maloney, 2013; Newcomer et al., 2019). *National Cooperative Highway Research Program* (*NCHRP) Synthesis 450: Forecasting Highway Construction Staffing Requirements* states that, "STAs are managing larger roadway systems with fewer in-house staff than they were 10 years ago. For the 40 STAs that responded to the survey, between 2000 and 2010 state-managed lane miles increased by an average of 4.10%, whereas the number of full-time equivalents (FTE) decreased by 9.68%" (Taylor and Maloney, 2013).

As the existing national infrastructure ages and needs repairs, the number of projects required to complete necessary construction activities increases, resulting in additional hazardous scenarios for a decreasing number of STA project inspectors. Therefore, STAs must investigate new methods to automate required tasks traditionally performed by in-house personnel for the improved safety of their workforce by eliminating unsafe working conditions (Chi et al., 2013; Xu et al., 2022). Newly implemented methodologies may also allow STAs to gain improved project data retention and management, but to accomplish this, an emphasis must be placed on incorporating existing but under-utilized innovative technologies. To implement a formal policy change, a commitment from top-level management is critical along with a proper evaluation before the introduction of a field solution (Kasana et al., 2020).

Asphalt paving is one of the most significant inspection activities for STA personnel and ideal for targeting technology deployment in the field due to the quantitative nature of the inspection (Newcomer et al., 2019). Efforts to introduce technology to the weigh ticket collection process have been aided by the Federal Highway Administration (FHWA) "Every Day Counts" (EDC) technology implementation initiative. The EDC-6 cycle specifically focuses on e-ticketing, or the provision for all project stakeholders to "produce, transmit, and share materials data and track and verify material deliveries" electronically while integrating "material data with construction management systems for acceptance, payment and source documentation" (Federal Highway Administration, 2021a). The same data found on paper weigh tickets, such as time/date, project name/number, ticket number, haul vehicle information, and material name/tonnage, can be tracked and archived completely electronically with an e-ticketing system, with the additional benefit of moving STA project inspectors away from potentially dangerous scenarios within the work zone (Wilkinson and Schroeder, 2020). E-ticketing also allows STA project inspectors to upload field notes onto specific ticket files, such as temperature readings, load delivery times, quality assurance sampling information, or load rejection and waste tonnage by accessing the digital ticket file on electronic devices such as a phone or tablet, which are generally accessible in the field.

Once saved within the e-ticketing system, this information is immediately visible and available for download by any project stakeholder, unlike with traditional paper weigh tickets. The collection of this information in an electronic format also allows STA project inspectors to focus on the primary interconnected factors of construction: quality, compliance, and progress (Lu et al., 2022).

2.1.3 Research Drivers

However, as a rule of thumb, many large organizations tend to resist change, and STAs are no exception to this rule. Implementing new methodologies, such as an alteration to material documentation, can disrupt a status quo that has been set for decades and encounter significant stakeholder resistance. Kimmel et al. (2015) note that the public road construction sector is "inertially bound" or slow to seek and adopt innovative technologies produced by industry. *NCHRP Special Report 249: Building Momentum for Change* states that innovation barriers are "widespread", "complex", and "deeply embedded" and points to institutional inertia as a considerable cultural aspect to be overcome within the highway construction sector (Transportation Research Board, 1996).

Therefore, the need to combat the potential for institutional inertia regarding adopting e-ticketing as a standard of practice drives this research effort. Due to the previously noted safety risks and workflow inefficiencies, e-ticketing appears to meet the requirements of STAs to continue to collect required project data while both protecting employees and better utilizing construction data to inform transportation network management. However, the first step in encouraging the use of e-ticketing systems for asphalt paving applications is to show the potential benefits of implementation, which was pointed out as a primary research need by Dadi et al. (2020).

The goal of the research presented in this paper is two-fold: first, determine the progression of e-ticketing use for asphalt paving in STA policy nationally from pre-pandemic to post-pandemic while second, examine potential benefits and concerns of e-ticketing adoption for asphalt paving through an in-depth analysis by utilizing the Kentucky Transportation Cabinet (KYTC) as a case study. By tracking the progression of various STAs in their implementation efforts, lessons can be learned and shared between STAs who could be classified as early adopters and those who may be beginning the process. Additionally, collecting potential benefits and concerns of e-ticketing adoption allows for discussion of methods to mitigate concerns, which by extension can encourage further e-ticketing adoption as a STA standard of practice.

This chapter is organized into four subsections. Previous e-construction and e-ticketing implementation efforts are first described. Then, the research methodology is outlined. Next, the survey and case study results are presented, analyzed, and discussed. Finally, the chapter concludes with contributions regarding the stated research outcomes and areas of future research.

2.1.4 Literature Background

FHWA began the EDC program in 2009, and in the 2015-2016 cycle featured e-Construction as a select innovation during EDC-3 (Dadi et al., 2020). For this phase of the EDC program, FHWA determined e-Construction to be defined as "the collection, review, approval and distribution of construction contract documents in a paperless environment" (Federal Highway Administration, 2017). The EDC-4, 2017-2018, cycle remained focused on e-Construction as an innovation, but the emphasis shifted to a combined focus on e-Construction and Partnering (Federal Highway Administration, 2017). The baseline report for the EDC-4 cycle showed that significant progress had been made incorporating e-Construction principles from EDC-3. FHWA also viewed EDC-4 as an opportunity to promote e-ticketing as an innovation to be utilized by STAs who had become more receptive to e-Construction principles after the introduction under EDC-3. The statuses for each EDC cycle are shown in Table 2.1.

Table 2.1 EDC-3 Baseline Report Statuses (FHWA, 2015) and EDC-4 Baseline Report Statuses (Adopted from FHWA, 2017)

	EDC-3		**EDC-4**	
	Baseline (January 2015)	**Goal (December 2016)**	**Baseline (January 2017)**	**Goal (December 2018)**
Implementation	1	16	13	21
Assessment	5	9	10	19
Demonstration	10	11	12	9
Development	27	9	15	2
Not Implementing	11	9	4	3
Total	54	54	54	54

Throughout 2018, FHWA convened several peer exchanges between STAs to promote discussions surrounding experiences with innovative technologies. STAs such as Indiana Department of Transportation (INDOT) sought to determine whether e-ticketing was useful in improving operations such as material tracking or quantity payments for hot-mix asphalt, concrete, and aggregate (Federal Highway Administration, 2018). In a separate peer exchange, Virginia Department of Transportation (VDOT) stated its desire to explore several innovative technologies and commercial applications, including e-ticketing (Federal Highway Administration, 2019).

However, as previously mentioned, STAs are normally classified as institutionally inertial, which has caused them to be slow to investigate topics such as material tracking between production location and project site, which is a primary benefit of e-ticketing systems (Gavin et al., 2004). This has historically been viewed as economically prohibitive but now is more viable with recent advances in automated data collection (Lee and McCullouch, 2008; Song et al., 2006). Real time haul vehicle monitoring alleviates traditional trucking limitations, such as reliable reporting of locations between drivers and dispatchers (Naresh and Jahren, 1997). Additionally, developments in automated data collection have allowed fleet managers access to extensive data related to operational use, costs, and condition of heavy equipment, which allows for optimization to complete work tasks (Said et al., 2016).

As e-ticketing began to be introduced to various STAs, a survey was completed by the American Association of State Highway and Transportation Officials Committee on Construction (AASHTO COC) membership as part of the National Cooperative Highway Research Program (NCHRP) Synthesis 545. Each STA was asked about the use of e-ticketing in construction management for the agency regarding asphalt materials. The results indicated that many survey respondents (36 of 48 total responses) had not yet used e-ticketing but were interested while only 4 agencies were interested in adopting e-ticketing as policy or had a standard specification in place for its use (Dadi et al, 2020).

Initial STA adoption for e-ticketing has been primarily focused on asphalt materials since it is the predominant roadway construction material (Federal Highway

Administration, 2016). Between 2018 and 2020, several states entered various phases of e-ticketing adoption (Federal Highway Administration, 2020a). This increase in e-ticketing usage was spurred on by the COVID-19 pandemic and the challenges of social distancing on project sites (McLoud, 2020; Schmitz, 2020). As noted by Assaad et al. (2022), the COVID-19 pandemic has had a potential positive impact on the increased reliance upon construction-related technologies to aid in task completion. Nationally, 13 STAs entered initial pilot phases for e-ticketing adoption, while an additional 11 STAs allowed e-ticketing practices on construction projects in lieu of the COVID-19 pandemic. As of the end of 2020, at least 5 STAs were prepared for or were considering e-ticketing as an agency policy, as seen in Figure 2.1. Most recently, two research efforts have investigated e-ticketing adoption and challenges. Robertson et al. (2022) investigated the potential benefits and limitations of e-ticketing with respect to the New Mexico Department of Transportation through focus group meetings and interviews. Noted benefits included increased field employee safety and efficiency improvements while also acknowledging challenges related to internet connectivity, random material sampling responsibilities for STA project inspectors, and the difficulties with tracking haul vehicles. Subramanya et al. (2022a) conducted a literature review of STA memorandums and specifications and determined 3 adoption phases for e-ticketing. The findings of this study are illustrated in Figure 2.2 and show that 56% of STAs were in the conception phase, 32% were in the partial implementation phase, and only 12% had fully implemented e-ticketing.

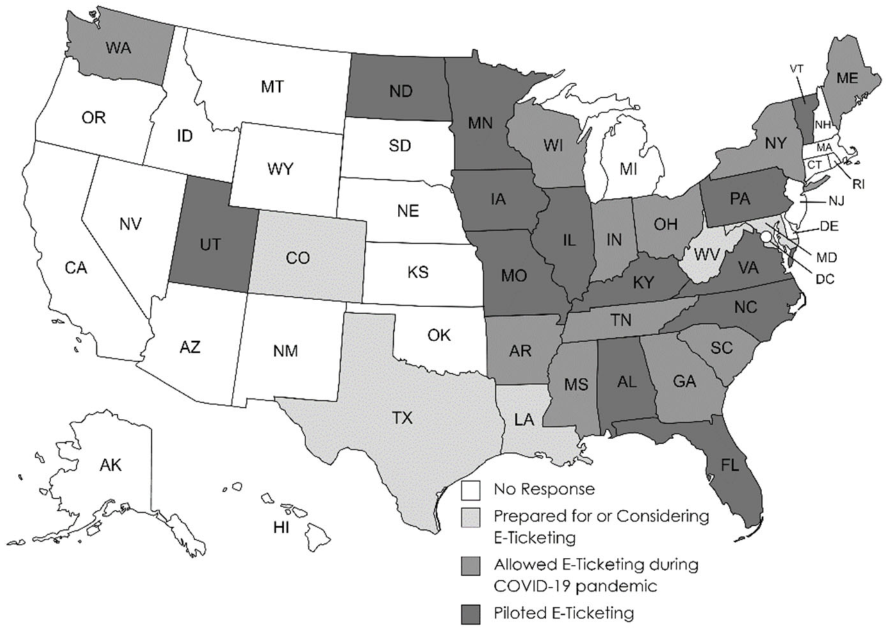


Figure 2.1 FHWA E-Ticketing Adoption Phase (Adopted from FHWA, 2020a)

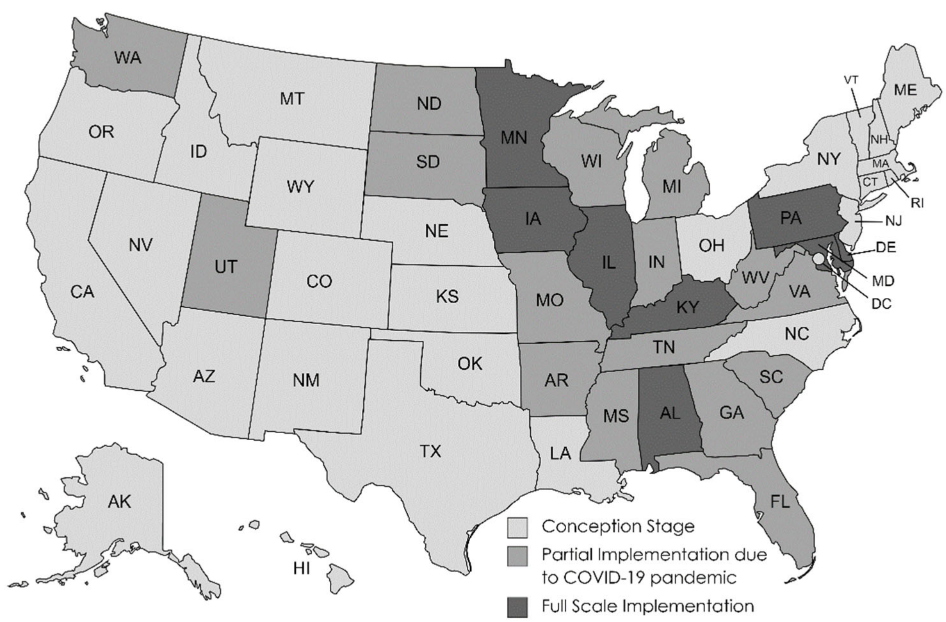


Figure 2.2 Adoption Phase by STA (Adopted from Subramanya et al, 2022a)

2.1.5 Existing Knowledge Gap

Therefore, through comparison of the data collected from NCHRP Synthesis 545 and the 2020 FHWA adoption report, there appears to be movement towards adoption of e-ticketing. However, data collection for both research efforts either pre-dates the COVID-19 pandemic or was completed during the height of the pandemic. The focus group discussions conducted by Robertson et al. (2022) illustrate primary data collection, but with a focus solely on one STA without a national perspective for comparison. The literature review conducted by Subramanya et al. (2022a) post-pandemic points to an apparent increase in e-ticketing implementation, but the data source for the study is entirely from secondary sources. Therefore, a knowledge gap exists due to the lack of primary source data available in academic literature which illustrates the change in adoption of e-ticketing over time by STAs to include changes made after the COVID-19 pandemic. The research presented in this paper seeks to gather this missing primary source data from STAs across the country to determine if there has been an increase in e-ticketing implementation for asphalt paving operations or whether STAs may revert to traditional documentation practices while also sharing noted benefits, challenges, and potential mitigation strategies from a case study to encourage STAs who may not have considered weigh ticket policy alteration.

2.2 Methodology

As previously mentioned in section 2.1.3, the primary objectives of the research are to observe the change in e-ticketing implementation by national STAs through policy alteration from pre-pandemic through post-pandemic and examine potential benefits and challenges of e-ticketing through the perspective of different project stakeholders. The beginning of the COVID-19 pandemic saw multiple STAs issue emergency orders to refuse paper weigh ticket collection on project sites to prevent the spread of the virus (McLoud, 2020). States such as Alabama, Florida, Kentucky, Indiana, and Mississippi instituted temporary "contactless ticketing" policy changes to satisfy rapidly deployed guidelines for social distancing. However, as the pandemic nears an end, STA leadership groups must consider whether the impact of e-ticketing on construction processes necessitates permanent policy change for engineering/inspection staff along with contractor stakeholders or if weigh ticket policy should revert to the inefficient, paper-based documentation of the pre-pandemic era. As discussed in sections 2.1.3 and 2.1.4, due to the cultural barrier of institutional inertia present in many STAs, the proposed methodology aims to identify e-ticketing adoption leaders who can share lessons learned through the emergency use of e-ticketing and ideas for persuading individual stakeholders who may be resistant to change.

The methodology of the research is illustrated in Figure 2.3. The literature review identified knowledge gaps related to a lack of primary source data which includes post-pandemic responses, highlighting a need for a new data collection effort. The data collection proposed required feedback from multiple organizations representing both STA and highway contractor stakeholders. Through this combined feedback, a holistic analysis can be completed by comparison of agency and contractor perspectives regarding e-ticketing. Additionally, the collection of national and state feedback allows for comparison of policy practices and potential adaptations to enhance e-ticketing applications.

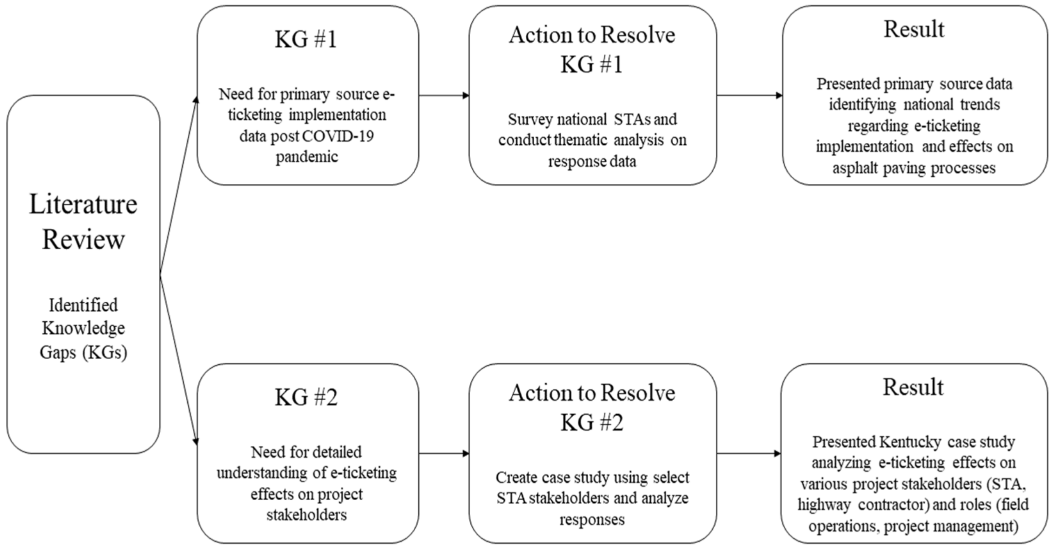


Figure 2.3 E-Ticketing Progression Research Methodology Flowchart

2.2.1 Resolution to Knowledge Gap #1

To determine whether there was an observable change in e-ticketing implementation after efforts during the COVID-19 pandemic, a national perspective was necessary. An anonymous survey was distributed to the AASHTO COC using Qualtrics, whose membership is comprised of representatives from each STA in the country. The development of survey questions was aided through the literature review and previous discussions with STA personnel identified as champions of digital project delivery. The beginning portion of the survey requested demographic information from the respondent followed by questions regarding a description of previous agency experiences with e-ticketing. Next, several questions were presented to gain an understanding of how e-ticketing has affected both agency and contractor personnel, including both field and management positions. Finally, respondents were asked about current satisfaction with e-ticketing policies and what concerns had been posed regarding future adoption of e-ticketing by the local STA.

2.2.2 Resolution to Knowledge Gap #2

To examine potential benefits and challenges of e-ticketing more in-depth, a case study method was decided upon. Due to previous experience with e-ticketing pre-pandemic, the state of Kentucky was selected. Several organizations in Kentucky were solicited for responses. Two highway contractor professional organizations, the Kentucky Association of Highway Contractors (KAHC) and the Plantmix Asphalt Industry of Kentucky (PAIKY), were approached regarding participation within the study. These professional organizations share an overlap in membership that represents a large portion of pre-qualified highway contractors in the state of Kentucky. While KAHC has a membership of approximately 150 regular members and 140 associate members across various work operations that comprise the highway construction industry, PAIKY membership is restricted to companies involved in the production or supply of asphalt materials in Kentucky. This survey similarly requested anonymous demographic information regarding the contractor company, including the amount of work performed on an annual basis to be able to identify trends related to contractor operational size. Next, several questions asked about company-specific experiences with e-ticketing and how e-ticketing has affected current operations. Finally, the survey asked if e-ticketing modified the outlook for the company.

To provide the agency perspective for Kentucky, the membership of the KYTC DPD were solicited for responses. This subcommittee seeks to address the intersection between design and construction and how to implement technology such as e-ticketing to collect available construction operation data. The subcommittee is comprised of 27 individuals combining both field and management positions related to highway construction. The survey requested anonymous demographic information, descriptions of e-ticketing experiences on past projects, and finally input on satisfaction and concerns about future adoption of e-ticketing as policy in Kentucky.

2.2.3 Benefit of Combined Methodology

By combining the survey and case study methodology, the overall power of the study is increased. The national survey provides an updated state of practice for asphalt paving e-ticketing for many national STAs while the Kentucky case study can either reinforce or argue against previously identified trends. The combination of methodologies allows for the collection and presentation of both the breadth (national survey) and depth (Kentucky case study) of information surrounding e-ticketing application to enhance current understandings and promote further implementation by national STAs who may be resistant to change due to the phenomenon of institutional inertia.

2.3 Results and Analysis

The results of the surveys collected from the four committees and organizations are described in detail in the following sections. First, national data is analyzed to determine implementation progression of e-ticketing for asphalt paving applications. Secondly, the Kentucky case study is presented to perform an in-depth analysis on the potential benefits and challenges of e-ticketing for asphalt paving applications.

2.3.1 National Asphalt E-Ticketing Implementation

In total, 36 responses were collected representing 33 different STAs across the country from the AASHTO COC survey. According to the collected data, 94% of the respondents work for their agencies within a construction division, and 83% of the respondents have at least 10 years of experience in administering highway construction projects or managing highway construction materials.

To determine the implementation of e-ticketing across national STAs, the AASHTO COC survey provides primary source data previously identified as missing in the published literature. Several methods were initially accepted as e-ticketing during the early stages of the COVID-19 pandemic, including scanned pictures of weigh tickets (Michigan) and compiled portable document formats (PDFs) of weigh tickets (Virginia) in addition to traditional e-ticketing software. The map shown in Figure 2.4 depicts a portion of the results. Responses show that 7 agencies have now entered some form of agency adoption, through either a standard specification or allowance for use on asphalt paving projects. Additionally, 16 agencies have reached a form of phased implementation, beyond pilot projects but not yet to the point of creating a specification or policy. Finally, 7 agencies have begun piloting e-ticketing while 3 agencies are in the process of researching or procuring e-ticketing vendors to begin pilot projects.

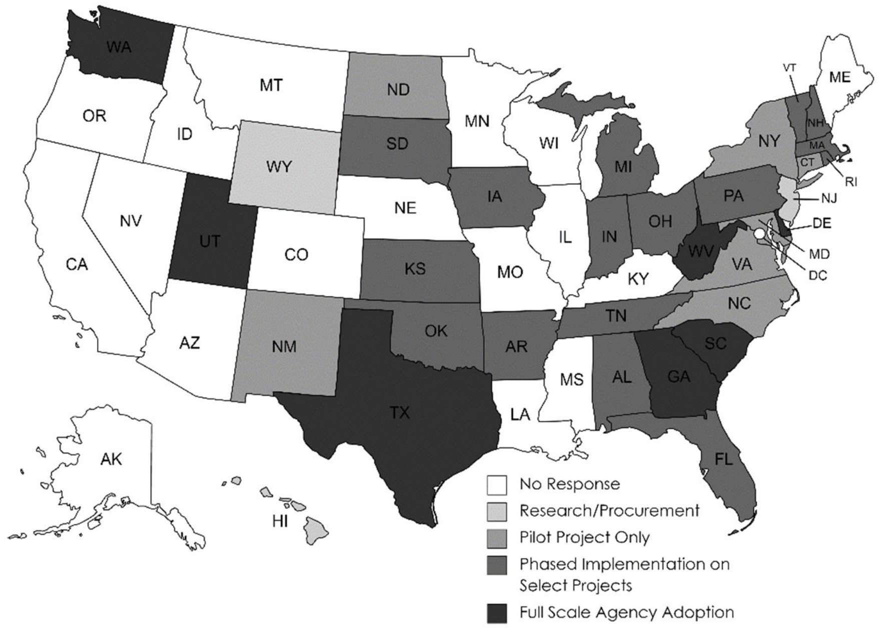


Figure 2.4 STA E-Ticketing Implementation Phase

To determine whether implementation of e-ticketing for asphalt paving applications has increased across the county, the data collected from the AASHTO COC survey is compared to previous efforts compiled by the NCHRP Synthesis 545 and FHWA. Table 2.2 summarizes the implementation advancement from each survey.

Using the ranking system shown for each implementation phase, from Rank 1 representing the Research/Procurement stage to Rank 4 representing the policy adoption stage, a numerical distribution is created to summarize each survey effort. Next, a one-way ANOVA calculation is performed using the three numerical summaries. The results of the one-way ANOVA calculation show there is statistical significance ($p = 0.00001$) to suggest that e-ticketing implementation for asphalt paving applications has progressed from previous national surveys. Furthermore, there is a statistical significance for each pairwise comparison in Table 2.2 using Tukey's HSD, indicating that there had been statistically significant progression in e-ticketing implementation with each national survey effort. Based upon free responses provided by the AASHTO COC survey respondents, several STAs are targeting implementation either through special provisions in project lettings during the 2022 construction season (Oklahoma) or policy changes with target dates between 2023-2025 (Florida, Iowa, North Carolina, Maryland, Pennsylvania, and Ohio).

Table 2.2 E-Ticketing Implementation Advancement

	NCHRP Synthesis 545 (2020) (Sample Size = 48)	**FHWA (2020a) (Sample Size = 29)**	**AASHTO COC (2022) (Sample Size = 33)**
Research/Procurement (Rank 1)	39	5	3
Pilot Only (Rank 2)	4	13	7
Phased Implementation (Rank 3)	4	11	16
Agency Adoption (Rank 4)	1	0	7
Result Details			
f-ratio	38.48157		
p-value	0.00001		
Pairwise Comparison P-Values			
NCHRP Synthesis 545 vs. FHWA	0.00001		
NCHRP Synthesis 545 vs. AASHTO COC	0.00000		
FHWA vs. AASHTO COC	0.00363		

Even as STAs progress towards phased implementation or policy adoption, there is apparent room for growth. From the 36 collected responses, only 7 agencies indicated that they were actively investigating the capability to automate data transfer from e-ticketing system to the chosen agency construction management system (Delaware, Hawaii, Iowa, New York State, North Carolina, Utah, West Virginia). 10 agencies planned to investigate automated data transfer but have not had the opportunity to investigate this potential advantage (Alabama, Arkansas, Indiana, Kansas, Michigan, New Hampshire, North Dakota, Ohio, Pennsylvania, Virginia). 3 agencies (Arkansas, Florida, Indiana) indicated that e-ticketing use on projects is left to the contractor or supplier to formally request. Therefore, even after the COVID-19 pandemic, several STAs across the country either have additional capabilities they hope to incorporate within selected e-ticketing systems or additional experience to be gained before e-ticketing becomes a policy rather than a project choice.

2.3.1.1 National Asphalt E-Ticketing Benefits and Concerns

From Figure 2.5, the general response concerning e-ticketing for asphalt materials was positive regarding potential adoption as agency policy. A list of noted concerns is shown below along with the agencies expressing the specific concern.

1. **E-Ticketing performance on construction projects in areas of poor cellular coverage and connectivity** (Connecticut, Florida, Indiana, New York State, North Carolina, North Dakota, Ohio, Oklahoma, Tennessee, Utah, Washington State, West Virginia, Wyoming)
2. **Determination of stakeholder responsibility for acquiring e-ticketing capabilities and the effects of different choices** (Kansas, Maryland, Pennsylvania, South Dakota, Vermont)
3. **Capability to automate data transfer from e-ticketing system to construction management software** (Arkansas, Delaware, Hawaii)
4. **Utilizing multiple e-ticketing systems versus one standard system** (Iowa, Michigan)

5. **Reality of the benefit of trading digital storage for physical storage space** (Virginia)

However, many agencies polled do not consider these concerns as detrimental to the overall introduction of e-ticketing as policy and believe concerns can be adequately addressed. The way the listed concerns can be addressed centers around increased partnership between STAs, highway contractors, and e-ticketing software vendors. Concerns 1 and 3 should be determined through collaboration between STAs and software vendors, while concerns 2 and 4 should be resolved through discussion between STAs and their highway contractor stakeholders. Further mitigation strategies for this list of concerns are found in section 2.4. Even with the listed concerns, an overall desire was expressed to move from primarily asphalt applications and expand to other construction materials measured and paid for by weight.

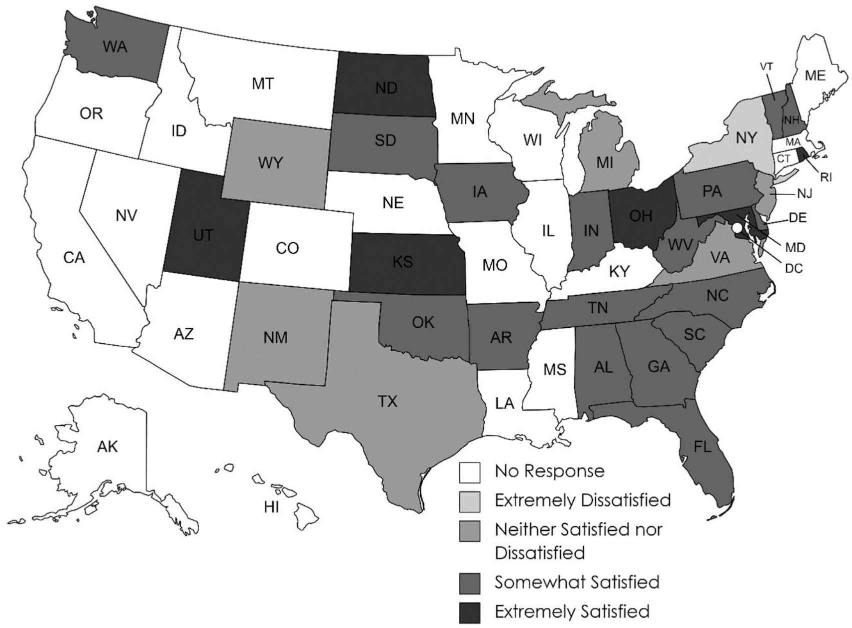


Figure 2.5 AASHTO COC Survey Agency Satisfaction

STA responses indicated several benefits of implementing e-ticketing for asphalt paving on field personnel. A list of the benefits is shown below along with the agencies expressing the specific benefit.

1. **Increased personal safety** (Alabama, Connecticut, Delaware, Georgia, Florida, Indiana, Iowa, Kansas, Maryland, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Utah, Vermont, Washington)
2. **Increased availability for project inspector** (Alabama, Georgia, Indiana, Kansas, Maryland, North Dakota, Pennsylvania, South Carolina, Vermont)
3. **Reduction of physical project data** (Arkansas, Delaware, Indiana, Ohio, New Hampshire, Pennsylvania, Rhode Island, South Dakota, Texas)

STA responses also indicated several benefits of implementing e-ticketing for asphalt paving for project management personnel. A list of the benefits is shown below along with the agencies expressing the specific benefit.

1. **Improved project documentation** (Alabama, Arkansas, Delaware, Georgia, Indiana, Maryland, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Utah, Vermont)
2. **Reduced potential for payment errors** (Connecticut, Florida, Georgia, North Carolina, North Dakota, Oklahoma, South Carolina, South Dakota, Texas, Utah)
3. **Reduced time for pay estimate review/processing** (Delaware, Georgia, Ohio, Rhode Island)
4. **Optimized trucking cycles** (Florida, South Dakota)

Highway contractors play an integral role in the adoption of e-ticketing practices as a primary stakeholder in the construction process. Therefore, it is noteworthy that the contractors who operate in each state are less satisfied on average with e-ticketing to date than the agencies who were surveyed, as seen in Figure 2.6. Some contractors noted that they still need to produce paper tickets for other city/county government agencies, which means they must operate multiple systems at production plants. Some subcontractors, such as haul trucking companies, prefer a paper weigh ticket as proof of delivery to ensure payment. Several contractors are hesitant to the change from paper to digital information delivery, while others are concerned with high prices needed for new systems and plant infrastructure when they may not perform a large percentage of their work for STAs. Another noted trend was that contractors who owned their own plants view e-ticketing more favorably, while those without their own plants are generally more hesitant, although they eventually come around as their viewpoint improves with more exposure to e-ticketing.

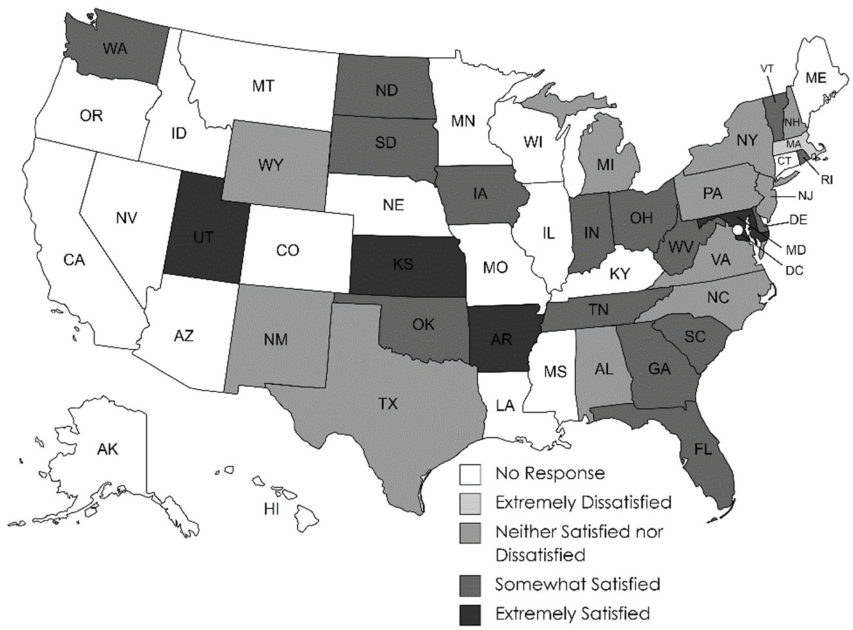


Figure 2.6 AASHTO COC Survey Contractor Satisfaction

There is an apparent difference between the satisfaction of STAs with e-ticketing systems and their respective highway contractors. Satisfaction scores are calculated 1-5, with 1 indicating extreme dissatisfaction and 5 indicating extreme satisfaction with e-ticketing. On average, STAs hold e-ticketing in higher esteem than their contractor partners, with an average agency satisfaction score of 3.818 compared to an average contractor satisfaction score of 3.697. However, this is not a statistically significant result ($p = 0.5872$). This could, though, indicate a need for STAs to reach out to their contractor stakeholders and determine how to best implement e-ticketing strategies so that contractor stakeholders are more receptive to the process.

2.3.2 Kentucky Case Study

While the AASHTO COC survey provided information regarding national e-ticketing implementation and opinions regarding agency and contractor satisfaction with adoption plans to-date, utilizing a case study allows for in-depth analysis. Since Kentucky has experience with e-ticketing for asphalt projects pre-dating the COVID-19 pandemic to 2018, it was selected to serve as the subject for the case study. To compile responses for both agency and contractor stakeholders, the KYTC DPD, KAHC, and PAIKY were solicited for information, respectively.

The KAHC and PAIKY survey resulted in 10 responses from highway contractors in Kentucky. The responses depicted companies ranging from those who completed less than 5 projects annually for KYTC to more than 50 projects annually, and who produced asphalt material value from $1 million to $50 million annually for KYTC.

From Table 2.3, most highway contractors surveyed indicated that they had not adopted e-ticketing as a regular practice. 6 contractors indicated that they had instituted e-ticketing for a short time, either on specified pilot projects or during the height of the COVID-19 pandemic, while only 2 contractors had changed company policy to adopt e-ticketing. Since only a small percentage of respondents indicated that e-ticketing had been adopted as regular practice since the COVID-19 pandemic, this could illustrate an ineffectiveness noted in the Kentucky adoption of e-ticketing for asphalt materials. This result also indicates the presence of institutional inertia within the asphalt industry in Kentucky, particularly for contractor stakeholders.

Table 2.3 KAHC/PAIKY E-Ticketing Status

KYTC Annual Projects Completed	Annual Asphalt Material Value (Millions of Dollars per year)	No noted Previous Experience	Utilized during COVID-19, now returned to paper tickets	Utilized on specific projects or pilot projects	Regular Practice since COVID-19
0-5	1-5	X			
0-5	5-10		X		
5-10	5-10				X
10-15	1-5		X		
10-15	10-15		X		
10-15	15-20			X	
10-15	20-25	X			
25-50	15-20				X
25-50	20-25			X	
50 or more	25-50		X		

From Table 2.4, in Kentucky, third-party trucking appears to be the primary method to bring asphalt materials from plant to project, as 7 companies indicated that it was preferred to in-house trucking options. Additionally, 6 companies, 5 of which indicated primarily using third-party trucking, indicated that GPS systems were used within haul vehicles to monitor locations during delivery of materials. Of the 6 companies that indicated GPS utilization, 4 stated that GPS capabilities allowed for optimization of the trucking fleet, meaning that excess haul vehicles could potentially be redistributed to other projects during a given shift. Yet while fleet optimization is a noted possibility, the responding contractors generally did not feel that there was a noticeable monetary benefit associated with this capability.

Also, due to the prevalence of third-party trucking in the hauling of asphalt paving material, who generally use paper tickets to keep track of their own billable records, there appears to be a minimal monetary benefit from a potential conversion from physical to digital records. While there is possible convenience from digital records, physical records still appear to be a necessity given current business processes.

Table 2.4 KAHC/PAIKY Haul Vehicle Breakdown

KYTC Annual Projects Completed	**Annual Asphalt Material Value (Millions of Dollars per year)**	**Trucking Source**	**GPS Capability Enabled?**	**Fleet Optimization?**
0-5	5-10	Third-Party Trucking	Yes	Yes
5-10	5-10	Third-Party Trucking	Yes	No
10-15	1-5	Third-Party Trucking	No	N/A
10-15	10-15	Third-Party Trucking	No	N/A
10-15	15-20	In-House Trucking	Yes	Yes
25-50	15-20	Third-Party Trucking	Yes	Yes
25-50	20-25	Third-Party Trucking	Yes	No
50 or more	25-50	Third-Party Trucking	Yes	Yes

2.3.2.1 Kentucky Highway Contractor E-Ticketing Benefits and Concerns

As seen in Table 2.5, smaller highway contractors tended to point out the benefit of e-ticketing regarding field personal safety either at the plant or on the project. Another noted benefit was the time allowed for field personnel to focus on production-related tasks instead of being concerned about tracking constant documentation. It is of note that multiple contractors felt that e-ticketing offered no benefit to their field personnel, with 1 contractor noting that field personnel received additional tasks in having to assist KYTC personnel in operating the selected e-ticketing system.

For project management personnel, the predominant benefit noted was the ability to transfer digital data, either from plant scale house to an office or between offices. One response noted that e-ticketing system demonstrated a need for increased trucking to maximize efficiency, which was impeded by an ongoing trucking shortage. As with field personnel benefits, multiple contractors mentioned that utilizing e-ticketing did not seem to benefit their project management personnel.

It is apparent that smaller highway contractors view e-ticketing systems as a benefit primarily to avoid lost documentation, such as paper tickets damaged during field operations. In addition to this, minimizing lost documentation has the potential to lead to more accurate and quicker progress estimates issued by the KYTC. Larger highway contractors appear to view e-ticketing systems as an internal check for business operations and an improvement to worker safety. E-ticketing systems allow for real-time adjustment of assets to ensure contractors keep projects on-budget and reduce worker task load in the field to minimize situations of potential injury.

Table 2.5 KAHC/PAIKY E-Ticketing Personnel Effects

KYTC Annual Projects Completed	Annual Asphalt Material Value (Millions of Dollars per year)	Field Personnel Effects	Project Management Effects	General Comments
5-10	5-10	Ability to track haul vehicles in route between plant and project. Decreased touch points during COVID-19 pandemic.	Difficult to assure complete coverage of GPS units in haul vehicles. Ability to connect to plant scales is a benefit.	Transparency for shift processes. Efficiency in payments.
10-15	1-5	No longer requires haul vehicle drivers to leave truck to enter plant scale house.	Makes sharing information between satellite offices and main offices much easier.	Do not have to keep paper tickets.
10-15	15-20	No change.	No change.	N/A
10-15	20-25	N/A	N/A	No benefit noted.
25-50	15-20	No change.	Able to stay updated on daily plant production logs.	Retrieval of lost tickets.
25-50	20-25	Increased workload due to having to support KYTC with setting up user accounts or providing training.	Minimal change. Systems indicate a need for more trucks to reach optimal efficiency, which is already known and affected by trucking shortage.	Tracking quantities. Staying within budget.
50 or more	25-50	Increased personal safety. Increased time spent on production related activities.	Unknown.	Safety.

From Table 2.6, there is a separation between small and large contractors in how they perceive the usefulness of e-ticketing systems. Only 2 of the larger contractors surveyed indicated the use of e-ticketing systems for projects outside of the KYTC's domain, which may point to its lack of effectiveness in business operations. Additionally, the same 2 larger contractors are satisfied with the way in which e-ticketing systems are currently being used, while the other contractors responding indicate either a dissatisfaction or a neutral response for e-ticketing in its current form in Kentucky. Calculating a contractor satisfaction score like those previously discussed for the AASHTO COC survey, the average score for Kentucky contractors is 2.875, which is below the national average and represents a somewhat dissatisfied view of e-ticketing in Kentucky.

Table 2.6 KAHC/PAIKY E-Ticketing Satisfaction

KYTC Annual Projects Completed	**Annual Asphalt Material Value (Millions of Dollars per year)**	**Using E-Ticketing System outside KYTC projects?**	**Satisfaction Level**
0-5	5-10	No	Neither satisfied nor dissatisfied
5-10	5-10	Maybe	Somewhat dissatisfied
10-15	1-5	Maybe	Somewhat dissatisfied
10-15	10-15	No	Neither satisfied nor dissatisfied
10-15	15-20	No	Neither satisfied nor dissatisfied
25-50	15-20	Yes	Somewhat satisfied
25-50	20-25	Maybe	Somewhat dissatisfied
50 or more	25-50	Yes	Somewhat satisfied

The predominant concerns from highway contractors with the potential for e-ticketing adoption is a concern over cellular signal coverage and the GPS requirements for haul vehicles. Due to the prevalence of third-party trucking in Kentucky, it is difficult to ensure that GPS units are consistently maintained in every haul vehicle utilized for a project. Additionally, some regions of Kentucky do not have strong cellular signal coverage, causing potential connection issues with e-ticketing systems.

2.3.2.2 Kentucky Transportation Cabinet E-Ticketing Benefits and Concerns

Another survey was created and distributed to the KYTC's Digital Project Delivery Construction Subcommittee to capture information from KYTC employees regarding their experience with e-ticketing processes. A portion of the results are shown in Table 2.7.

Table 2.7 KYTC DPD Subcommittee E-Ticketing Effects

District/ Division	E-Ticketing Effect on Field Personnel Duties	E-Ticketing Effect on Project Management Duties	Level of Satisfaction
3	Previous system used was cumbersome. Eventually requested PDF tickets.	Helpful in eliminating potential missing tickets. Harder to verify tickets with trucks due to difficult app navigation and poor cellular service. E-Ticketing system required unique email address for each contractor, which caused increased difficulties.	Somewhat dissatisfied
3	Allows for a single inspector to monitor material placement and compaction along with documentation. Assists with laying out random cores. Provides a factor of safety by not positioning inspector near haul trucks and traffic.	Reduced/eliminated missing tickets. Allows engineer to monitor progress on multiple projects remotely. Allows inspectors to monitor multiple operations. Easily resolves last load disputes if material is unused.	Extremely dissatisfied
4	Eliminated the need to place to put an inspector in potentially dangerous locations. Increased the reliability of retaining the ticket records.	Improved documentation reliability due to eliminating missed tickets.	Somewhat dissatisfied
11	Increases inspector safety and allows additional time for inspection. Inspectors were impeded though by not knowing current tonnage to calculate material yield. Void/Rejected material still showed on report and couldn’t be eliminated.	Found e-ticketing systems to be inaccurate, which required additional verification.	Extremely dissatisfied
N/A	Increased safety due to inspectors not having to be near haul vehicles. Increases difficulty of keeping track of material yield. Large areas of no cell coverage. Learning curve for inspectors who must constantly monitor haul vehicles to know the current tonnage.	E-Ticketing app helps ensure correct tickets are digitally stored and none are missed.	Extremely satisfied

From the KYTC DPD survey, several benefits of e-ticketing were noted for field personnel. The primary benefit is the ability to remove the project inspector from a dangerous position near heavy equipment and traffic. Additional benefits mentioned included the ability to help lay out random testing per specification, reduction in job tasks for an inspector, and better project documentation. However, several difficulties were also noted. These included difficulties within the selected e-ticketing system, such as difficulty monitoring material yield and void/rejected material still appearing on summary reports. Additionally, larger difficulties such as working in areas of poor cellular coverage were also noted.

Several benefits were also noted for project management personnel, including improved weigh ticket documentation, a reduction in job tasks for both engineers and inspectors, and increased transparency between the KYTC and contractor if questions arose over disputed quantities for payment. However, some difficulties within selected e-ticketing applications were noted along with poor cellular coverage affecting system performance.

General feedback on e-ticketing from the KYTC DPD was varied. Several respondents pointed out issues they encountered with a selected system, such as a need for easier in-app navigation or mistakes on ticket information when project requirements changed. However, some responses were generally positive, with one respondent wanting to see e-ticketing implemented for all weighed material on KYTC specifications. As for potential areas of concern before moving towards agency-wide adoption, the main area of need is a solution for areas with poor cellular coverage, followed by greater training opportunities and program support (i.e., ensuring project inspectors have necessary electronic devices to maximize effectiveness of e-ticketing system). Of the 10 respondents, 4 have negative reviews, 2 have neutral reviews, and only 1 has a positive review of e-ticketing. Calculating an agency satisfaction score like those previously discussed for the AASHTO COC survey, the average score for the KYTC is 2.429, which is below the national average and represents a somewhat dissatisfied view of e-ticketing in Kentucky.

2.4 Discussion

A primary trend across the national and Kentucky surveys are the concerns regarding signal strength issues in rural areas and potential issues revolving around connectivity. Despite pilot projects and phased implementation across multiple agencies, these concerns still have not been widely mitigated, even at a national level. Robertson et al. (2022) also highlighted cellular connectivity as a major challenge for implementation in New Mexico. Based upon the Kentucky case study, smaller contractors who normally perform asphalt paving work in rural locations are less satisfied and generally more wary about adopting e-ticketing systems as standards of practice, while larger contractors are more willing to accept adoption of e-ticketing systems. STA and software vendor discussion can yield mitigation strategies for poor cellular coverage, such as storing asphalt ticket data in the cloud while connectivity is lost and implementing an alternative field action so that pertinent information is delivered to both highway contractor and STA personnel, such as a quick response (QR) code, as suggested by Robertson et al. (2022). Maintaining accurate information in the field is critical for STA personnel to monitor for random quality assurance testing and for highway contractor personnel to monitor production metrics.

A secondary trend across the national and Kentucky surveys are the concerns over whether a STA will allow the use of multiple e-ticketing systems or standardize the use of a single system as efforts to move towards adoption increase. Through pilot project efforts or the emergency need for "contactless ticketing" in the height of the pandemic, many contractors have utilized several e-ticketing systems and become familiar with or developed a preference for one system. If a STA moves towards adoption but away from a previously piloted e-ticketing system, there may be potential challenges in stakeholder acceptance. Additionally, STAs will need to determine whether contractor partners are required to acquire e-ticketing systems and maintain them or if the STA will be responsible for providing a portal or standardized solution where contractors can transfer data from their own plant systems. An STA controlled and maintained portal solution would minimize the number of potential e-ticketing systems that STA personnel must be familiar with while allowing highway contractor stakeholders to select the system with which they are most comfortable, which may be the simplest and most profitable resolution. The role of e-ticketing software vendor is critical to increased adoption efforts, as they possess the technical expertise required to address potential concerns over data formats and security. Software vendors can serve as an intermediary stakeholder to mitigate concerns from both highway contractor and STA stakeholders, which should aid in further acceptance of e-ticketing by the asphalt industry. Software vendors can work with highway contractor stakeholders to ensure electronic data from asphalt plants are consistent and compatible with STA systems while also working to ensure that the electronic data is transferred securely to the appropriate stakeholders.

A tertiary national trend was the concern over the automation of ticketing data into the construction management software utilized by STAs. While field data can be collected electronically through e-ticketing systems, there is still the potential for human error since payment must be manually entered. Therefore, it is important that STAs and e-ticketing software vendors collaborate to determine if current construction management software can be modified to allow data to transfer directly from the field or if future software will allow for automated transfer and eliminate the potential for human error.

Utilizing the Kentucky case study, smaller contractors seem to use e-ticketing mainly to keep secure project documentation, while larger contractors use e-ticketing as an internal business check (and extend its use to non-KYTC projects) and to improve worker safety. However, due to a prevalence of third-party trucking, it does not seem that introducing e-ticketing as an agency requirement for KYTC will lead to the permanent elimination of paper weigh tickets for Kentucky highway contractors, as they would still be necessary for subcontractors and other city or county government agencies for whom work is performed.

Additionally, the Kentucky case study highlights relative unsatisfaction with e-ticketing processes to date, as seen by the low satisfaction scores from both the highway contractor and KYTC personnel surveys. Both scores are lower than their respective national category averages. This may indicate a need for further investigation by KYTC into e-ticketing policy revision and how to better benefit both stakeholders due to low satisfaction scores.

The primary benefit of e-ticketing as mentioned in both the Kentucky case study and the national survey was increased safety for field personnel for both agency and contractor stakeholders, as also discussed by Robertson et al. (2022) and Subramanya et al. (2022a). A secondary benefit of e-ticketing implementation in both the Kentucky case study and national survey is the increase in availability of field personnel to perform other job tasks, either quality assurance/quality control for STA personnel or production-related activities for contractor personnel, as also highlighted by Subramanya et al. (2022a). However, some KYTC respondents felt that e-ticketing increased project inspector workload by having to constantly monitor haul vehicles to know current tonnages for material yield and random testing while also correcting for voided or rejected material. The major benefits to contractor stakeholders, as noted by both Kentucky and national contractors, include continuous electronic documentation of material records, leading to better project control, along with the capability to remotely monitor haul vehicles, which in turn leads to the ability to optimize haul fleets across multiple projects in a single shift. However, due to the prevalence of third-party haul vehicles in Kentucky, coordinating GPS installation to allow remote monitoring may prove difficult, as mentioned by the New Mexico Department of Transportation (Robertson et al., 2022).

2.5 Conclusions

The primary objectives of the study were to determine the change in e-ticketing implementation by national STAs through policy alteration and examine potential benefits and challenges of e-ticketing through the perspective of different stakeholders. The anonymous survey sent to members of the AASHTO COC to provide updates on e-ticketing usage in their areas after changes made during the COVID-19 pandemic establishes that STAs across the nation have progressed implementation of e-ticketing for asphalt paving projects. This finding reinforces the success of FHWA's technology implementation efforts in the face of the barrier of institutional inertia. To balance the national implementation investigation findings, a case study methodology was implemented using the KYTC and highway contractor representatives from KAHC and PAIKY to provide additional data for an in-depth analysis.

Collected survey responses reinforced various safety, documentation, task load, and resource allocation benefits provided by e-ticketing for asphalt paving operations. However, several concerns were noted by various stakeholders, primarily centered around connectivity on project sites and determination of the responsibility for acquiring compliant e-ticketing systems. These concerns can be alleviated with continued partnership efforts between STAs, highway contractors, and e-ticketing software vendors.

The primary limitation of this research effort is the response rate from survey subjects. An increase in response rate from STAs and their highway contractor partners may lead to statistically significant results and allow further investigation into the effect of highway contractor size on how companies feel e-ticketing impacts their operations. Due to the challenges expressed by participating contractor partners, STAs should look for ways to increase partnership between stakeholders before adopting e-ticketing policy changes to increase buy-in from potentially resistant members. Increased input from contractor stakeholders may also allow STA leadership to better modify e-ticketing applications and policies to address the needs of all end-users before implementation.

CHAPTER 3. ASPHALT MATERIAL E-TICKETING WORKFLOW: A QUALITATIVE AND QUANTITATIVE ANALYSIS

3.1 Introduction

According to the American Society of Civil Engineers (ASCE) 2021 Infrastructure Report Card, the United States has underfunded roadway maintenance for an extended period, resulting in approximately $786 billion of backlogged needs (American Society of Civil Engineers, 2021). For reference, the state of Kentucky suffers from backlogged bridge, asphalt paving, routine maintenance, and other specialty projects totaling approximately $4 billion (Americans for Transportation Mobility, 2019). As such, State Transportation Agencies (STAs) must continually complete increasingly complex projects to satisfy the needs of the traveling public (Taghizadeh et al., 2020). Project complexity ranges due to factors including project type, size, and location (Dao et al., 2017). According to Crossett and Hines (2007), on any given day, an STA has hundreds of projects of varying size underway with a common purpose of assuring that travelers experience a functional transportation network.

Many public construction contracts use unit-price constructs (Ewerhart and Fieseler, 2003; Mandell and Brunes, 2014). Unit-price constructs require contractors to submit pricing for portions of the total project scope on a per-unit basis, which is estimated primarily upon anticipated quantities listed in the contract documents (Bour, 2022). These contracts require documentation be retained throughout the project lifetime to verify paid quantities since payment is typically rendered to highway contractors based on actual quantities performed rather than estimated quantities (Hyari et al., 2017). By nature, highway and infrastructure projects completed by STAs require large amounts of construction materials, which in turn generates large amounts of necessary data to verify the material used on the project. Historically, though, this data is maintained in a static, paper format (Nipa et al., 2019). As indicated by Navon and Shpatnitsky (2005) and Kasim (2015), this typical workflow for transmitting data between the production location and project site is inefficient and too human-dependent. Electronic data generated at the production location from a typical scale or load-out system is transferred onto paper tickets to be delivered to the project site by the haul-vehicle driver and is then provided to the STA project inspector to verify the listed information and add any additional field notes (North Carolina Department of Transportation, 2022). At the end of the day, this data may later be re-scanned into an electronic storage space for STA records. Sadasivam et al. (2021) notes the considerable number of resources expended by both contractors, producers, and STAs to produce, record, and archive physical weigh tickets with minimal traceability and potential for future use in the operations and maintenance phase of asset management. Therefore, these noted inefficiencies in collecting and using data place more emphasis on the need for innovative technologies to digitize the current process.

In addition, the workflow of paper weigh tickets for construction material tracking, as previously described, carries with it a high human cost. As noted by Embacher (2021) and illustrated in Figures 1.1 and 1.2, paper weigh ticket collection has resulted in project inspectors being placed in hazardous scenarios due to their proximity to heavy equipment and high-speed traffic within the work zone. Worker fatalities in roadway construction projects are most likely to occur in scenarios where workers are near the traveling public or heavy equipment necessary to complete the daily operation

(Federal Highway Administration, 2020b). As STAs accelerate more projects into the construction phase to meet constituency demand, the number of potentially hazardous scenarios also increases. Using construction cost as a guiding metric, one work zone fatality occurs for every $112 million worth of roadway construction expenditures (Federal Highway Administration, 2021b). Agencies must consider how to improve worker safety, especially in the face of an already decreasing staffing level, as previously pointed out by Taylor and Maloney (2013).

Chi et al. (2013) noted it is the responsibility of safety managers to eliminate unsafe working conditions and thereby minimize the risk for potential harm. Therefore, STAs must investigate new methods to automate inspection tasks to minimize inefficient traditional practices, reduce unsafe working conditions and supplement the lack of inspection personnel while also gaining improved management and future utility of project data. Public agencies have sought the introduction of technology into construction processes for over a decade to improve such project-level outcomes (Gurevich and Sacks, 2020).

Efforts to improve technology use in the weigh ticket collection process has been aided by the Federal Highway Administration (FHWA) "Every Day Counts" (EDC) technology implementation initiative. One focus of the sixth EDC cycle is e-ticketing, or the provision for all project stakeholders to "produce, transmit, and share materials data and track and verify material deliveries" electronically (Federal Highway Administration, 2021a). Acceptance and institution of e-ticketing practices can lead to project data being collected in the field and maintained electronically while also achieving an important benefit of moving STA project inspectors away from potentially dangerous scenarios within the work zone (Wilkinson and Schroeder, 2020). E-ticketing procedures also allow for the potential to "integrate material data with construction management systems for acceptance, payment and source documentation", which holds potential to improve operational efficiency for STAs (Federal Highway Administration, 2021a).

While it is apparent that STAs face a combination of increased project demands, inefficient workflows, and increasing workforce needs, they are still organizations that are typically slow to adopt change. An attempt to implement new technologies, such as e-ticketing, is a disruption to the status quo for processes that have been in place for a considerable amount of time and is likely to encounter resistance from various stakeholders. Kimmel et al. (2015) notes that the public road construction sector is "inertially bound" or slow to seek and adopt innovative technologies produced by industry while *NCHRP Special Report 249: Building Momentum for Change* states that innovation barriers are "widespread", "complex", and "deeply embedded" and points to institutional inertia as a considerable cultural aspect to be overcome within the highway construction sector (Transportation Research Board, 1996). Therefore, combating the obstacle of institutional inertia is a primary driver of this research effort. To accomplish this, an investigation of the potential impacts of implementation is necessary, as pointed out by Dadi et al. (2020) as a primary research need.

The intent of this research is two-fold: first, determine through qualitative analysis the primary costs and benefits associated with e-ticketing through experience gained by emergency deployment during the COVID-19 pandemic while secondly, utilize the additional e-ticketing experience to advance the existing benefit-cost analysis and determine a quantitative analysis of the associated costs and benefits through an in-depth case study with the Kentucky Transportation Cabinet (KYTC). This chapter is organized into six total sections to present previous e-ticketing implementation efforts, the research methodology, the qualitative and quantitative analyses, a discussion section, and conclusions with contributions regarding the stated research outcomes and areas of future research.

3.2 Literature Review

FHWA began the EDC program in 2009, with the 2015-2016 cycle featuring e-Construction as a select innovation during EDC-3 (Dadi et al., 2020). For this phase of the EDC program, FHWA defined e-Construction as "the collection, review, approval and distribution of construction contract documents in a paperless environment" (Federal Highway Administration, 2017). The focus on e-Construction represented a significant advancement in the realm of construction project administration to shift project-related documentation from a paper-based to electronic format. The EDC-4 cycle in 2017-2018 indicated that significant progress had been made incorporating e-Construction principles from EDC-3, but the emphasis shifted to a combined focus on e-Construction and Partnering to promote team relationships between project stakeholders while using specific technologies to enhance communication (Federal Highway Administration, 2017). Partnering describes the formal process through which stakeholder connections are formed to "improve outcomes and complete quality projects that are built on time and within budget, focused on safety, and profitable for contractors" (Federal Highway Administration, 2017). One specific technology promoted by FHWA to improve collaboration and acceptance of e-Construction principles during the EDC-4 cycle was e-ticketing.

Initial STA adoption for e-ticketing was primarily focused on asphalt materials since it is the predominant highway roadway construction material (Federal Highway Administration, 2016; Epps, 2019). Between 2018 and 2020, several states entered various phases of e-ticketing adoption (Federal Highway Administration, 2020a). A survey was distributed to the American Association of State Highway and Transportation Officials Committee on Construction (AASHTO COC) membership, as part of the National Cooperative Highway Research Program (NCHRP) Synthesis 545. The report findings indicated that the research most needed to advance materials tracking and management in highway construction is a benefit-cost analysis of e-ticketing (Dadi et al., 2020).

3.2.1 Benefit-Cost Analysis

Benefit-cost analysis (BCA) evaluates the benefits and costs associated with one or several investment options to select the best alternative for a given decision (Saad and Hegazy, 2015). The investment is then considered acceptable if the noted benefits exceed the noted costs. BCA became part of public administration policy decision making in 1936 when the U.S. Flood Control Act required that the expected benefits from planned flood-control projects should exceed presumed costs (Arler, 2006). Since then, BCA has become an essential tool within governmental decision making and is recognized as a tool to ensure the assessment of "losses and gains, guarantee highest return over the money spent, and gain the public support" (Saad and Hegazy, 2015). Liu et al (2022) note that BCA quantifies the value of all consequences of an investment in monetary terms and helps decision makers properly allocate resources.

Benefit-cost analysis has both an informal and formal component. The informal component, commonly referred to as qualitative analysis, investigates relationships between perceived costs and benefits while the formal component, referred to as quantitative analysis, relies on numerical data and provides more precise analysis (Ikpe et al., 2012; Sinden, 2015). While some studies may tend to lean toward more qualitative or quantitative approaches, mixed method research can incorporate elements of both approaches. Therefore, with both approaches used concurrently, the overall strength of the study becomes greater than either a qualitative or quantitative study (Creswell, 2009).

3.2.2 Previous E-Ticketing Benefit-Cost Analysis

Several previous efforts have been made to quantify prospective benefits and costs regarding e-ticketing for asphalt operations.

Table 3.1 summarizes the benefits of e-ticketing noted in the literature review while Table 3.2 summarizes the challenges noted. Sturgill et al. (2019) noted benefits and challenges at both the field and project management levels for both STA and highway contractor stakeholders after pilot projects were conducted with the Kentucky Transportation Cabinet (KYTC) during the 2018 construction season. Subramanya et al. (2022a) identified benefits relating to project cost/schedule, safety, and project stakeholders while also reviewing previous research efforts and e-ticketing adoption methods implemented by STAs in the beginning of the COVID-19 pandemic. Robertson et al. (2022) also noted benefits and challenges for e-ticketing adoption after conducting focus group interviews with New Mexico Department of Transportation engineers.

Table 3.1 Noted E-Ticketing Benefits

Category	Description	Reference
Safety	Field personnel safety is increased through data automation.	Robertson et al., 2022 Sturgill et al., 2019 Subramanya et al., 2022a
Data Availability and Retention	Project information is electronically stored and readily accessible for stakeholders to review.	Robertson et al., 2022 Sturgill et al., 2019 Subramanya et al., 2022a
Information Management	Improved field data collection allows for improved construction office operations, such as contractor payment, and agency operations, such as pavement monitoring and asset management.	Robertson et al., 2022 Sturgill et al., 2019 Subramanya et al., 2022a
Knowledge of Haul-Vehicle Locations	Knowledge of haul-vehicle locations allows paving operations to be altered for increased pavement mat quality.	Sturgill et al., 2019 Subramanya et al., 2022a
Technology Integration	Innovative technologies, such as intelligent compaction, infrared thermal scanning, etc. can be combined and reduce manhours needed for project inspection.	Subramanya et al., 2022a

Table 3.2 Noted E-Ticketing Challenges

Category	Description	Reference
Cellular Connection	Limited internet accessibility at rural asphalt plants and projects.	Robertson et al., 2022 Sturgill et al., 2019 Subramanya et al., 2022a
GPS Coverage in Third-Party Haul Vehicles	Prevalence of third-party haul vehicles makes it difficult to ensure responders/sensors are always present and working during shift.	Robertson et al., 2022 Sturgill et al., 2019 Subramanya et al., 2022a
Determination on E-Ticketing System	Agencies must decide whether to purchase systems from outside software vendors or create in-house applications. Allowance of multiple systems increases required trainings and access for various personnel and may increase resistance to adoption efforts.	Sturgill et al., 2019 Subramanya et al., 2022a
Data Format and Ownership	Data file formats from e-ticketing systems are not standardized. Additionally, there are concerns over the privacy, storage, and ownership of the project data.	Sturgill et al., 2019 Subramanya et al., 2022a
Determination of QA Testing Locations	If connection issues arise on projects, a lack of real-time tonnage increases the difficulty of field inspectors determining locations for quality assurance testing.	Robertson et al., 2022
E-Ticketing QA/QC Processes	Quality assurance and quality control processes are necessary to ensure that ticket information is correct from plant to ticket system.	Robertson et al., 2022
Geozone Setup	Improper setup of geozones around locations such as the plant, project, or paver can lead to improper data storage.	Subramanya et al., 2022a

While Tables 3.1 and 3.2 highlight qualitative benefits and challenges identified through e-ticketing research efforts, none of the previously mentioned studies discuss the quantitative aspect considered by benefit-cost analysis. Powe (2020) briefly discusses the potential cost savings by eliminating one person from the STA asphalt paving inspection group, but the analysis is limited to theoretical assumptions based upon STA program budgets and resource allocation.

Therefore, as seen from the previous efforts regarding e-ticketing implementation for the asphalt paving process, there are multiple benefits as well as challenges and limitations worthy of further consideration. However, the qualitative data presented in each effort either pre-dates the COVID-19 pandemic or was collected during the pandemic. Additionally, the literature review conducted by Subramanya et al. (2022a) lacks primary source information from STA leadership regarding e-ticketing implementation beyond initial efforts made at the beginning of the COVID-19 pandemic while the items identified by Robertson et al. (2022) are derived primarily from one STA source. Powe (2020) and Subramanya et al. (2022b) discuss potential quantitative benefits in terms of monetary resources saved, but the approach is highly theoretical without field observations to reinforce conclusions. Therefore, the research presented in this paper seeks to gather primary source data from STAs across the country regarding current e-ticketing adoption efforts and information learned through the COVID-19 pandemic to create a qualitative benefit-cost analysis for e-ticketing implementation for asphalt paving processes while utilizing KYTC to both reinforce national opinions and serve as the basis for constructing a quantitative benefit-cost analysis for e-ticketing that illustrates whether the potential monetary savings are worth championing toward agency policy adoption.

3.3 Methodology

As previously mentioned, the primary objectives of this research are to determine the costs and benefits of e-ticketing for asphalt paving operations, both qualitatively and quantitatively. The research methodology is illustrated in Figure 3.1. The literature review identified knowledge gaps (KGs) related to the reliance on pre-pandemic data, a lack of primary source or field collected data, or the use of small sample sizes, illustrating a need for new data collection. The study design underwent Institutional Review Board (IRB) review at the University of Kentucky and was approved.

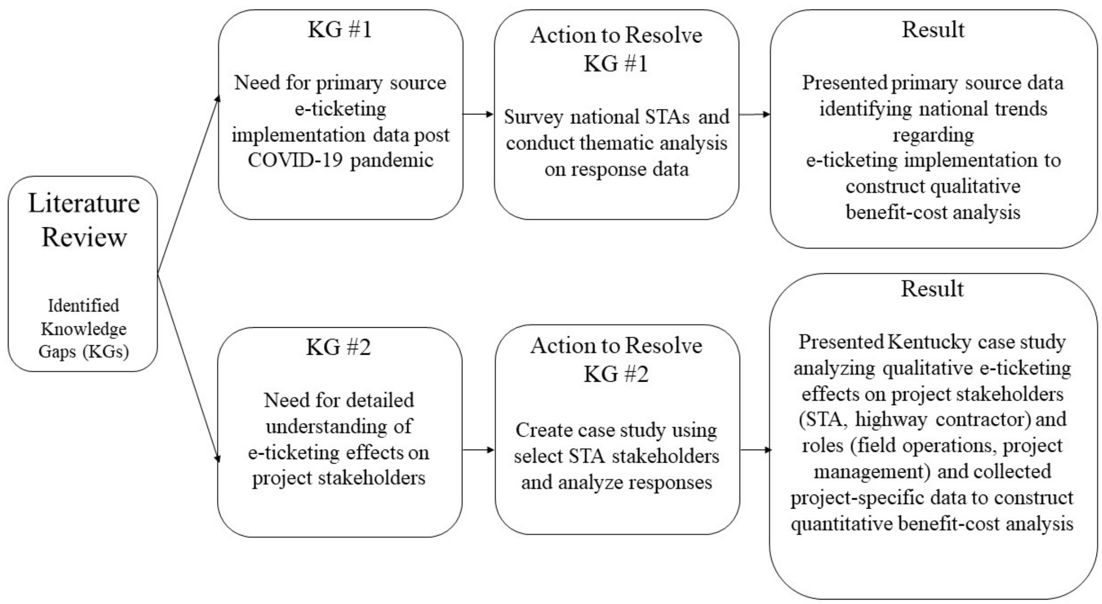


Figure 3.1 Qualitative and Quantitative Analysis Research Methodology Flowchart

To determine the costs and benefits qualitatively associated with e-ticketing for asphalt paving operations, a national perspective was necessary. An anonymous survey was distributed online using Qualtrics to the American Association of State Highway and Transportation Officials Committee on Construction (AASHTO COC), whose membership is comprised of representatives from each STA in the country. The development of the survey questions was aided through the literature review and previous discussions with STA personnel identified as champions of digital project delivery. The beginning portion of the survey requested information from each respondent regarding which agency they represented and a description of previous agency experiences with e-ticketing. Next, several questions were presented to gain an understanding of how e-ticketing has affected both agency and contractor personnel, including field and management staff. Finally, respondents were asked about their current satisfaction with e-ticketing policies and what concerns had been posed regarding future adoption of e-ticketing.

To examine potential benefits and challenges of e-ticketing in-depth, a case study method was decided upon. Due to previous experience with e-ticketing pre-pandemic, the state of Kentucky was selected. Several organizations in Kentucky were solicited for a second set of survey responses. Two highway contractor professional organizations, the Kentucky Association of Highway Contractors (KAHC) and the Plantmix Asphalt Industry of Kentucky (PAIKY), were approached regarding participation within this study. These professional organizations share an overlap in membership that represents a large portion of pre-qualified highway contractors in the state of Kentucky. While KAHC has a membership of approximately 150 regular members and 140 associate members across various work operations that comprise the highway construction industry, PAIKY membership is restricted to companies involved in the production or supply of asphalt materials in Kentucky. The online Qualtrics survey for these groups similarly requested anonymous information regarding the respondent’s role or job title and the contractor company, including the amount of work performed on an annual basis to be able to identify trends related to contractor operational size. Next, several questions collected company-specific experiences with e-ticketing and how e-ticketing has affected current operations. Finally, the survey asked if e-ticketing modified the outlook for the company.

To provide the agency perspective for Kentucky, a third survey was distributed online using Qualtrics to the membership of the KYTC Digital Project Delivery (KYTC DPD) committee. This subcommittee seeks to address the intersection between design and construction and how to implement technology such as e-ticketing to collect available construction operations data. The subcommittee is comprised of 27 individuals including both field and management staff related to highway construction. The survey requested anonymous information regarding the division or district the respondent represented along with their role or job title, descriptions of e-ticketing experiences on past projects, and input on the satisfaction and concerns about future adoption of e-ticketing as policy in Kentucky.

To quantify the costs and benefits of e-ticketing for asphalt paving processes, the Kentucky case study method is further advanced by way of project data. Data related to specific paving operations on KYTC projects was solicited from both field inspectors and project engineers associated with the KYTC DPD construction subcommittee. Project data was collected from across the state and combined with responses from highway contractors from KAHC and PAIKY and e-ticketing vendors that are commonly utilized in Kentucky. Additionally, safety information from the Occupational Safety and Health Program of the Kentucky Labor Cabinet was used to incorporate safety data into the quantitative analysis. This process is further described in the following Results and Analysis section.

Through feedback from multiple groups, a holistic analysis can be completed by comparing agency and contractor perspectives regarding e-ticketing and the associated costs and benefits. Additionally, the collection of national and state feedback allows for comparison of policy practices and potential adaptations to enhance e-ticketing applications.

3.4 Results and Analysis

The results of the surveys collected from the four committees (AASHTO COC, KAHC, PAIKY, and KYTC DPD) are described in detail in the following sections. First, national data is analyzed to determine qualitative benefits and costs associated with e-ticketing for asphalt paving applications. Second, the Kentucky case study is presented to perform an in-depth analysis on the potential qualitative benefits and costs associated with e-ticketing for asphalt paving applications. Additionally, project-specific data related to the role of the project inspector and project engineer is collected from KYTC projects with asphalt paving operations to create the basis for a quantitative analysis while also combining responses from highway contractors, e-ticketing vendors, and safety data from the state of Kentucky. From the case study, a quantitative framework is produced for STA adoption of e-ticketing for asphalt paving processes.

3.4.1 Qualitative Analysis

The survey of the AASHTO COC results in a total of 36 responses representing 33 different STAs from across the country. By surveying the AASHTO COC, first-hand information regarding e-ticketing implementation efforts and lessons learned throughout the course of the COVID-19 pandemic are gathered and compared with previously identified benefits and challenges noted before the COVID-19 pandemic as noted in the Literature Review. According to the collected data, 94% of the respondents work for their agencies within a construction division, and 83% of the respondents have at least 10 years of experience in administering highway construction projects or managing highway construction materials.

The general responses from the STAs, as previously discussed in section 2.3.1.1, are shown aggregated in Tables 3.3 and 3.4. Table 3.3 illustrates noted benefits with respect to field personnel and project management roles, while Table 3.4 lists concerns surrounding e-ticketing adoption as agency policy. Table 3.3 lists 7 total benefits as defined by the AASHTO COC. These are listed in descending order of magnitude based upon the number of responses and separated as related to either field operations or project management operations. The main benefits noted are safety and efficiency due to how e-ticketing processes alter typical functions of the project personnel and data retention for work reports and progress estimates. Table 3.4 lists 5 primary concerns identified by the AASHTO COC, also listed in descending order of magnitude based upon the number of responses. The concerns include cellular connectivity, e-ticketing system procurement, and data transfer automation.

Table 3.3 E-Ticketing Benefits for Field and Project Management Personnel

Project Delivery Role	Category	STAs Indicating Benefit	Percent of Responding STAs Indicating Benefit
Field Personnel	Increased Personal Safety	Alabama, Connecticut, Delaware, Georgia, Florida, Indiana, Iowa, Kansas, Maryland, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Utah, Vermont, Washington	63.64%
	Increased Project Inspector Availability	Alabama, Georgia, Indiana, Kansas, Maryland, North Dakota, Pennsylvania, South Carolina, Vermont	27.27%
	Reduction of Physical Project Data	Arkansas, Delaware, Indiana, Ohio, New Hampshire, Pennsylvania, Rhode Island, South Dakota, Texas	27.27%
Project Management	Improved Project Documentation	Alabama, Arkansas, Delaware, Georgia, Indiana, Maryland, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Utah, Vermont	48.48%
	Reduced Potential for Payment Errors	Connecticut, Florida, Georgia, North Carolina, North Dakota, Oklahoma, South Carolina, South Dakota, Texas, Utah	30.30%
	Reduced Time for Estimate Review/Processing	Delaware, Georgia, Ohio, Rhode Island	12.12%
	Optimized Trucking Cycles	Florida, South Dakota	6.06%

Table 3.4 E-Ticketing Concerns for STAs

Category	STAs Indicating Concern	Percent of Responding STAs Indicating Concern
E-Ticketing performance on projects with poor cellular coverage/connectivity	Connecticut, Florida, Indiana, New York State, North Carolina, North Dakota, Ohio, Oklahoma, Tennessee, Utah, Washington State, West Virginia, Wyoming	39.39%
Determination of Stakeholder responsibility for acquiring e-ticketing system and consequences of choice	Kansas, Maryland, Pennsylvania, South Dakota, Vermont	15.15%
Capability to automate data transfer from e-ticketing system to construction management software	Arkansas, Delaware, Hawaii	9.09%
Use of multiple e-ticketing systems versus standardized system	Iowa, Michigan	6.06%
Reality of the benefit of trading digital storage for physical storage	Virginia	3.03%

To verify the results from the AASHTO COC survey, a case study method was utilized focusing on the state of Kentucky due to previous pre-pandemic experience with e-ticketing. The results from the KAHC/PAIKY survey were previously summarized in Table 2.5 while the KYTC DPD survey results were presented in Table 2.7. From Table 2.5, highway contractors in Kentucky focused on the safety savings provided by e-ticketing, along with the potential for greater supervision of their third-party hauler vehicles. Project-related information was also mentioned as being more secure, which allows for easier quantity tracking and improved payments. Table 2.7 illustrated that KYTC engineers focused on the improved availability that e-ticketing offered project inspectors, as more time during a shift could be focused on random material sampling or tracking void/rejected material in addition to the previously noted safety benefits. Regarding project management, e-ticketing allowed engineers to monitor multiple projects remotely while also decreasing the potential for damaged or missing documentation which could lead to complications regarding payments issued to contractors.

By combining the data presented in Tables 2.5, 2.7, 3.3, and 3.4, a qualitative benefit-cost analysis is created from the primary data collected through the national surveys and the Kentucky case study. The qualitative analysis is shown in Table 3.5. The qualitative analysis is separated between benefits and costs related to both field personnel and project management personnel. Additionally, the relative strength of each benefit and cost is noted by indicating in which survey effort it was mentioned.

Table 3.5 Qualitative Benefit-Cost Analysis for E-Ticketing

Project Delivery Role	Category	Benefit?	Cost?	Survey Effort: National STA	Survey Effort: KAHC/ PAIKY	Survey Effort: KYTC
Field Personnel	Personal Safety	X		X	X	X
	Project Documentation	X		X	X	X
	Inspector Availability & Task Load	X		X		X
	Laborer Availability & Task Load	X			X	
Project Management	Accuracy of Pay Estimates	X		X	X	X
	Trucking Cycle Optimization	X		X	X	
	Automation of Data Transfer to Construction Management System	X		X		
	Data Distribution to Company Stakeholders	X			X	
	Cellular Connectivity		X	X	X	X
	Procurement of E-Ticketing System		X	X		

As seen from the qualitative analysis, the benefits for e-ticketing implementation on asphalt paving processes significantly outweigh the potential costs for implementation. The benefits shown can be summarized in the areas of safety, efficiency, and transparency, with impacts to both field and project management personnel. However, the level of significance can only be adequately determined through a quantitative analysis informed by the identified benefits and costs in the qualitative analysis, which is discussed in the following section.

3.4.2 Quantitative Analysis

While the qualitative analysis presented in Table 3.5 indicates that e-ticketing for asphalt paving operations is worth further exploration for adoption as STA policy, a quantitative analysis is necessary to provide further evidence to STA leadership to reinforce the potential savings associated with such policy changes. As previously mentioned, the benefits of e-ticketing can be shown in the areas of safety, efficiency, and transparency while the primary associated costs center around the procurement and function of the e-ticketing system.

To begin the quantitative analysis, project specific data was solicited from KYTC project inspectors and engineers to gain a detailed perspective on the effect of e-ticketing on field operations and project management personnel, respectively. Collection of the project data from inspectors and engineers utilized an online daily survey created in Qualtrics. Project engineers and inspectors were asked for the KYTC contract identification number, project county, project scope, controlling asphalt operation, number of loads received on the project, and the corresponding tonnage for each asphalt mixture. Project inspectors were then asked to approximate the amount of time spent during the shift collecting tickets following traditional methods (receiving paper ticket from haul vehicle drivers) compared to the time spent utilizing an e-ticketing system. Engineers were asked to approximate the amount of time spent reviewing weigh tickets, confirming information recorded on the Daily Work Report, and filing and storing this information in project files with traditional methods utilizing paper weigh tickets compared to the time spent to complete the same tasks utilizing an e-ticketing system.

The data collection for Kentucky resulted in information from 18 construction projects in 6 different counties, totaling 159 observations. From the data collection, two samples can be established: traditional and e-ticketing workflows. The data are independent in that the results for the e-ticketing workflow survey do not depend on the traditional workflow survey. The data are also representative of a simple random sample from the population of all KYTC construction projects. Finally, the data appears to be generally normally distributed without a severe skew, which allows for a two-sample t-test to be performed to determine if e-ticketing effects various project roles by determining if the mean collection or processing times differ from one another. Tables 3.6 and 3.7 illustrate the aggregated results for KYTC inspectors and engineers, respectively.

Table 3.6 KYTC Inspector Project Data

Workflow Type	**Sample Size**	**Mean Collection Time (Minutes per ticket)**	**Standard Deviation (Minutes per ticket)**	**T-Statistic**	**Degrees of Freedom**	**Significance Level (p-value)**
Traditional	90	2.48	4.0117	-5.245	178	<0.0001
E-Ticketing	90	0.24	0.5674			

Table 3.7 KYTC Engineer Project Data

Workflow Type	Sample Size	Mean Processing Time (Minutes per ticket)	Standard Deviation (Minutes per ticket)	T-Statistic	Degrees of Freedom	Significance Level (p-value)
Traditional	69	0.75	2.5037	-0.477	136	0.6345
E-Ticketing	69	0.55	2.4262			

Therefore, from Tables 3.6 and 3.7, apparent reductions in the time required to collect, review, and store weigh ticket information are possible for both the project inspector and the project engineer, although only the project inspector savings is found to be statistically significant, assuming a 95% confidence interval (or p-value < 0.05).

Next, equations must be defined for the benefits and costs determined during the qualitative analysis. Table 3.8 defines the equations used for the quantitative analysis.

Table 3.8 Quantitative Analysis Equations

Project Delivery Role	Category	Equation
Field Personnel	Inspector Personal Safety	(Workers Compensation Insurance Costs) x (Inspector Hourly Rate) x [(Traditional Inspector Time per Ticket) - (E-Ticket Inspector Time per Ticket)]
	Laborer Personal Safety	(Workers Compensation Insurance Costs) x (Laborer Hourly Rate) x [(Traditional Inspector Time per Ticket) - (E-Ticket Inspector Time per Ticket)]
	Project Documentation	(Engineer Hourly Rate) x [(Traditional Engineer Time per Ticket) – (E-Ticket Engineer Time per Ticket)]
	Inspector Availability & Task Load	(Inspector Hourly Rate) x [(Traditional Inspector Time per Ticket) - (E-Ticket Inspector Time per Ticket)]
	Laborer Availability & Task Load	(Laborer Hourly Rate) x [(Traditional Inspector Time per Ticket) - (E-Ticket Inspector Time per Ticket)]
Project Management	Accuracy of Pay Estimates	[(Engineer Hourly Rate) x (Traditional Engineer Time per Ticket)] + (Monetary Value of Corrected Payments)
	Trucking Cycle Optimization	-
	Automation of Data Transfer to Construction Management System	(Engineer Hourly Rate) x (Traditional Engineer Time per Ticket)
	Data Distribution to Company Stakeholders	-
	Cellular Connectivity	-
	Procurement of E-Ticketing System	-

The equations listed in Table 3.8 for the benefit and cost categories previously defined have units of “Dollars per Ticket” which can then serve as a multiplier. However, to calculate each equation, several terms within Table 3.8 must be defined. These definitions are shown below.

1. **Workers Compensation Insurance Costs**: Approximated as $0.97 per $100 of covered wages (Murphy et al., 2021).
2. **Inspector Hourly Rate**: Defined three separate pay grades with corresponding minimum and maximum hourly rates for KYTC construction inspectors from Kentucky state job classifications.
3. **Engineer Hourly Rate**: Defined four separate pay grades with corresponding minimum and maximum hourly rates for KYTC construction engineers from Kentucky state job classifications.
4. **Laborer Hourly Rate**: Defined two separate hourly rates for construction laborers for non-federal and federal wage requirements from various KYTC contract proposals and the United States Bureau of Labor Statistics data for Kentucky (Bureau of Labor Statistics, 2021).
5. **Monetary Value of Corrected Payments**: Defined payments recorded as less than ten tons as a change to the daily total payment made upon review by the project inspector or engineer. Therefore, the total monetary value is calculated by multiplying these correction totals by the listed unit price.

To complete the quantitative analysis, statewide data for the 2022 KYTC construction season was collected. This data set was provided by the KYTC Division of Construction, detailing 3,149 payments for asphalt paving work on 749 projects, including KYTC contract identification numbers, asphalt mixture bid items, unit prices, and installed quantities. For the analysis, the installed quantities were divided by 20 tons and 25 tons to create a theoretical minimum (185,278 tickets) and maximum (231,598 tickets) number of tickets that would need to be addressed by both field and office personnel. Next, the equations from Table 3.8 were multiplied against the statewide data set while varying the estimated number of tickets and hourly rates for KYTC engineers, inspectors, and highway contractor laborers. Finally, to determine an approximate monetary value for each category, KYTC personnel information was utilized to determine the distribution of inspectors and engineers across the defined pay grades and hourly wage rates. Construction laborer monetary values were determined by the federal or non-federal funding status of each project, which dictated required hourly wage rates. Cost monetary values were determined through discussions with multiple e-ticketing software vendors. For the quantitative analysis, costs were calculated under the assumption of an STA-controlled e-ticketing portal, with an annual cost of $10,000 according to one software vendor. More information is located within the Discussion section of the paper. Table 3.9 illustrates the approximated monetary value for each benefit and cost category of the quantitative analysis.

Table 3.9 Quantitative Analysis of E-Ticketing Benefits and Costs

Benefit or Cost?	**Category**	**Monetary Value assuming minimum number of tickets**	**Monetary Value assuming maximum number of tickets**
Benefit	Inspector Personal Safety	$1,633.28	$2,041.60
	Laborer Personal Safety	$1,414.72	$1,768.40
	Project Documentation	$20,465.79	$27,296.68
	Inspector Availability & Task Load	$168,379.33	$218,229.33
	Laborer Availability & Task Load	$161,474.32	$201,842.90
	Accuracy of Pay Estimates	$105,252.18	$124,438.86
	Trucking Cycle Optimization	-	-
	Automation of Data Transfer to Construction Management System	$76,746.72	$95,933.40
	Data Distribution to Stakeholders	-	-
	Benefit Category Totals	*$535,366.34*	*$671,551.17*
Cost	Cellular Connectivity	-	-
	Procurement of E-Ticketing System	$10,000.00	$10,000.00
	Cost Category Totals	*$10,000.00*	*$10,000.00*

From Table 3.9, the monetary combined benefit of e-ticketing for both STAs and highway contractors in Kentucky based upon 2022 construction data ranges from $535,366.34 to $671,551.17. To complete the benefit-cost analysis, a benefit-cost ratio (BCR) is calculated by dividing the present value of expected benefits by the present value of expected costs (Mizusawa and McNeil, 2009). Therefore, the estimated BCR for e-ticketing adoption for Kentucky ranges from 53.54 assuming the minimum number of tickets to 67.16 assuming the maximum number of tickets.

A sensitivity analysis should also be carried out in conjunction with any benefit-cost analysis to determine whether a holistic view of the analysis is being presented. This secondary portion of the analysis helps determine how net benefits and costs may change if different factors included in the analysis are varied. This also helps determine whether the uncertainty over values, which in the case of this analysis is the monetary value assigned to different portions of the benefit-cost structure, is significant. Sensitivity analyses are normally conducted in four main ways: best/worst case analysis, partial sensitivity analysis, breakeven analysis, and Monte Carlo simulations (Scioto Analysis, 2020). These different analysis types are described in Table 3.10.

Table 3.10 Sensitivity Analysis Descriptions

Analysis Type	**Description**
Best/Worst Case	Takes all inputs and sets them to the most optimistic or pessimistic reasonable assumption. This allows for a clear view of what happens if all goes right, or all goes wrong, respectively. This analysis also allows for discovery of whether the final evaluation ever changes signs from positive to negative, depending on the assumptions made.
Partial Sensitivity	Adjusts one variable at a time to see the impact on the study results. Can give insight into the effect of variable based upon the change in results.
Breakeven	Adjusts variables to find the point at which costs equal benefits. Can provide answers as to the scenario in which viability of a given procedural change is minimal from current standards.
Monte Carlo	Generation of large numbers of possible outcomes by varying all assumptions. From this, confidence intervals can be estimated for different cost-benefit outcomes.

As shown in Table 3.9, the structure of the benefit-cost analysis depends primarily on the number of tickets processed. Therefore, a best/worst case analysis is selected for the sensitivity analysis structure, and since the calculated BCR is always greater than one, the implementation of e-ticketing is always considered to be beneficial.

3.5 Discussion

The qualitative analysis of both national and state-level responses regarding e-ticketing for asphalt operations point towards an expected benefit for all stakeholders. However, the power of a qualitative analysis is limited without a quantitative analysis for comparison. The project specific data collected from the 2022 Kentucky Transportation Cabinet construction operations reinforces the findings of the qualitative data since it indicates significantly higher expected monetary benefit than expected monetary costs.

One major finding from the quantitative analysis is that time savings measured is only statistically significant for project inspectors and not project engineers. This may be due to project engineers generally having multiple ongoing projects at any given time, so time designated for project information review is generally restricted to verifying tonnage calculations and ensuring that there is no lost data, such as missing tickets. This is not the case for project inspectors, who are normally assigned to one construction project and are responsible for verifying ticket information in the field, such as haul vehicle identification, asphalt mixture information, asphalt load time between the plant and project, and field quality assurance test results, such as asphalt mixture temperatures and density cores. By utilizing e-ticketing on project sites, collection of paperwork can be eliminated through digital automation and allow the project inspector to focus solely on completing field quality assurance testing. Therefore, the quantitative analysis does not assume that the introduction of e-ticketing as inspection policy would allow for project inspection personnel to be removed from one project and assigned to another since many STAs already rely upon consultant inspection personnel due to a shortage of in-house staff. Instead, the quantitative analysis assumes that the automation of weigh ticket collection through e-ticketing reduces the number of tasks to be completed by the project inspector and allows for the primary focus to be on ensuring the quality of the asphalt material being placed on the project.

Several benefits and costs noted in the qualitative analysis were not enumerated in the quantitative analysis. This was largely due to the responses from the highway contractor survey efforts. Highway contractors noted that e-ticketing platforms allowed for the potential to optimize trucking cycles between the plant and the project, as well as distributing data to various project stakeholders. However, even though the potential for these benefits was noted, no consensus could be reached regarding a monetary approximation for either category. Therefore, for the purposes of the analysis, these benefits are considered intangible. It is possible that improved data distribution may already be quantified in areas such as increased accuracy of pay estimates, while haul vehicle optimization may be quantified under an area such as reduced project management costs, which was not specifically identified within the AASHTO COC or KAHC/PAIKY surveys.

Similarly, cellular connectivity is listed as a potential cost due to the concern raised by STAs and highway contractor stakeholders alike in the qualitative analysis, but the cost is not quantified within the quantitative analysis. This is due to the role of the e-ticketing software vendor within the asphalt paving construction paradigm. Through contractual obligations between an e-ticketing software vendor and either an STA or highway contractor, the e-ticketing software vendor is responsible for establishing and maintaining the functionality of the digital environment. So, while connectivity is a primary concern for multiple stakeholders, the only direct cost to be paid is for the procurement of the system, after which addressing concerns within the system becomes the responsibility of the software vendor. Through conversations with multiple e-ticketing software vendors, connection issues can be addressed in a variety of ways, including quick response (QR) codes utilized by haul vehicle drivers with weigh ticket information embedded or storing field inspection notes electronically that can be synchronized later when a device re-establishes cellular connection. Therefore, for the purpose of the quantitative analysis, cellular connectivity is included within the procurement cost, which is based upon an annual fee paid by the STA to an e-ticketing software vendor to construct an e-ticketing portal for highway contractors to use. The vendor cost information may differ depending upon the selection of e-ticketing software vendor, as other companies determine costs based upon the number of tickets processed or a percentage of awarded contract values. Additionally, costs may also differ if an STA elects to create an in-house system as opposed to contracting with an e-ticketing software vendor.

Finally, the safety benefit calculations noted in the quantitative analysis are relatively low when compared to other noted benefits. Due to the definition of the equations in Table 3.8, the monetary benefits shown are calculated as a difference in exposure between traditional workflows and augmented workflows utilizing e-ticketing. The calculations as shown in Table 3.9 do not consider the potential monetary costs associated with a work zone injury. Table 3.11 utilizes the United States Department of Labor Occupational Safety and Health Administration $afety Pays Program estimated costs calculator to assess the potential monetary impact of common workplace injuries that may occur due to exposure to heavy equipment often found in the work zone during asphalt paving operations (Occupational Safety and Health Administration, 2023).

Table 3.11 OSHA $afety Pays Injury Cost Estimates

Injury Type	**Direct Cost**	**Indirect Cost**	**Total Cost**
Hearing Loss (Cumulative injury)	$18,828	$20,710	$39,538
Sprain	$30,487	$33,535	$64,022
Strain	$32,023	$35,225	$67,248
Fracture	$54,856	$60,341	$115,197
Crushing	$67,003	$73,703	$140,706
Dislocation	$75,190	$82,709	$157,899
Multiple Physical Injuries	$78,141	$85,955	$164,096
Amputation	$96,003	$105,603	$201,606

The approximated costs in Table 3.11 are those for just one instance of each category of injury. For reference, the highway/street/bridge construction industry in Kentucky experienced between 100 and 300 nonfatal injuries per year between 2011-2021 (Bureau of Labor Statistics, 2023). During this same period, the industry experienced 3 work fatalities in 2012, 1 in 2015, 2 in 2017, 1 in 2018, 2 in 2019, and 3 in 2020 (Bureau of Labor Statistics, 2023). According to the National Safety Council, in 2021, the cost per work death (both direct and indirect costs) was $1,340,000 (National Safety Council, 2023). Therefore, if reducing field employee exposure for both STA project inspectors and highway contractor laborers results in just one reduction of the nonfatal injuries shown in Table 3.11, the calculated value of the BCR would increase, indicating an even larger return-on-investment (ROI) for asphalt paving stakeholders. Additionally, if e-ticketing implementation prevents a field employee fatality, such as the Iowa Department of Transportation experienced, which drove their research into e-ticketing, the calculated BCR value and the ROI would dramatically increase (Mulder, 2019).

3.6 Conclusions

The primary objectives of the study were to provide an updated qualitative analysis of e-ticketing for asphalt paving operations through experience gained by emergency deployment during the COVID-19 pandemic while also creating an approach for quantitative analysis to investigate the monetary value associated with the benefits and costs identified in the qualitative portion of this study. The qualitative portion of the study identified several benefits not previously captured with respect to both field and project management personnel in the areas of safety, efficiency, and transparency. This additional e-ticketing experience gained through the pandemic allowed for advancements in the existing benefit-cost analysis and the opportunity to quantify both benefits and costs. To perform the quantitative analysis, a case study methodology was used centering on KYTC and associated highway contractors, featuring field observations collected from various KYTC projects and project personnel. These field observations pointed to a statistically significant time savings for KYTC field personnel, but savings were deemed not statistically significant for project management personnel. While the monetary portion of the quantitative analysis also indicates that most of the benefit of e-ticketing favors field personnel, there is inherent benefit to project management personnel as well due to factors such as the improved accuracy of project documentation. e-Ticketing is a market-ready innovation that is the most adopted technology in the history of FHWA's EDC program (Sadasivam et al., 2021). Yet while the adoption of e-ticketing is prevalent, the justification and noted benefits of this innovation has been mostly anecdotal to date due to a lack of valuation framework (Weisner, 2021). This study combines anecdotal evidence, theoretical contributions, and statistical evidence to create the case for e-ticketing implementation. The study incorporates anecdotal evidence collected from subject matter experts regarding e-ticketing benefits and costs to create an improved benefit-cost analysis method applied to a new domain of electronic bulk material weigh tickets for highway construction. The quantitative benefit-cost framework presented is useful both to STAs as a proof-of-concept for e-ticketing adoption as agency policy and by other transportation-focused researchers for evaluating emerging technological applications.

The main limitation of this study is the participation of highway contractors in the quantitative portion of the analysis. While contractor responses in the qualitative portion of the analysis highlighted benefits of e-ticketing, such as haul vehicle cycle optimization and improved data distribution to project stakeholders, minimal information was present regarding the realization of the monetary value of these benefits. Therefore, one area of future research may include partnering with specific highway contractors to better understand the monetary benefits particularly outlined in the qualitative analysis. The ability to estimate monetary benefits for highway contractors has the potential to increase the calculated benefit-cost ratio defined in this study and further reinforce the economical case for e-ticketing policy adoption in asphalt paving operations. A secondary area of future research may include investigating how overtime rates for project inspection personnel affect the quantitative benefit-cost analysis, in addition to the effect of the use of consultant inspection on STA construction projects, as neither factor was included in this study.

CHAPTER 4. A QUANTITATIVE ANALYSIS TOWARDS GUIDANCE FOR IMPLEMENTING E-TICKETING FOR ASPHALT PAVING OPERATIONS

4.1 Introduction

The United States has routinely underfunded necessary roadway maintenance for an extended period, resulting in backlogged needs for the national transportation network, as reported by the American Society of Civil Engineers (ASCE) 2021 Infrastructure Report Card (American Society of Civil Engineers, 2021). Therefore, due to an aging infrastructure continually deteriorating into a state of disrepair, state transportation agencies (STA) must continually complete an increasingly large number of complex projects to satisfy the needs of the traveling public and ensure a safe and functional transportation network (Crossett and Hines, 2007; Taghizadeh et al., 2020). Many of these public construction contracts utilize unit-price constructs, which require substantial documentation as proof for quantities paid based on installation rather than preliminary estimates, and to protect against audit (Ewerhart and Fieseler, 2003; Mandell and Brunes, 2014; Hyari et al., 2017). Specifically, highway construction projects generally require large amounts of various materials to complete, which invariably leads to significant amounts of paper-based data to be retained verifying material delivery to a project (Nipa et al., 2019). Typical workflows for highway construction materials require electronic data from a production plant or quarry to be transferred onto paper weigh tickets, which are then delivered to the project by the haul-vehicle driver and provided to the STA project inspector. At the completion of a work shift, the STA project inspector may then be required to re-scan the paper weigh ticket back into an STA-controlled electronic storage location for documentation retention purposes. This constant shift in data mediums from electronic storage to physical paper back to electronic storage is inefficient at best, largely human-dependent to complete, and subject to potential destruction and data loss due to field conditions once the weigh ticket moves onto a physical paper copy (Navon and Shpatnitsky, 2005; Kasim, 2015). As previously described, there are considerable amounts of resources necessary to produce, record, and archive physical weigh ticket data with minimal stakeholder benefits, such as traceability and potential for future use in the operations and maintenance phase after project completion, as noted by Sadasivam et al. (2021).

As the number of projects to be completed by STAs increases to meet the needs of their transportation network and local constituency, the amount of material compensated by weight also increases, and in turn, the number of weigh tickets to be processed for payment to be rendered. Due to the increased number of weigh tickets and the traditional processes employed on construction projects that lead to hazardous scenarios for field employees, the associated human costs must be considered. Traditional methodology results in field employees, and specifically STA project inspectors, being placed in proximity to dangerous work conditions, such as heavy construction equipment and high-speed traffic moving through the work zone (Embacher, 2021). The necessity for project inspectors to routinely enter these precarious locations along a jobsite place them at higher risk for serious injury and fatality due to increased exposure to large vehicles, which accounts for most roadway construction accidents involving workers (Federal Highway Administration, 2020b). Chi et al. (2013) noted that it is the responsibility of safety managers to eliminate unsafe working conditions and thereby minimize the risk for potential harm. Therefore, STAs must change their operational strategy for the safety benefit of their workers.

In addition to safety concerns, agencies must also find ways to counteract decreasing in-house staffing levels. Between 2000 and 2010, STAs included in the *National Cooperative Highway Research Program (NCHRP) Synthesis 450: Forecasting Highway Construction Staffing Requirements* stated that their state-managed lane miles increased by an average of 4.10% while their number of full-time equivalent staff decreased by an average of 9.68% (Taylor and Maloney, 2013). Due to legal mandates and difficulty in recruiting and retaining employees with necessary skillsets, this issue has only become more exacerbated (Al-Haddad et al., 2022). However, even when faced with factors that necessitate change, STAs tend to resist changes in the status quo by default. Kimmel et al. (2015) note that the public road construction sector is "inertially bound" or slow to seek and adopt innovative technologies produced by industry while *NCHRP Special Report 249: Building Momentum for Change* states that innovation barriers are "widespread", "complex", and "deeply embedded" and points to institutional inertia as a considerable cultural aspect to be overcome within the highway construction sector (Transportation Research Board, 1996). Christensen and Lægreid (1999) also discuss the common resistance to public sector reform initiatives, while Rahman et al. (2023) indicates that leadership is a determining factor in either overcoming or perpetuating organizational inertia to resist change.

Therefore, due to the previously stated inefficient workflows, safety concerns for a constantly decreasing amount of field personnel, and the obstacle of institutional inertia, STAs must investigate new methods to automate inspection tasks. These deficiencies emphasize a need for digital processes and increased usage of innovative technologies. Efforts to improve technology use in the weigh ticket collection process have been aided by the Federal Highway Administration (FHWA) "Every Day Counts" (EDC) technology implementation initiative. The EDC-6 cycle specifically focuses on e-ticketing, or the provision for all project stakeholders to "produce, transmit, and share materials data and track and verify material deliveries" electronically (Federal Highway Administration, 2021a). With the acceptance and institution of e-ticketing practices, project data can be digitally tracked and archived with the additional benefit of removing STA project inspectors away from potentially dangerous scenarios within the work zone (Wilkinson and Schroeder, 2020). E-ticketing procedures allow for the potential to "integrate material data with construction management systems for acceptance, payment and source documentation" (Federal Highway Administration, 2021a). However, the qualitative research present to-date has not yet yielded progression by all agencies. Therefore, a quantitative aspect to the research must be presented to meet this need.

The intent of the research presented is to investigate the quantitative impact of e-ticketing on various project stakeholders to better guide implementation efforts for STAs, which was pointed out by Dadi et al. (2020) as a primary research need. To accomplish this, a quantitative analysis utilizing the Kentucky Transportation Cabinet (KYTC) as a case study was completed focusing on the impact of e-ticketing for asphalt paving operations due to the prevalence of asphalt as a primary roadway construction material (Federal Highway Administration, 2016; Epps, 2019). This chapter is organized into five sections to present previous e-ticketing implementation efforts, quantitative analysis methods, the research methodology, the analysis results, a discussion, and conclusions with contributions to the body of knowledge and areas of future research.

4.2 Methods

4.2.1 Literature Review

FHWA began the EDC program in 2009, with the 2015-2016 cycle featuring e-Construction as a select innovation during EDC-3 (Dadi et al., 2020). The EDC-4 cycle in 2017-2018 remained focused on e-Construction as an innovation, but the emphasis shifted to a combined focus on e-Construction and Partnering, emphasizing the need for stakeholder participation and cooperation in the face of evolving construction practices for transportation agencies (Federal Highway Administration, 2017). The baseline report for the EDC-4 cycle showed that significant progress had been made incorporating e-Construction principles from EDC-3. Additionally, FHWA also viewed EDC-4 as an opportunity to promote e-ticketing as an innovation for utilization by STAs who had become more receptive to e-Construction principles after the EDC-3 cycle. Between 2018 and 2020, several states entered various phases of e-ticketing adoption (Federal Highway Administration, 2020a). A survey was also completed by the American Association of State Highway and Transportation Officials Committee on Construction (AASHTO COC) membership, as part of the National Cooperative Highway Research Program (NCHRP) Synthesis 545, indicating that the research most needed to advance materials tracking and management in highway construction is a benefit-cost analysis of e-ticketing (Dadi et al., 2020). Additionally, it was noted that “the implementation of this technology in the industry has been slow and challenging to many STAs” (Dadi et al., 2020).

4.2.2 Previous E-Ticketing Benefit-Cost Analysis

Several previous efforts have been made to aggregate prospective costs and benefits regarding e-ticketing for asphalt operations. As previously discussed in Chapter 3, Sturgill et al. (2019) conducted pilot projects with the Kentucky Transportation Cabinet (KYTC) during the 2018 construction season. Subramanya et al. (2022a) also conducted a literature review of e-ticketing adoption methods used by STAs in the beginning of the COVID-19 pandemic. Finally, Robertson et al. (2022) identified benefits and limitations of e-ticketing adoption after conducting focus group interviews with stakeholders in New Mexico. These previous research efforts are summarized in Tables 3.1 and 3.2.

While these previous research efforts detail qualitative costs and benefits, there is minimal literature available regarding the quantitative impacts of e-ticketing in asphalt paving applications and guidance for implementation efforts by STAs. Powe (2020) briefly discusses the potential cost savings to be realized by eliminating one person from the STA asphalt paving inspection group. However, this analysis is limited to theoretical assumptions based upon estimated STA program budgets and assumed resource allocation. Subramanya et al. (2022b) conducted a survey of STAs to estimate the impact of e-ticketing particularly with a focus on project inspectors. However, this analysis is limited to survey responses from a small sample of STAs and included some respondents who did not visit construction sites on a regular basis.

4.2.3 Quantitative Analysis

Therefore, a quantitative analysis of e-ticketing for asphalt paving operations is missing from the academic literature discussing the relative benefits of e-ticketing and best practices for implementing as standard policy. To properly complete this analysis, several aspects are necessary to consider for the experimental design. First, survey efforts and focus groups can be utilized to ascertain distinctive factors indicating areas of further study (Dai et al. 2009; Jang and Skibniewski, 2009; Mostafavi et al., 2012). Once important factors or roles have been identified, the effect of e-ticketing can be quantified to aid in implementation efforts. To do this, multivariate techniques such as cluster analysis can be used to classify data into groups, which can then be used to support decision making (Dell'Acqua et al., 2012; Rudeli et al., 2018; Nassereddine et al., 2022).

4.2.4 Existing Knowledge Gap

As seen from the previous research efforts, there are multiple benefits and challenges worthy of further consideration regarding adopting e-ticketing as a standard of practice for asphalt paving operations. However, the literature is predominantly qualitative in nature and either pre-dates the COVID-19 pandemic or was collected during the early stages of the pandemic. While Powe (2020) offers potential quantitative benefits for STAs in terms of monetary resources saved upon implementing e-ticketing, the approach is highly theoretical without field observations to reinforce the conclusions. Therefore, the research presented in this paper seeks to gather field observations from KYTC asphalt paving projects completed after the COVID-19 pandemic to construct a quantitative analysis observing the effects of e-ticketing while using cluster analysis to aid in e-ticketing implementation as STA policy and help satisfy the research needs indicated by Dadi et al. (2020).

4.2.5 Methodology

As previously mentioned, the primary research objective is to investigate the impact of e-ticketing on various project stakeholder roles to better guide implementation efforts for STAs if e-ticketing is adopted as standard policy. The study design adopts a modified action research approach. Action research emphasizes engaging practitioners as collaborators within the research effort to generate knowledge needed to resolve specific challenges and problems faced within an industry while formulating effective solutions that can be implemented (Stringer and Aragón, 2020). The literature review identified knowledge gaps (KGs) related to a lack of quantitative data regarding the impact of e-ticketing on various project personnel and a need for implementation guidelines if STAs progress towards adopting e-ticketing as a standard of practice for asphalt paving operations. The research methodology is illustrated in Figure 4.1. The study design underwent Institutional Review Board (IRB) review at the University of Kentucky and was approved.

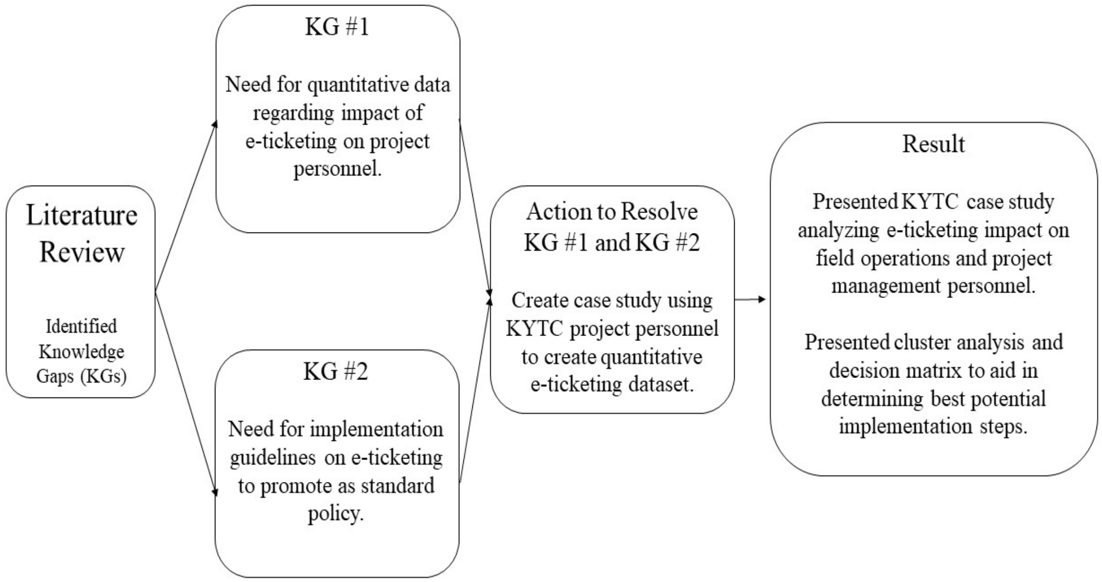


Figure 4.1 E-Ticketing Implementation Guidance Research Methodology Flowchart

To fulfill the need for quantitative data showing the impact of e-ticketing on various project personnel roles and define implementation guidelines to aid in promoting e-ticketing as standard policy, a case study methodology was used. Due to previous experience with e-ticketing pre-pandemic, the state of Kentucky was selected. To provide quantitative data necessary to support adoption and implementation decisions from STA leadership and follow the action research model, information was solicited from KYTC field inspectors and project engineers overseeing asphalt paving projects as part of KYTC's 2022 construction program. Data collection from inspectors and engineers utilized a daily survey created in Qualtrics for projects where asphalt paving was completed. Project engineers and inspectors were asked for the KYTC contract identification number, project county, project scope, controlling asphalt operation, number of loads received on the project, and the corresponding tonnage for each asphalt mixture. Inspectors were then asked to approximate the amount of time spent during the shift collecting tickets following traditional methods (receiving paper ticket from haul vehicle drivers) compared to the time spent utilizing an e-ticketing system. Engineers were asked to approximate the amount of time spent reviewing weigh tickets, confirming information recorded on the Daily Work Report, and filing and storing this information in project files with traditional methods utilizing paper weigh tickets compared to the time spent to complete the same tasks utilizing an e-ticketing system.

Creation of this new dataset allows for additional statistical analysis. First, mean collection and processing times for traditional and e-ticketing workflows can be compared for each project role across various project factors to determine the quantitative impact of changing workflows. Collecting information regarding project scope, the controlling asphalt operation, number of loads received, and corresponding asphalt tonnages from each project allows for analysis regarding essential tasks associated with the administration of asphalt paving, such as the identification and collection of quality assurance asphalt field cores based upon theoretical and cumulative tonnages by STA project inspectors and the review of weigh ticket information for acceptance and payment by STA project engineers (Daniel et al., 2018; Sturgill et al., 2019; Von Quintus et al., 2023). Second, multivariate analysis methods, such as cluster analysis, can be utilized to help understand patterns within the dataset that are more difficult to realize and that can provide further insights into implementation recommendations. Further details about the data collection and analysis are found in the following Results section.

4.3 Results

The data collection effort for KYTC asphalt paving projects resulted in information from 18 construction projects in 6 different counties, totaling 185 observations. The 185 observations are further broken down, with 89 observations collected from project engineers and 96 observations collected from project inspectors. For project engineers, the traditional weigh ticket workflow is compared to the augmented e-ticketing workflow. Using the Wilcoxon Ranked Sum Test to conservatively estimate since the dataset does not have a known distribution, the difference between the traditional and e-ticketing workflows is not statistically significant. For project inspectors, a similar comparison is made between the traditional and e-ticketing workflows. In this case, again using the Wilcoxon Ranked Sum Test to conservatively estimate since the dataset does not have a known distribution, the difference between the workflows is statistically significant, assuming a 95% confidence interval (or p-value < 0.05) since the p-value is low (2.2 x 10^{-16}). Therefore, it appears that the benefit of e-ticketing is largely realized by the field personnel rather than project management personnel. However, this apparent realization necessitates further evaluation for both project engineers and project inspectors.

4.3.1 Project Engineer Analysis

For the project engineer, the e-ticketing workflow as a whole does not offer statistically significant time savings, as discussed previously. However, the entire workflow for the project engineer can be further broken down into two phases: review and storage. Reviewing the ticket consists of determining whether the ticket shows all necessary information, such as the asphalt mix design, load count number, time leaving the plant and arriving on site, the load tonnage, and verifying the cumulative tonnage production placed on the project. Storing the ticket accounts for the time required to digitize the ticket and place in a central electronic location, such as a project file, to retain for project closeout purposes.

Therefore, the traditional workflow can be compared to the augmented e-ticketing workflow for the project engineer dataset using the two identified phases of reviewing and storing asphalt weigh tickets. Using the Wilcoxon Ranked Sum Test, the difference between the workflows is not statistically significant for the project engineer review phase. However, using the Wilcoxon Ranked Sum Test, the difference between the workflows is statistically significant for the project engineer storage phase, assuming a 95% confidence interval, since the p-value is low (0.04556).

4.3.2 Project Inspector Analysis

For the project inspector, the e-ticketing workflow as a whole does offer statistically significant time savings, as discuss previously. However, it is also important to consider the quality assurance (QA) responsibilities associated with an individual project. Depending upon the contract documents, some projects require inspectors to determine locations for random asphalt density testing while other projects do not carry this requirement. For KYTC projects, “Compaction Option A” refers to projects where inspectors are responsible for determining random sampling locations for asphalt density testing while “Compaction Option B” does not require inspectors to determine random sampling locations.

Therefore, the traditional workflow can be compared to the augmented e-ticketing workflow for the project inspector dataset using the two compaction options to describe the task loading responsibilities for field personnel. Using the Wilcoxon Ranked Sum Test, the comparison between the workflows is statistically significant for the Compaction Option A projects, assuming a 95% confidence interval, since the p-value is low (8.445 x 10^{-16}). Once again, using the Wilcoxon Ranked Sum Test, the comparison between workflows is statistically significant for the Compaction Option B projects, assuming a 95% confidence interval, since the p-value is low (2.984 x 10^{-6}).

4.3.3 Cluster Analysis

As previously discussed, cluster analysis is a multivariate method by which complex datasets can be processed by organizing observations into groups based upon the closeness of their association. In this research effort, k-means cluster analysis was used on both the project engineer and project inspector datasets to gain insight into areas where e-ticketing has the greatest potential effect.

Both the project engineer and project inspector datasets include the corresponding project type for each collected observation. Six total project types were identified during the data collection: Interstate Rehabilitation, Preventative Maintenance Resurfacing, Rural Secondary Resurfacing, Traditional Resurfacing, Grade & Drain Widening, and Highway Safety Improvements. For each project type, the average e-ticketing variable is calculated for both the project engineer and the project inspector. For the project engineer, this includes the average review time, storage time, and total processing time. For the project inspector, this includes only the total processing time. Cluster analysis is then used to group the data by comparing the average e-ticketing variable value for each project type. If the difference between a value and other values already in a cluster is significant, the selected value is separated into a different cluster.

The k-means cluster analysis allows for the ability to identify the number of clusters that balances the minimal number of clusters with the minimum sum of square errors within each cluster. The number of clusters is then obtained by finding the “elbow” in the scree plot (Hothorn and Everitt, 2014). The scree plot for this analysis is shown in Figure 4.2.

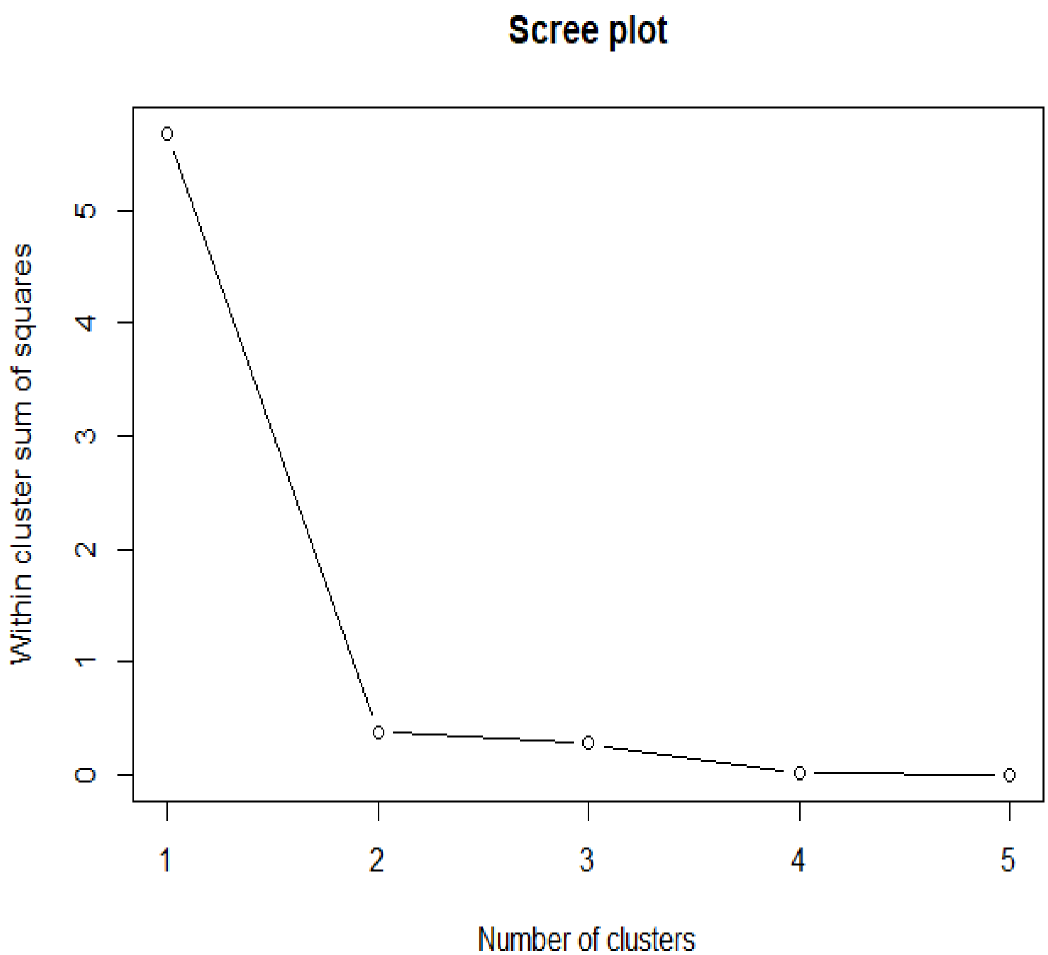


Figure 4.2 Scree Plot for k-means cluster analysis

The scree plot shown in Figure 4.2 visually suggests that the appropriate number of clusters for the analysis is 2, after which the decrease in the sum of squares is relatively constant.

For the project engineer dataset, the project type clusters are shown in Table 4.1. These clusters are the same for each average e-ticketing variable previously mentioned (review, storage, and total process). For the project inspector dataset, the project type clusters are shown in Table 4.2. These clusters are based around the one average e-ticketing variable for inspectors previously mentioned (total process).

Table 4.1 Project Type Clusters for Project Engineers

Cluster Grouping	Project Types	Average E-Review (Minutes)	Average E-Storage (Minutes)	Average E-Process (Minutes)
1	Rural Secondary Resurfacing	2.000	1.000	3.000
	Traditional Resurfacing	2.205	1.159	3.364
	Highway Safety Improvements	2.600	1.000	3.600
	Preventative Maintenance Resurfacing	4.083	1.417	5.500
2	Interstate Rehabilitation	8.286	3.500	11.786
	Grade & Drain Widening	13.111	2.778	15.889

Table 4.2 Project Type Clusters for Project Inspectors

Cluster Grouping	Project Types	Average E-Process (Minutes)
1	Rural Secondary Resurfacing	0.000
	Interstate Rehabilitation	0.111
	Preventative Maintenance Resurfacing	3.182
2	Traditional Resurfacing	5.306
	Highway Safety Improvements	6.063
	Grade & Drain Widening	7.556

Therefore, as seen in Tables 4.1 and 4.2, the 6 project types mentioned before are separated into two different clusters. For the project engineers in Table 4.1 and project inspectors in Table 4.2, the project types where e-ticketing has the greatest potential for effect are those in Cluster 1.

4.4 Discussion

As previously mentioned, the benefits of e-ticketing for asphalt paving operations are realized most by the project inspectors rather than by project engineers. Project inspectors receive the largest time savings, and therefore monetary benefit, from utilizing an augmented e-ticketing workflow in comparison to traditional workflows. However, this is not to say that there are no benefits for project engineers using e-ticketing workflows, as the results from the analysis show statistically significant time savings in data storage, although the overall process for project engineers does not differ significantly between traditional and augmented workflows.

To further guide the implementation process for agency adoption of e-ticketing, variables including the individual phases for project management responsibility and QA responsibility for field personnel were investigated. The analysis resulted in statistically significant findings for the data storage phase for project engineers, indicating that there are substantial efficiency gains from maintaining project information in an electronic format and eliminating the delay in transitioning data from physical to electronic records or reconciling lost and/or damaged tickets. Additionally, the analysis showed statistically significant findings for project inspectors regardless of the level of QA responsibility, although the greater statistical significance came from "Compaction Option A" projects where the project inspection responsibilities were more strenuous. Finally, a k-means cluster analysis was completed on both the project engineer and project inspector datasets to identify project types where the greatest benefit of e-ticketing would be realized based upon stakeholder roles and responsibilities. The structure of the cluster analysis presents a tiered-approach for STAs to consider when constructing implementation plans during agency adoption of e-ticketing workflows.

Due to the presented results, STAs would be best served by aiming initial implementation efforts at project types from the project inspector cluster analysis, as described in Table 4.2, since this stakeholder role showed statistically significant time, and therefore monetary, savings potential. Additionally, the statistical analysis indicated greater statistical significance associated with the "Compaction Option A" projects with more strenuous QA responsibilities. Observing Cluster 1 from Table 4.2, this corresponds to interstate rehabilitation projects, as both rural secondary resurfacing and preventative maintenance resurfacing projects are considered "Compaction Option B" projects under KYTC specifications. Interstate rehabilitation projects generally have asphalt paving as the controlling operation and generate large quantities of weigh ticket data, which also means that this project type is a good candidate to maximize the benefit of e-ticketing for project engineers in the realm of data storage. Therefore, to realize the greatest benefit for both field and project management personnel, e-ticketing should first be implemented on large asphalt resurfacing projects, such as interstate rehabilitations. Selecting these projects to initially begin adopting the augmented e-ticketing workflow on allows STAs to realize the maximum potential benefit and allows project stakeholders to build familiarity before the agency expands its use in a tiered implementation approach. These statistical findings presented in this study also support the anecdotal recommendations promoted in FHWA EDC peer exchanges that some of the authors have participated in.

Following the presented logic for beginning e-ticketing implementation as agency policy with interstate rehabilitation projects, a decision matrix was created and is shown in Table 4.3 for all project categories identified in the study. The decision matrix shown in Table 4.3 follows the Multiple Attribute Decision Making (MADM) procedure utilized by decision makers to make preference decisions concerning available alternatives that are normally characterized by multiple, and sometimes competing, attributes (Hwang and Yoon, 1981). Nearly all MADM methods require information regarding the relative importance of each attribute, and category weights can be either be developed through additional methodology or assigned directly by the decision maker (Yoon and Hwang, 1995). Therefore, as previously discussed, the consideration factors are ordered to follow with the results of this study, indicating greater preference should be given to project characteristics that affect the project inspector, leading to higher weights assigned to the "Project Inspector Cluster Grouping" and "Project Compaction Option" factors. The "Asphalt Paving Controlling Process" and "Average Tonnage per Shift" factors are included to incorporate the project characteristics that affect the project engineer and illustrate the benefit of e-ticketing in area of data storage. Each individual factor score per project type is calculated by multiplying the assigned factor weight by the assigned rating. For the "Project Inspector Cluster Grouping", "Project Compaction Option", and "Asphalt Paving Controlling Process" factors, the possible outcomes are somewhat binary in their nature (Cluster #1 or #2, Option A or B, and "Yes" or "No", respectively), therefore the possible ratings are "1" if the selected answer is the first possible option or "0.5" if the selected answer is the second possible option. In the case that either option is potentially possible, a rating of "0.75" is assigned. For the "Average Tonnage per Shift" factor, the average tonnage is calculated for each project type and ranked from greatest to least between the previously identified ratings of "1" and "0.5" with an increment of 0.1. Finally, the total score is calculated by computing the sum of the entire row for each project type, and the highest total score indicates the most ideal implementation candidate.

Table 4.3 Project Type Proposed Implementation Order Decision Matrix

	Consideration Factors				
Project Type	**Project Inspector Cluster Grouping** (Weight = 4)	**Project Compaction Option** (Weight = 3)	**Asphalt Paving Controlling Process?** (Weight = 2)	**Average Tonnage per Shift** (Weight = 1)	**Total Score** (Maximum = 10.00)
Rural Secondary Resurfacing	Cluster #1 (4 x 1 = 4)	B (3 x 0.5 = 1.5)	Yes (2 x 1 = 2)	617.70 (1 x 0.6 = 0.6)	8.10
Interstate Rehabilitation	Cluster #1 (4 x 1 = 4)	A (3 x 1 = 3)	Yes (2 x 1 = 2)	1421.81 (1 x 1 = 1)	10.00
Preventative Maintenance Resurfacing	Cluster #1 (4 x 1 = 4)	B (3 x 0.5 = 1.5)	Yes (2 x 1 = 2)	730.43 (1 x 0.8 = 0.8)	8.30
Traditional Resurfacing	Cluster #2 (4 x 0.5 = 2)	A or B (3 x 0.75 = 2.25)	Yes (2 x 1 = 2)	850.01 (1 x 0.9 = 0.9)	7.15
Highway Safety Improvements	Cluster #2 (4 x 0.5 = 2)	A or B (3 x 0.75 = 2.25)	No (2 x 0.5 = 1)	345.27 (1 x 0.5 = 0.5)	5.75
Grade & Drain Widening	Cluster #2 (4 x 0.5 = 2)	A or B (3 x 0.75 = 2.25)	Possible (2 x 0.75 = 1.5)	682.96 (1 x 0.7 = 0.7)	6.45

Therefore, if agencies wish to implement e-ticketing as a tiered-approach, the provided decision matrix in Table 4.3 offers several options for the identified project categories. If STAs wish to implement slowly to build familiarity and stakeholder buy-in, the decision matrix provides a 6-step plan (first interstate rehabilitations, then preventative maintenance resurfacing, rural secondary resurfacing, traditional resurfacing, grade & drain widening, and finally highway safety improvements). However, if STAs wish to implement on a faster pace, the decision matrix could be condensed into a 4-step plan (first interstate rehabilitations, then preventative maintenance resurfacing and rural secondary resurfacing, next traditional resurfacing and grade & drain widening, and finally highway safety improvements). As seen in Table 4.3, both preventative maintenance resurfacing and rural secondary resurfacing projects scored similarly, so they could be grouped together. Additionally, traditional resurfacing and grade & drain widening projects could be grouped together into one implementation step due to a higher number of asphalt tickets that are normally produced on a given shift when compared to highway safety improvement projects.

4.5 Conclusions

The primary objective of the study was to provide implementation guidelines for STAs for e-ticketing on asphalt paving operations. To complete this objective, a quantitative analysis was performed using both action research and a case study methodology centering on KYTC, featuring field observations collected from various KYTC projects and project personnel. The primary contributions to the body of knowledge include a modified action research methodology applied to electronic bulk material tickets to incorporate practitioner expertise into the determination of implementation guidelines paired with a quantitative analysis indicating that optimized e-ticketing implementation is best achieved by utilizing e-ticketing first on projects with asphalt paving as the controlling process, such as interstate rehabilitation asphalt resurfacing projects. These projects, which require asphalt density samples to be collected from the field, yield the greatest benefits for project inspectors and engineers. For project inspectors, task loading is reduced by the elimination of collecting paper weigh tickets so more attention can be given to visual inspection of the asphalt material and checking traffic control for the paving operation. For project engineers, e-ticketing on large asphalt resurfacing projects, such as on the interstate system, can be helpful in minimizing and eliminating data errors when multiple projects are being completed simultaneously. As part of the research, a full implementation decision matrix is provided for agencies based upon the project types identified in this study.

The main limitation of this study is the sample size of the datasets within the KYTC case study. A larger sample of observations for project types such as rural secondary resurfacing or highway safety improvements may have allowed for additional statistical comparisons to be made. Therefore, an area of future research could be an additional case study focusing on STA project engineers to determine if statistical significance for the augmented e-ticketing workflow could be realized with a larger dataset. Additionally, there are also other project types completed by STAs that were not identified in this research effort that could be included in future studies.

Finally, this research focuses primarily upon STA personnel to guide the creation of e-ticketing implementation efforts. However, it is important to consider the other stakeholders affected by the implementation of new policy, specifically the highway contractors who perform work for STAs. Therefore, another area of future research could investigate the time and monetary savings associated with e-ticketing upon highway contractor personnel, including field laborers and project managers/superintendents.

CHAPTER 5. CONCLUSIONS

5.1 National Survey Effort and Kentucky Case Study Trends

From the research presented in Chapter 2, several key trends were identified in both the national surveys and the Kentucky case study.

First, signal strength and cellular connectivity in remote project areas is still a primary concern for agency and contractor stakeholders alike when considering a process workflow change such as e-ticketing. No matter whether the workflow being used is the traditional, paper-based method or electronically delivered to project stakeholders, the information must be provided in an accurate and timely manner for both the agency to complete quality assurance procedures and the contractor to complete quality control procedures and track production metrics. Ultimately, this concern can be mitigated by continued partnering between both the state transportation agency and the e-ticketing vendor to provide alternative means for data to be accessible during asphalt operations.

Second, there is concern over whether one or multiple e-ticketing systems will be utilized if state transportation agencies shift to augmented workflows. The broad nature of emergency implementation orders during the COVID-19 pandemic resulted in agency and contractor personnel gaining experience with various e-ticketing systems. However, if agencies shift towards augmented workflows for project documentation, it may be prudent to determine a single system to utilize. If both agency and contractor personnel must only familiarize themselves with one system, adoption resistance that has previously been noted may decrease.

Third, there is still work that can be accomplished to further the electronic documentation workflow from production site to project to a state transportation agency to render payment for work performed. Most all state transportation agencies utilize a construction management software system to record and render payment to contractor stakeholders for work performed on a given project. However, not much work has been done to automate the recording of quantities and data transfer from an e-ticketing system to the construction management software. Therefore, this data is still manually recorded and therefore open to human error.

This research effort indicates that while there has been significant interest and steps made to adopting e-ticketing for asphalt paving operations and augmenting the traditional workflow, there is still significant work to be done. While the work that the Federal Highways Administration has completed with the Every Day Counts initiative has nationally moved more state transportation agencies towards full-scale adoption, there are still many states that are working through challenges and resistance to changes in well-established processes.

5.2 Qualitative and Quantitative Benefit-Cost Analysis Findings

From the research shown in Chapter 3, the impact of a shift to e-ticketing documentation and augmented workflows is overall positive. Specifically, most of the impact for e-ticketing is aimed towards field personnel and not specifically management personnel. This is not to say that there is no benefit of an augmented workflow for management personnel, but the time savings is only statistically significant for the field personnel. This finding is significant for state transportation agencies, specifically, in that, as already discussed previously in sections 2.1.2, 3.1, and 4.1, they are tasked with overseeing ever-expanding transportation networks with a constantly decreasing available staff. Therefore, a change in documentation workflows affords agencies a chance to allow an already limited staff to reduce their task loading and focus on experience-driven tasks such as quality assurance testing and visual inspection.

Additionally, e-ticketing on asphalt operations offers a chance to increase the safety of field personnel necessary on a given project site. Utilizing an augmented workflow offers the potential to reduce hazard exposure for these employees and minimize the potential for experiencing either serious injuries or fatalities as discussed in section 3.5.

This research presents both the benefits and costs associated with a potential change from traditional, paper-based documentation methods to augmented electronic methods in both a qualitative and quantitative analysis. The results for both indicate that the shift to augmented electronic methods possesses a significant benefit related to the associated costs and therefore serves as a key piece of evidence for state transportation agencies to advocate for policy change.

5.3 Quantitative Guidance for E-Ticketing Implementation Recommendations

From the research shown in Chapter 4, before e-ticketing is adopted by a state transportation agency as policy, an implementation plan must be formed. Additionally, this guidance would be best if based on quantitative results, such as those gathered in the Kentucky case study, rather than being based upon anecdotal evidence previously offered.

Following the research results presented in Chapter 3, this implementation guidance should be aimed towards the party who receives the most benefit from e-ticketing, which is field personnel, as previously discussed. Therefore, a decision matrix was produced to provide state transportation agencies with a path to implement new policy most effectively.

This research provides a quantitative approach to creating an implementation strategy for new state transportation agency policy. Additionally, the results of the study and the production of the decision matrix provide agencies a starting point based upon the stakeholder roles in a normal project and various project types to build stakeholder buy-in for new policy and reduce institutional inertia and resistance, which often hinders policy adoption.

5.4 Study Impact

In section 1.4, three main research questions were posed to help guide the study effort. These included whether e-ticketing for asphalt paving operations aligned with a state transportation agencies mission statement, what were current project stakeholder opinions of e-ticketing practices to date, and whether e-ticketing usage could be an initial step towards greater e-Construction adoption for state transportation agencies.

Throughout the completion of the qualitative portion of the study, the survey responses highlighted benefits included safety, efficiency, and transparency for e-ticketing in asphalt paving operations. For reference, the U.S. Department of Transportation's mission statement is to "deliver the world's leading transportation system, serving the American people and economy through the safe, efficient, sustainable, and equitable movement of people and goods" (U.S. Department of Transportation, 2022). Therefore, the qualitative portion of the study confirms that e-ticketing for asphalt paving operations does align with the national transportation agency mission statement, and this alignment makes e-ticketing an innovation primed for greater adoption.

However, while e-ticketing does align with the overall mission statement of the U.S. Department of Transportation, there are some noted concerns regarding adoption as policy. These concerns mainly center around performance of systems in areas of weak cellular signal and the responsibility of procuring a system for use. Both concerns can be mitigated by continued partnership by all primary stakeholders: state transportation agencies, highway contractors, and software vendors. Through collaboration, alternative procedures can be created and put in place so that all stakeholders receive the necessary information that they need to perform their duties in the general asphalt paving operation.

Finally, as stakeholder concerns are alleviated in the transition from paper-based to electronic-based documentation workflows, e-ticketing may be an encouraging step towards greater e-Construction principle use. State transportation agencies generate and retain large quantities of data, and therefore shifting to maintaining data in electronic forms may allow for continued innovation to integrate systems that would be beneficial to many agencies. Data could be retained longer by agencies and used to improve the quality of construction project documentation and as-built records, which may lead to improved and more targeted maintenance operations and project planning for future development.

5.5 Limitations and Areas of Future Research

This research effort has a couple noted limitations, but also lends itself to several potential avenues for future research to continue to look at the impact of e-ticketing and e-Construction in transportation agency operations in the future.

First, a large portion of the work presented in this study focuses on state transportation agency personnel and uses their opinions and collected data to guide the quantitative benefit-cost analysis and implementation recommendations. However, this creates an inherent limitation within the study because of the comparatively small input from highway contractors and software vendors, who are both integral stakeholders in the highway construction project environment. Therefore, similar studies could be conducted in the future with greater focus on the participation of highway contractor personnel to better understand the impact of e-ticketing upon their operations. A better understanding of modified agency policy on highway contractor stakeholders may also impact how state transportation agencies implement policy changes to minimize the impact on other parties.

Second, the implementation recommendations put forward as part of this study draw on the quantitative case study from Kentucky, which had a total of six different project types represented. However, state transportation agencies generally complete thousands of projects each year which may be categorized into substantially more than six unique classifications. Therefore, a future study could be completed with a larger sample of daily project data, which may provide additional insight into the impact of e-ticketing on project types that were not identified in this study which could change the implementation order that was presented.

Third, as previously mentioned, e-ticketing may be a preliminary step to encourage greater e-Construction principle use. However, this research effort limited the investigation of e-ticketing to a siloed environment and did not consider the potential for technological integrations. Therefore, future research might investigate how e-ticketing systems can integrate with other emerging transportation construction technologies to create data-rich environments that better inform future decisions that must be made by state transportation agency leaders, such as maintenance expenditures and future project development efforts, and whether the potential integration increases the benefit to project stakeholders. State transportation agencies operate with limited financial resources, therefore data-driven decision-making helps improve organizational efficiency and meet more needs of the local constituency.

APPENDICES

A. AASHTO COMMITTEE ON CONSTRUCTION SURVEY
B. KAHC/PAIKY SURVEY
C. KYTC DPD SUBCOMMITTEE SURVEY
D. KYTC ENGINEER DAILY SURVEY
E. KYTC INSPECTOR DAILY SURVEY

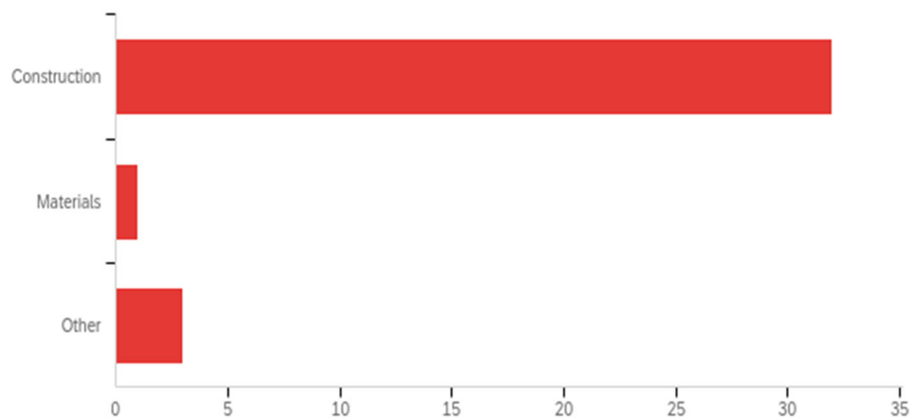
APPENDIX A. AASHTO COMMITTEE ON CONSTRUCTION SURVEY

1. For what agency do you work?

NMDOT
NYSDOT
NJDOT
Ohio Department of Transportation
Pennsylvania Department of Transportation
Tennessee Department of Transportation
Washington State Department of Transportation
Maryland Department of Transportation - State Highway Administration (MDOT SHA)
Georgia Department of Transportation
South Dakota DOT
Rhode Island Department of Transportation
SDDOT
Wyoming DOT
North Carolina Department of Transportation
Iowa Department of Transportation
New Hampshire Department of Transportation
Utah Department of Transportation
Virginia Department of Transportation
NDDOT
Vermont
INDOT
Kansas Department of Transportation
Delaware Department of Transportation
Hawaii Department of Transportation, Highways Division
Arkansas DOT

South Carolina Department of Transportation
Michigan DOT
Oklahoma Department of Transportation
WVDOH
Florida Department of Transportation
Texas Dept. of Transportation
NYSDOT

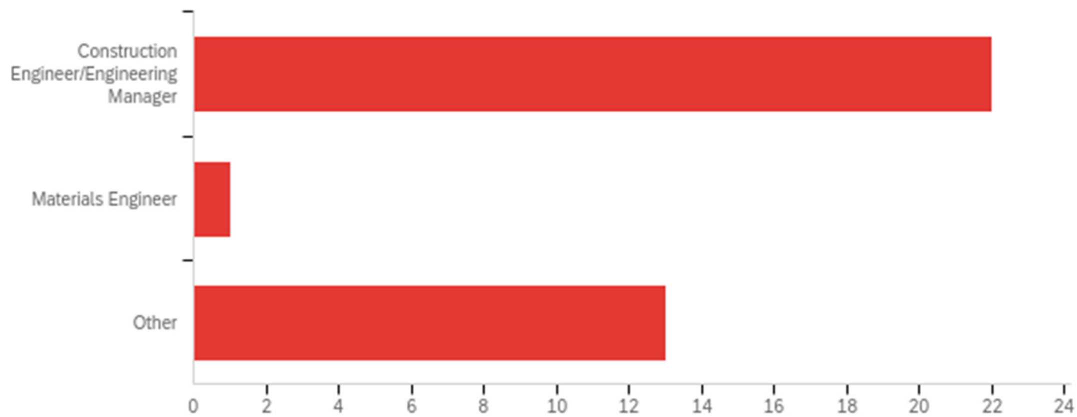
2. What division do you work for within your agency?
    a. Construction
    b. Materials
    c. Other?



#	Answer	%	Count
1	Construction	88.89%	32
2	Materials	2.78%	1
3	Other	8.33%	3
	Total	100%	36

Other - Text
Construction and Materials Bureau
Technical Support

3. What is your role or job title within your agency?
    a. Construction Engineer/Engineering Manager
    b. Materials Engineer
    c. Other?



#	Answer	%	Count
1	Construction Engineer/Engineering Manager	61.11%	22
2	Materials Engineer	2.78%	1
3	Other	36.11%	13
	Total	100%	36

Other - Text
AASHTOWare Project Admin/EUD
eConstruction Engineer
Systems Management Division Chief
Lead Construction Engineer Administration
e-Construction Program Manager
E-construction Coordinator
Bureau Chief of Construction and Materials
Division Administrator
Assistant Director - Publications
State Construction Pavement Engineer

4. How long have you worked for your agency?

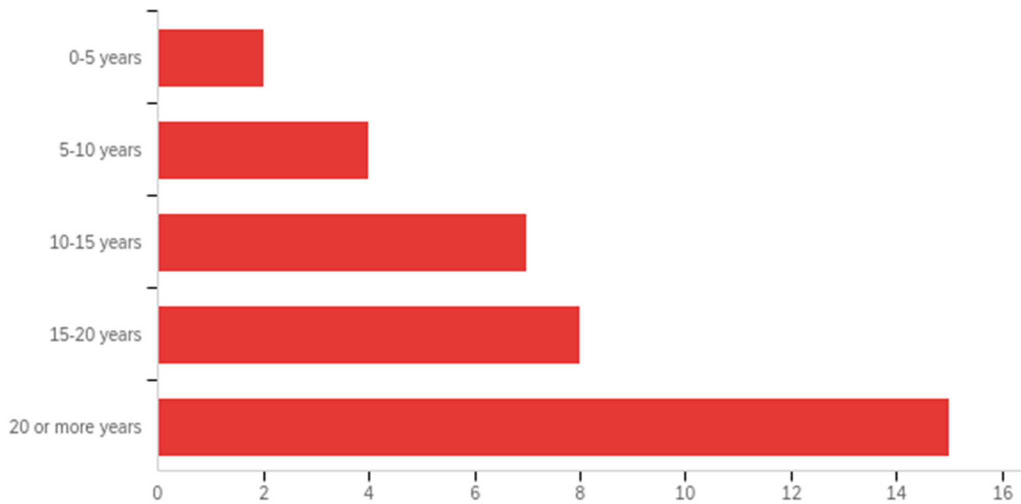
   a. 0-5 years

   b. 5-10 years

   c. 10-15 years

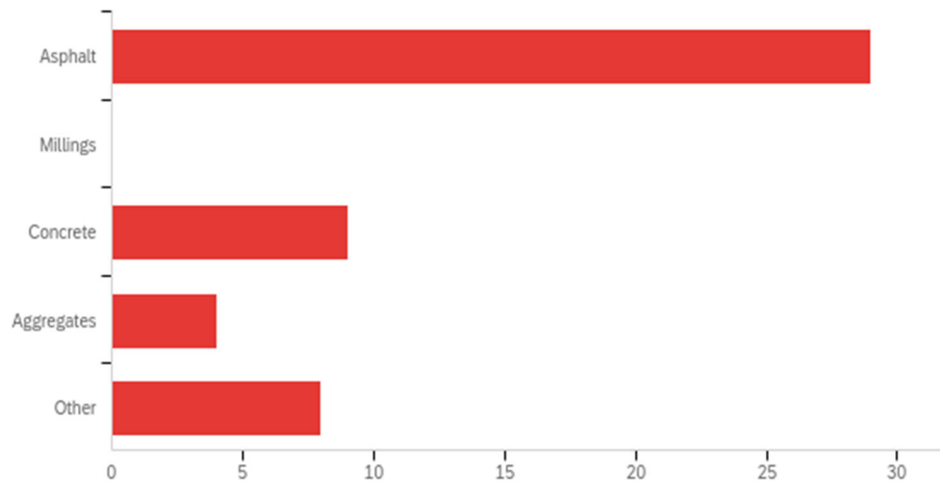
   d. 15-20 years

   e. 20 or more years



#	Answer	%	Count
1	0-5 years	5.56%	2
2	5-10 years	11.11%	4
3	10-15 years	19.44%	7
4	15-20 years	22.22%	8
5	20 or more years	41.67%	15
	Total	100%	36

5. What previous experience does your agency have with e-ticketing use for construction materials?
   a. Asphalt
   b. Millings
   c. Concrete
   d. Aggregates
   e. Other?



#	Answer	%	Count
1	Asphalt	58.00%	29
2	Millings	0.00%	0
3	Concrete	18.00%	9
4	Aggregates	8.00%	4
5	Other	16.00%	8
	Total	100%	50

Other - Text
None
N/A
None
Recieved digital PDF in place of paper tickets during pandemic
In development
Just scanned tickets at this point for aggregates
Mostly Asphalt, there was one Concrete e-Ticketing Pilot Project
None

6. Which e-ticketing system(s) has your agency used?

    a. FleetWatcher by Earthwave

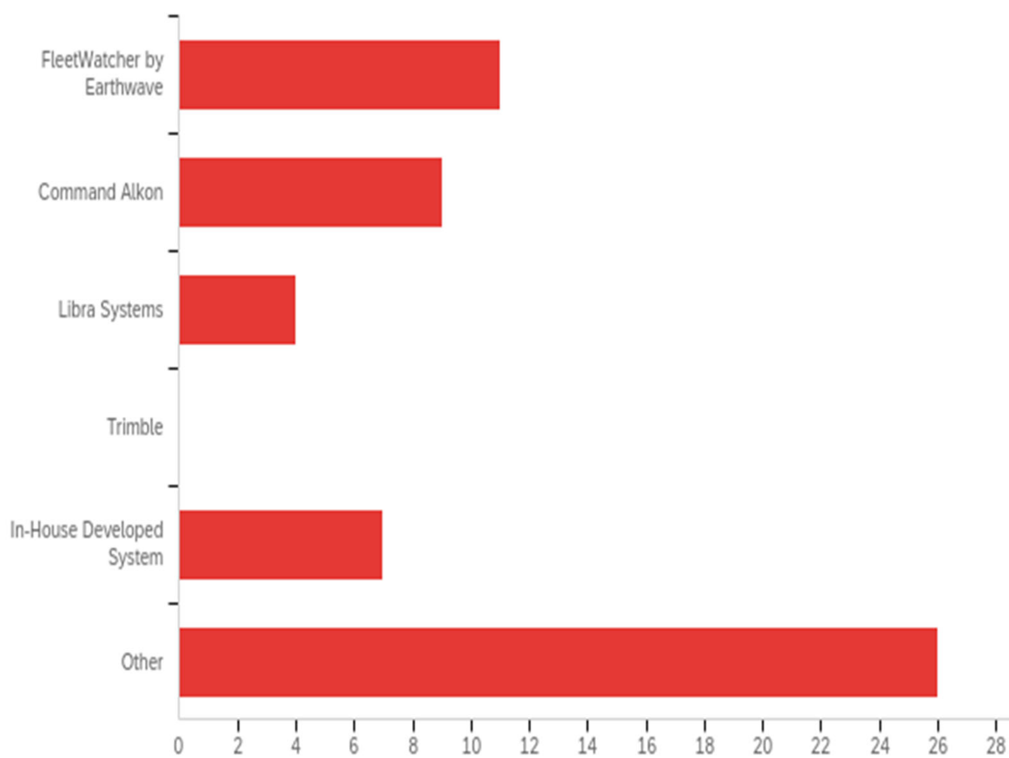
    b. Command Alkon

    c. Libra Systems

    d. Trimble

    e. In-House Developed System

    f. Other?



#	Answer	%	Count
1	FleetWatcher by Earthwave	19.30%	11
2	Command Alkon	15.79%	9
3	Libra Systems	7.02%	4
4	Trimble	0.00%	0
5	In-House Developed System	12.28%	7
6	Other	45.61%	26
	Total	100%	57

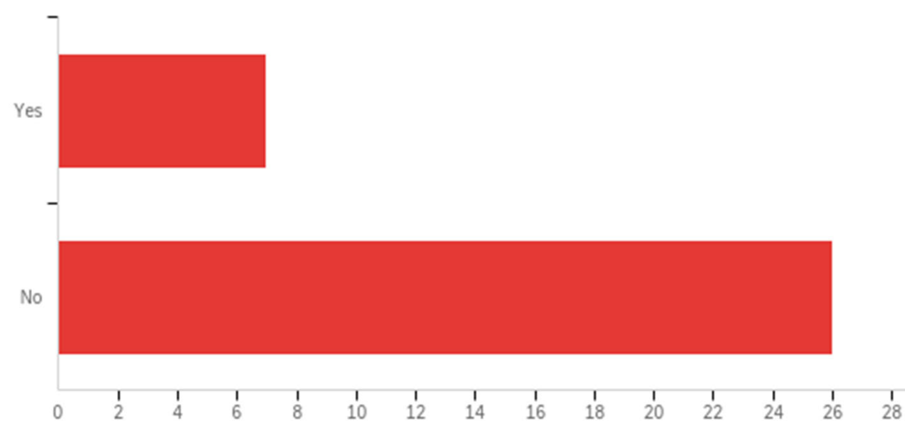
Other - Text
Haulhub
Jobsite
N/A
Haul Hub
HaulHub DOTSlips
Accepted PDF's of tickets
Haul Hub (Pilot)
Contractor Choice
Haul Hub
N/A
Haulhub
Sysdyne iStrada, Accu-pour
Haul Hub
HaulHUB
Haul Hub
haul hub
Haul Hub

Looking to accept data from Command Alkon
Haul Hub, XBE, ASTEC
We do not have a specific system.
HaulHub
HaulHub
Contractors are also using S.O.P. and Haul Hub
Various systems provided by Contractor
None

7. Does the e-ticketing system(s) incorporate GPS capabilities for haul vehicles?

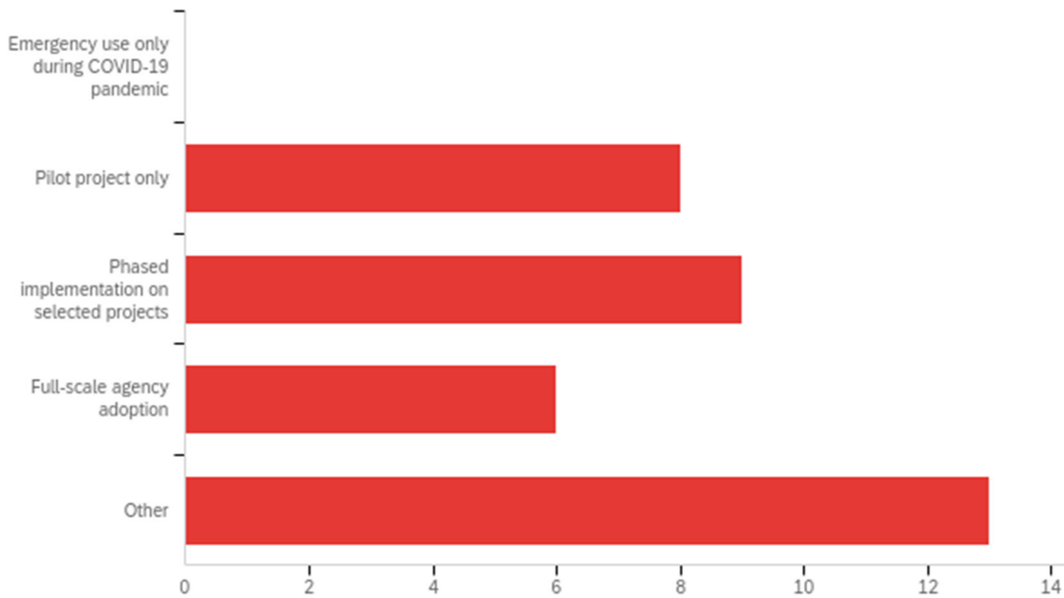
    a. Yes

    b. No



#	Answer	%	Count
1	Yes	21.21%	7
2	No	78.79%	26
	Total	100%	33

8. What best describes the extent to which your agency has implemented e-ticketing processes?
   a. Emergency use only during COVID-19 pandemic
   b. Pilot project only
   c. Phased implementation on selected projects
   d. Full-scale agency adoption
   e. Other?



#	Answer	%	Count
1	Emergency use only during COVID-19 pandemic	0.00%	0
2	Pilot project only	22.22%	8
3	Phased implementation on selected projects	25.00%	9
4	Full-scale agency adoption	16.67%	6
5	Other	36.11%	13
	Total	100%	36

Other - Text
In the process of procuring a Company
MassDOT has successfully piloted several projects and is in the process of moving into a phased implementation
Conducted internal discussions with a few field crews.
1st year of 3 year plan for full adoption
substitution of PDF for paper tickets was in response to pandemic. We have initiated a eTicketing pilot use HaulHub as a vendor.
We are allowing the use of e-ticketing on any project on which the prime contractor requests to do so.
we are expanding to using it for all asphalt projects and looking at expanding it to other materials
in development
We first implemented during COVID but have allowed contractor/suppliers to continue using on a project by project basis if requested.
We implemented a statewide specification in January 2022, but have not seen much work performed on those particular projects yet.
We used scanned pics during COVID and are now trying to pilot a new special provision.
We're past pilot projects and implemented "Contactless Ticketing" during pandemic of which methods, asphalt e-ticketing was an option. Some contractors have continued using e-ticketing past the pandemic, while some others have not. We're looking to add asphalt e-ticketing as an option in July 2023 Spec workbook. We'll continue to work with industry to move to asphalt e-ticketing becoming the norm.
TxDOT allows the use of e-ticketing on all projects, but it's not required.

9. Has the agency investigated automating the transfer of data from e-ticketing systems to construction management programs? If so, has the agency seen a realized monetary benefit?

No.
Haulhub to Unifier connection is very new. Data not available at this time.
We're investigating currently along with the project we have started to implement AASHTOware Construction and Materials
We are in second year of extensive piloting and will determine data to be transferred upon conclusion of pilot.
We have looked into it, but not much
In developing, piloting, and implementing our eTicketing goals, MassDOT has always required a transfer of data to our own network. This data transfer is currently handled through our GIS systems. MassDOT is currently evaluating this data and its uses, we have not realized a monetary benefit to date.
We are in our second year of piloting e-Ticketing and have plans to connect our application to internal Department mobile applications/systems in the future.
Not at this time. Enough issues remain in the eticketing process that the priority is mainly making sur the etickets are reliable and can fully replace paper tickets.
Have not automated data transfer at this time.
We've had this discussion as future thought but nothing has been set into place as we are currently piloting eTicketing solutions.
No
Not as of yet.
N/A
Yes. We are currently exploring this integration. This is a critical part of the E-Ticketing migration for us. We think it will save time.
Yes, we have developed a portal for intention of sharing with our document storage system. We hope to automate the process. The monetary benefit is in the safety aspect, elimination of redundancies and extra level of ensuring load made it to the site. This is not a simple calculation.
We have not done that yet, but will consider it with future CMS upgrades.
Currently working on this
Phase two of our pilot is the transfer of eTicketing data into our construction management software system (AWP construction module)
We have not officially started that as we are in the process of changing out our management program, but we hope that will be a feature of any future system.

No
We are currently trying to get as many contractors and suppliers to utilize e-ticketing as we can and we are encouraging them to use our portal to send their information to. We utilize Haul Hub and we utilize their Amazon Cloud to hold all of the information for now. In the next phase we will look into getting control of the data and be able to utilize it for reports. And from there we hope to integrate it into our other systems. So I do not think we are necessarily seeing a monetary benefit for now.
not yet but it is something we are looking into
Yes, we are in the process of implementing an API and building out an UI to transfer tickets from our eTicket Portal (DOT Slip by Haul Hub) to our construction management program (Primavera Unifier). This system is expected to be live by mid-July. We have not considered the monetary benefit, but we do expect this to reduce the labor costs involved with reviewing and paying for items paid by ticket.
Yes. We are working with Headlight (Pavia Systems) to accept e-tickets from vendors directly into their Fieldbook software.
Not at this time, but we do have plans in the future as we continue our AASHTOWare Project implementation.
No
Not applicable yet.
Not at this time
Yes. Software supplier (HaulHub) helped with transfer of data during pilot project and implementation. To my knowledge we have no information & are not tracking monetary benefit.
Not that I'm aware of.
No
Not yet.
We have only begun by the suppliers that want to use e-ticketing. We are collecting paper tickets in addition.

10. How have the deployed e-ticketing system(s) affected field personnel duties, both for agency and contractor employees (i.e., increased personnel safety, increased time spent on QA/QC activities, etc.)?

The Department is in the early stages of piloting three projects through out the states. We do not know the impacts for field personnel.
increased personnel safety, decreased time spent on QA/QC activities
We're still in demo so we haven't realized the affect on duties yet
Since we have not implemented a system yet we cannot answer this question.
Increased personnel safety in relation to proximity of ticket transfer and equipment. Increased knowledge and communication with relation to schedule of trucks, delivery of trucks, quantity placed and quantity in route. Increased number of individuals that can monitor a project real time or daily summary. Increased program monitoring by capturing all summaries for a project or material type for material acceptance and program approval.
Increased on job safety and saved time
This technology has provided a time savings to our inspectors by automating the material delivery tracking process.
This is our second pilot season, so as we transition, our inspection staff are navigating the change. We anticipate increased safety and less administrative work, which will allow the field staff to focus on their QA/QC activities.
We wanted to remove having an employee taking tickets from a truck driver, especially as many cases that puts them very close to the traffic. Secondly, we hoped that without the need to collect tickets and with our requirement for automated delivery notification, this would free up inspectors to do more work as a QA tech. On the first I think we have been successful, on the second less so because they have spent a lot of time fighting with the ticket software, no service, etc.
Increased safety because employees are no longer required to get tickets from the trucks.
Digital automation, safety & visibility, quality assurance, increase productivity & customer satisfaction. Current practices result in safety issues in the work zone, inefficient operations
increased personnel safety, increased time spent on QA/QC activities
Increase in worker safety, but no change in number of staff or division of duties.
Increased Personnel safety, increase efficiency of data transfer for payment, material tracking.
increased safety also saves time on daily totals...
N/A

We think it has increased inspector safety
Increased safety, during original Covid-19 protocols this ensured we were able to comply with 6 foot social distancing and also avoiding sharing paper. Seeing where the truck is, ensuring the load showed up at the site allows for better time management and focusing more on construction process than waiting to test another load or grab a ticket.
Participation in the use of e-tickets is voluntary on the part of our Department field personnel. Those that utilize the functionality find it most helpful in saving time at the end of each day, where with paper tickets a significant amount of time was spent scanning and saving copies of the paper tickets, and summarizing the tickets into Excel spreadsheets. This is automated with e-tickets.
In the field, neither the inspector or the contractor needs to worry about taking tickets from the truck driver, which allows the inspector to stay out of the way and keeps the dump man on the contractors side away also. It also gives the inspector and contractor a quick way to see what trucks are still on the road and gives them an idea of when the trucks will get to the project which helps with planning.
Increased safety, more time for other inspection duties.
QA noticed Increased safety, record management, allow more time for QA activities. Unaware of QC benefits.
Definitely increased safety and allowed our personnel to spend more time on other activities. It has also eliminated the need to have personnel review and check the tickets for quantities down the road.
we feel that it was increased safety and freed up some time for our inspectors
Agency - eTickets have created a need to improve staffing on projects to ensure trucks are marked delivered. They have also increased safety (no need to get ticket from truck), and improved worker efficiency (no need to wrangle and add up at stack of 80+ tickets each day). Contractor - Contractor's interaction with the eTickets is completely optional. One change was an elimination of plant inspector stamps on tickets, which has enabled the use of remote printers, making load/ship occur quicker.
It has helped with keeping up with loads and not having to keep up with the paper tickets. The data still is being required to be input into a separate in-house program for payment of materials.
Increased time spent on other QA/QC activities, increased safety for inspectors
Not applicable yet.
Increased personnel safety has been the largest benefit.
Agency and contractor have had to learn and adjust to new system (which adds additional effort and grief until new process is learned)... but all seem to like it & see benefits afterward.
I believe it has increased personnel safety since they don't need to get near trucks to obtain tickets. They can obtain tickets in advance. Aside from the initial learning curve and any connectivity issues, work load is about the same or slightly decreased.

When system worked, e-ticketing streamlined the process of accepting a load and allowed less exposure to traffic/truck hazards.
No need to keep up with paper tickets, or possibly losing one.
N/A

11. How have the deployed e-ticketing system(s) affected project management duties, both for agency and contractor employees (i.e., improved project documentation, decreased time for pay estimate review/processing, fleet optimization, etc.)?

N/A
improved project documentation, decreased time for pay estimate review/processing
We're still in demo so we haven't realized the affect on duties yet
N/A
Increased knowledge and communication with relation to schedule of trucks, delivery of trucks, quantity placed and quantity in route. Increased number of individuals that can monitor a project real time or daily summary. Single system can reduce the error for capturing different quantities, thus decreasing time to review pay estimate. Increased program monitoring by capturing all summaries for a project or material type for material acceptance and program approval.
Increased efficiency
This technology has provided a time savings to our inspectors by automating the material delivery tracking process. Typically it is saving the average inspector approximately 15 minutes a day in recording all of the material slips for their shift.
This is our second pilot season, anticipate consistency in reporting and documentation.
No major change at this time.
NA
reduces impact on schedules & streamlines documentation
improved project documentation - less file cabinets, no need to scan tickets; decreased time for pay estimate review/processing -- less time adding and verifying tickets
Less risk for the potential of missing or unaccounted for truck loads / tickets.
Improvement in project documentation. Some improvement in pay estimate review/ quantity confirmation.
Improved documentation (no loose or lost tickets) decreased time for daily totals contractor uses sys. for fleet management.

N/A
increased documentation efficiency reduced the amount of work required by inspectors to document daily paving quantities
Some redundancies remain as we phase into more projects. This year we are piloting our portal which should eliminate a few forms the inspector was required to complete as well as potentially the plant report as a whole.
I can only speak for the Department. The finals team is still reviewing each ticket and comparing the ticket to the summary sheets, just as they did with paper, and are finding errors with the e-tickets. Errors include missing tickets, duplicate tickets, etc. I cannot say that e-tickets have improved project documentation at this time.
The real time savings we are seeing is the in the use of the data at then end of the day when the tonnage is totaled up - the data is exported to a spreadsheet and easily summed up and is a simple QC check instead of having to take the tickets from the project site, a total hand calculated and then verified. In all cases the daily totals are completed and ready for payment before the inspector gets back to the office, the office manager can do it all. And it does make quantity reconciliation much simpler.
Has made the calculating process quicker for total tons.
QA improved document organization, advanced awareness of paving and fleet optimization and quantity tracking. Allows for other media documentation with direct ties to the material.
For the most part our people are on board with it and like the fact that they no longer need to run a calculator tape to check quantities or to run a secondary check. This saves time at the end of every day and when the final construction record goes in for review. We have heard that some of our people have declined to use it when requested by contractors, which probably means we need to perform some additional training.
the contractors like the ability to easily see production rates for the asphalt plants. We hope that in the future with integration to project management system it will result into reduced data entry time and better documentation
ETickets have brought additional focus to staffing the paving operation, but also reduced the book-keeping burden and has eliminated the possibility of transposed numbers by Department Staff.
Documentation may improve slightly, but it has not decreased review and processing time.. See previous question.
fewer lost tickets for payment, storage of paper tickets in unnecessary
Not applicable yet.
Helps eliminate "lost" tickets
Same as previous. Agency and contractor have had to learn and adjust to new system (which adds additional effort and grief until new process is learned)... but all seem to like it & see benefits afterward.
Has reduced need to scan paper tickets which has reduced some project personnel time. May have slightly reduced time reconciling paper tickets as daily, and other

totals can be provided by e-ticketing software or easily calculated by bringing e-ticketing CSV file into Excel. I believe most contractors are using e-ticketing data for fleet optimization and tracking of subcontractor trucking.
Digital ticket backups were very helpful. Also, the system displays a total tonnage for the day.
More organized data with less opportunity for error.
N/A

12. What feedback has been received from agency stakeholders involved in projects utilizing e-ticketing system(s)?

N/A
Too early in the process
N/A
Field users at first have been apprehensive about not receiving paper ticket to back up digital transfer. Concern related to connectivity or end of day loads (waste) Appreciate the real time information of data for materials onsite
Mostly good
All agency users have been pleased with this technology and have requested implementing it on all jobs they are involved in.
Those utilizing e-Ticketing see its benefits, they are looking at ways to expand eConstruction initiatives where it makes sense.
In general the direction we are going is supported and well received. However, there are a number of difficulties that are still issues. No connectivity in rural areas, missing trucks, trucks hauling millings receiving etickets for HMA.
None
We have support & partnerships onboard to advance eTicketing in Maryland, I believe our field staff are equipped & ready for implementation in the near future.
Contractors have been very favorable with the new process.
They like the ability to see where trucks are at during the hauling / paving process, and having the quantities in an electronic format.
Feedback has been positive from RIDOT.
so far positive feedback we just started pilots last year in 2021
N/A
very positive feedback from inspectors

With good cell reception the feedback is positive. Eliminating the pockets of bad cell service, through coordination with carriers and purchasing booster devices will hopefully reduce this concern.
Stakeholders don't see a big difference, because by the time it gets to them, either option is electronic and verified for accuracy.
On large paving projects they like it. Projects with small asphalt quantities they aren't too excited to do because there aren't a lot of tickets that need to be worried about.
Feedback has been generally very favorable. The inspectors really like the use of the systems and hope that it continues.
More awareness and easier acceptance of load slips allowed for more time to be spend on QA activities. Allows for more organized record keeping and saves time in the office.
For the most part our people who have been using like it and are hoping we can get supplier on board and work out the lack of internet availability in some areas of the state.
Main feedback has been to expedite and expand the rollout of eTickets. Currently we are live with bituminous concrete, and beginning testing/rollout for concrete. Agency stakeholders are primarily excited to eliminate paper and improve documentation, but they want the UI and integration with other programs to improve.
It is mostly positive. There would be more buy-in if the raw data could seamlessly be transferred to a pay system where there was no need for further inspector entry.
We only recently provided our inspectors with smart phones for this purpose. The positive feedback has been more related to that.
Not applicable yet.
The response has been very positive
Same as previous again. Agency and contractor have had to learn and adjust to new system (which adds additional effort and grief until new process is learned)... but all seem to like it & see benefits afterward.
FDOT and consultants have provided mostly positive feedback as noted above e-ticketing eliminates the need to scan and upload paper tickets for long-term records storage
None yet that I am aware of.

13. What feedback has been received from contractor stakeholders involved in project utilizing e-ticketing system(s)?

For the pilot projects so far we have very excited stakeholder but we are in the early stages of the pilot projects and construction has not began.
Too early in the process

N/A
The contractors seem to be adopting the effort more and more as we conduct the pilot for the benefits listed above.
Nothing yet
Several of our contractors/suppliers had implemented this software prior to COVID and have been singing its praise for a number of years.
We have received support from our contracting community for e-Ticketing.
Similar to above. Problems in the field are often difficult to resolve as paving happens at night when IT and company support isn't available.
Contractors are onboard. They just want the agency to pick a service and then place it into the contracts.
From conversations with industry, they have been doing eTicketing for years using their own solutions of choice. As MDOT SHA is looking to implement a portal concept this will allow industry to continue using their platform of choice while using an API, the data should integrate into an existing technology being used at MDOT SHA to bring together the data to be shared.
easlier, less paperwork, very favorable.
They like the fleet management functions.
Feedback has been mixed. Some contractors are naturally opposed to change of procedures and processes.
The contractor that we used for the pilots in 2021 has been using this sys for a few years and likes the fleet management side but also no trying to find lost tickets and safety are also some of the positive feedback that we received.
N/A
Contractors are slightly less excited about e-ticketing .. mainly because they expect an increase in costs somewhere
They prefer it, once set up they have limited involvement and it is not as much a focus, placing that back into the work.
Contractors are required to offer e-tickets. The HMA contractors have all indicated that they will continue generating paper tickets regardless, because of their own needs.
They like it also
Initially, feedback was poor, the systems were unreliable, required a lot of setup, and drivers were reluctant to use gps trackers. We have had more recent projects with more experienced contractors where the feedback was much more positive.
Struggle in achieving consistent service. Resorted to using the offline mode for work in remote areas. Once the system is setup, it's mostly maintenance free.
We are in good shape for the most part with HMA suppliers. Some concrete suppliers have also moved to e-tickets. Some of our concrete suppliers for whom we are a smaller part of our business do not want to move to it because they tell us that most of the purchasers of the concrete still want to do business on paper. The we of course have issues with suppliers out in the middle of no where who do not have connectivity

and others who are small companies and say that they cannot afford it. But as a general rule contractors like it and want to do it as much as they can.
the contractors i have heard from have been positive
This is divided into two groups, those which own their own plants, and those that don't. For the former, the stakeholders have in fact been pushing for eTickets and are excited to implement it. For the latter, there has been some hesitation, but generally once they are assured that suppliers are already tied-in they are mostly ambivalent to eTickets.
Contractors and producers that have used e-ticketing have a very positive feedback and most, once they use e-ticketing, have not gone back to paper tickets.
Most contractors were already utilizing this type of ticket in some way, so it has not been anything new to them.
Not applicable yet.
Most of them are appreciative of this move
Same as previous again. Agency and contractor have had to learn and adjust to new system (which adds additional effort and grief until new process is learned)... but all seem to like it & see benefits afterward.
Mostly positive from contractors. However, they still need to print paper tickets for cities and counties as well as their FOB customers, so they have to run both paper and e-ticketing systems.
None yet that I am aware of.
N/A

14. What feedback has been received from vendor stakeholders involved in projects utilizing e-ticketing system(s)?

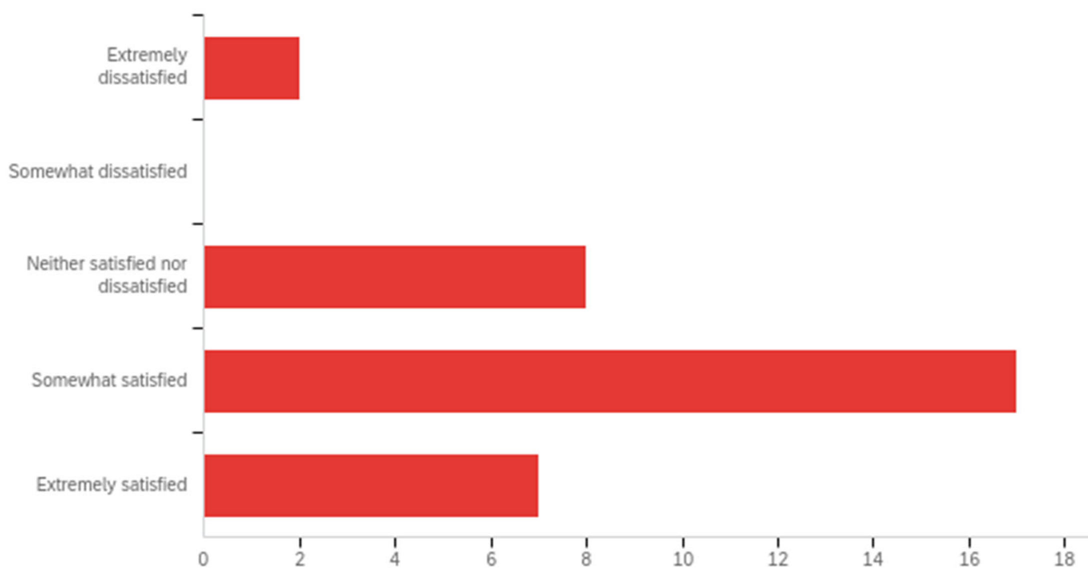
None.
Too early in the process
N/A
Premature to respond. Awaiting full pilot experience feedback. Some vendors are adopting quicker than others. Still a concern with smaller vendors.
Several of our contractors/suppliers had implemented this software prior to COVID and have been singing its praise for a number of years.
Our producers currently have a mixed reaction regarding e-Ticketing. Change is not easy, but we are working with them if concerns arise and are trying to make this switch as minimal of a cost to them as possible. The Department has provided a lump sum item in our construction contracts and has recently contracted with HaulHub

services to assist producers in connecting to the Departments e-Ticketing application at no cost to the producer.
Mostly, positive. They have had a lot of pushback overall over our automated delivery notification, but several vendors have managed to provide solutions that met our need.
NA
As I mentioned above, the Portal Concept allows all ticketing data from the producers or contractors regardless of their vendor/in-house solution to flow onto our DOT Staff using an API. That is what we are working towards with the vendors we are piloting.
none;
They are looking at ways to enhance their systems to potentially include adding project alignments so stationing can be electronically recorded at the point of discharge.
None.
N/A
All vendor feedback is positive but that could be due to their self-interests
Lots of interest, cell signal is the big concern.
None.
n/a
N/A
Vendors have been more than happy to adjust the e-ticket layout and priority of information/ additional information fields if requested by the Agency or RE.
See above.
Mix between positive feedback that we are improving processes, and some significant hesitation due to the age of the suppliers IT systems. Once the concerns about system integrity were resolved, suppliers have been generally positive.
Have not heard from vendors.
All vendors that we work with are very willing to make changes based on our needs.
Not applicable yet.
Some are still hesitant but most are embracing the change
Same as previous again. Agency and contractor have had to learn and adjust to new system (which adds additional effort and grief until new process is learned)... but all seem to like it & see benefits afterward.
Vendors have been positive and have supported e-ticketing projects.
None yet that I am aware of.

N/A

15. What is the level of satisfaction from agency project stakeholders with e-ticketing use to date?

    a. Extremely dissatisfied
    b. Somewhat dissatisfied
    c. Neither satisfied nor dissatisfied
    d. Somewhat satisfied
    e. Extremely satisfied

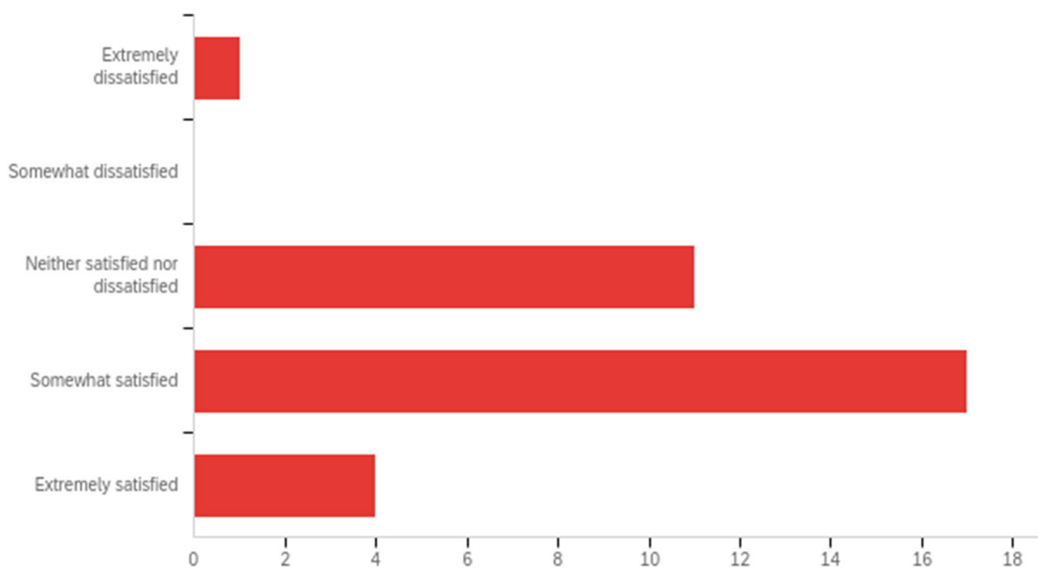


#	Answer	%	Count
1	Extremely dissatisfied	5.88%	2
2	Somewhat dissatisfied	0.00%	0
3	Neither satisfied nor dissatisfied	23.53%	8
4	Somewhat satisfied	50.00%	17
5	Extremely satisfied	20.59%	7

	Total	100%	34

16. What is the level of satisfaction from contractor project stakeholders with e-ticketing use to date?

    a. Extremely dissatisfied
    b. Somewhat dissatisfied
    c. Neither satisfied nor dissatisfied
    d. Somewhat satisfied
    e. Extremely satisfied



#	Answer	%	Count
1	Extremely dissatisfied	3.03%	1
2	Somewhat dissatisfied	0.00%	0
3	Neither satisfied nor dissatisfied	33.33%	11
4	Somewhat satisfied	51.52%	17
5	Extremely satisfied	12.12%	4

	Total	100%	33

17. What is the level of satisfaction from vendor project stakeholders with e-ticketing use to date?

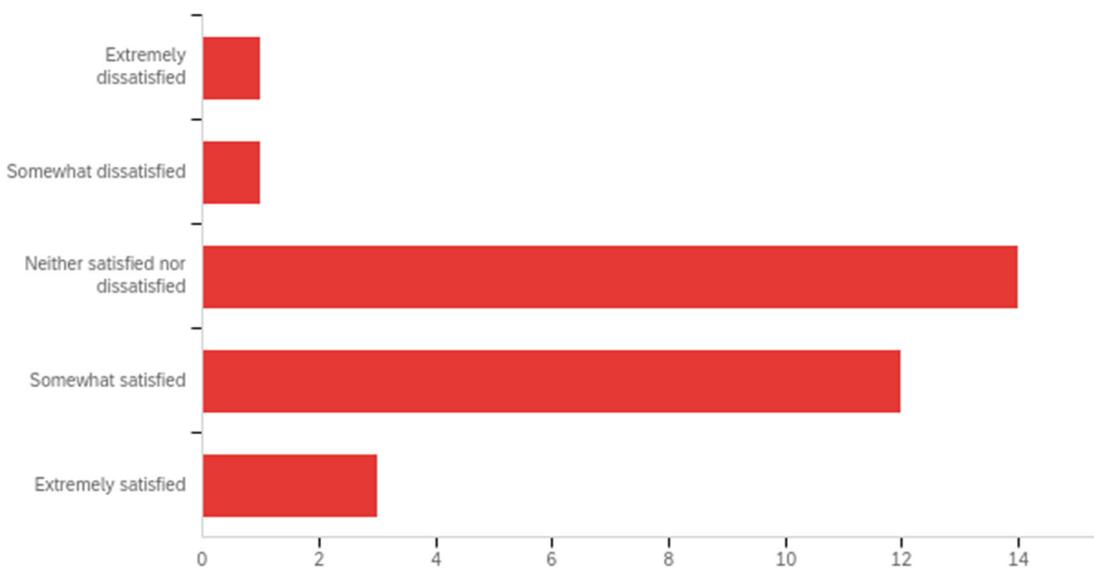
    a. Extremely dissatisfied

    b. Somewhat dissatisfied

    c. Neither satisfied nor dissatisfied

    d. Somewhat satisfied

    e. Extremely satisfied



#	Answer	%	Count
1	Extremely dissatisfied	3.23%	1
2	Somewhat dissatisfied	3.23%	1
3	Neither satisfied nor dissatisfied	45.16%	14
4	Somewhat satisfied	38.71%	12
5	Extremely satisfied	9.68%	3

	Total	100%	31

18. What concerns have been raised regarding e-ticketing adoption for the agency?

None at this time.
Connectivity - we have a lot of areas in the state that have no cell service
The current issue for NJDOT is procuring a Vendor and getting a system into Pilots ASAP. The process id very time-consuming.
Connectivity Agency rollout expectations for smaller vendors (all inclusive) Cost to participate
Just fear of change
n/a
The biggest concern is cost from our producers and information required to be submitted.
Reliability of etickets, especially in areas with poor cell service.
Working in rural areas without out cell coverage is challenging and current solutions struggle to be implemented.
If there would be any cost associated to Industry
Biggest concern is just getting used to not having a paper ticket.
Whether or not to pay for it on the contract.
None.
How to use with other material other than HMA. This is only our second season using e-ticketing we will have a better understanding after this season about concerns.
Privacy, remoteness/lack of cellular service at either the plant site or work site.
How will data dead zones be addressed? How will incorrect/error tickets be addressed electronically? What happens when iPads overheat in the field Sun glare can be annoying on iPad
We didn't want to learn 30 systems every time we get a new contractor and train our staff, so we set up a portal to take APIs from all of their systems into ours. The supplier can even take pictures of tickets to process into our system. We don't tell the contractor what system they must use.
The accuracy and completeness of the e-tickets remains a concern. The continuation of paper tickets on the part of the contractors is also a concern since one of the main goals was environmental protection, which is not being achieved currently.
How to get the system to work in areas where there isn't any cell coverage

To date, VDOT has not been able to substantiate a significant cost savings for this digital process. The digital process requires standalone software that minimizes scanning of paper tickets but still requires the reviewing and accepting of the ticket and material. As well as adding the documentation to the materials notebook. Also, while there is a process improvement we are incurring similar but different costs, i.e. digital storage cost in place of physical storage cost. We are also not able to reduce other costs as equipment (printer & scanner) or software (PDF viewer and markup) are still needed for other processes.
Cellular coverage and what happens when offline, costs to contractors that don't have a system yet, cost to department, number of e-ticketing systems that inspectors will have to learn to use.
Full implementation has not been met due to High bid prices from pilot projects and the smaller production facilities less likely to switch over to e-Ticketing.
Since we have scaled up the use to involve the ability to use it for all of our people, consultants and any contractor supplier who wants to get on board, the main concerns are the connectivity with plants with no service. As an agency we like it and look forward to continued adoption, and data integration.
impacts to smaller contractors
Reliability/uptime - This has been an unfounded concern as eTickets have an offline mode that works using paper tickets. Staffing - We have difficulty staffing Pave & Rehab projects appropriately. eTickets require that an inspector be by the paver at all times just to mark the material received. Integration - Integration between our eTicket Portal and Construction Management software was delayed. This integration is essential to better adoption of eTickets by DelDOTS staff.
Vendors were initially enthusiastic about eticketing in Hawaii. However, once HDOT made the decision to have Headlight develop a module to accept etickets from any vendor, vendor interest in working with HDOT has waned. HDOT chose to develop a module in Headlight to accept etickets to enable any vendor to feed etickets directly into our construction management software to eliminate the need manage multiple contracts and to minimize the number of data integrations.
The extra effort it is going to take to implement full e-ticketing across all materials and the automation needed to collect the raw data and move it into payment system to fully remove human error with data entry.
consistency of trucks arriving without GPS.
The use of a specific system versus allowing any system.
Areas of poor cell coverage
Not all parts of state (WV) have cell phone converge
Mainly connectivity issues. Lack of cell coverage on a project or in certain locations within a project is one of the greater challenges. From contractors, concern that they still have to run a paper system for cities, counties, and their FOB customers. Subcontractor trucking firms also prefer to have physical tickets as physical proof they delivered a certain number of loads in a shift.

Addressing the issues of obtaining e-tickets at night and in areas of limited cellular internet access.
None yet.
use in areas of no service. Temporary staff and equipment usage.

19. What plans does the agency have for future e-ticketing adoption?

Our agency plans to adopt e-ticketing statewide over the next couple of years.
Expanding the material types (i.e. Concrete, aggregates, etc) in the near future.
implementation
NJDOT hopes to be in full production of an e-ticketing solution simultaneously with the implementation of the AASHTOWare Project Construction software.
Upon completion of year two of pilot the agency is looking to integrate e-ticketing on larger scale with contract language to include. We believe we will have full adoption in the next three years.
Full roll out on asphalt, concrete and agg
MassDOT is planning to implement eTicketing throughout the state in the coming years for all HMA and concrete delivered to our projects.
The Department plans to fully implement e-Ticketing for asphalt, aggregate and concrete by 2024. Once that phase is complete, we will continue to work with Industry in parallel to explore other opportunities to streamline current paper processes. for example, batcher mixer slips.
We plan to fully expand to all asphalt tickets in the next couple years. Trial projects for Ready Mix Concrete were let this summer and we hope to begin using it widely for concrete on the near future. We also plan to expand to aggregates after we have concrete established.
Continue to advance the process and integrate e-ticketing into Oracle's Unifier program.
We'd like to implement during Construction Season 2023
Looking into concrete ready mix and aggregate.
Continue to allow it if the Contractor chooses to use it, and not limit it to only asphalt paving operations.
RIDOT is considering expanding to concrete delivery and possibly aggregate deliveries.
Continue to do more pilots not just with HMA but also other materials.
Continue to have discussions with industry and field districts as a voluntary option.
We are planning to continue piloting in 2022 and for the next year. We are planning to advertise invitation for proposal to solicit e-ticketing vendor assistance to help bring smaller (mom/pop) suppliers up to date with e-Ticketing capabilities.

Full implementation by 2025.
We hope to expand e-tickets for aggregates in the near future. Someday we may also expand to concrete, but not in the near term.
Just that - looking to do full adoption where it makes sense, not just a blanket mandatory action on each project.
will complete a one year pilot and develop a strategy based on findings.
Plan to implement as much as conditions allow.
Looking into acquiring agency owned/maintained e-ticekting platform to achieve full implementation.
See previous answers.
currently we are looking at expanding the use from just HMA to other materials
Currently in production for bituminous concrete and beginning to integrate with Ready Mix suppliers. Expect to take Ready Mix to production this fall with aggregate integration and implementation to follow. Once we have fully implemented the system, we intend to begin using the collected data to do analytics. Additionally, some initial discussions have been had on potentially rolling out the system to any shipped material. i.e. precast elements, rebar, ect.
HDOT is starting with asphalt tickets and hopes to expand to concrete and aggregates.
We will work toward e-ticket data dump into a pay system in the future, but currently the Department is implementing AASHTOWareProject so it will have to wait until Project is fully functional.
While working out issues with our implementation for Asphalt, we plan to phase in it's use with Aggregates and Concrete.
We are trying to pilot an e-ticketing system special provision.
Starting with the May 2022 letting we put our special provision in every asphalt project. This is to get the contractors and field personnel used to it. Beginning January 2023 it will be required.
We are looking at expanding it into aggregates and other materials.
We plan to continue to work with industry on this. We'll move to add asphalt e-ticketing as an option in our July 2023 Spec Workbook, and continue discussions with the contracting industry, project personnel, e-ticketing vendors, etc., about the future of e-ticketing and potential to make it more and more the norm.
Right now, agency plans to pilot e-ticketing further.
Potentially making it mandatory.
We look to implement e-ticketing once it has been reviewed by our ITS Department.

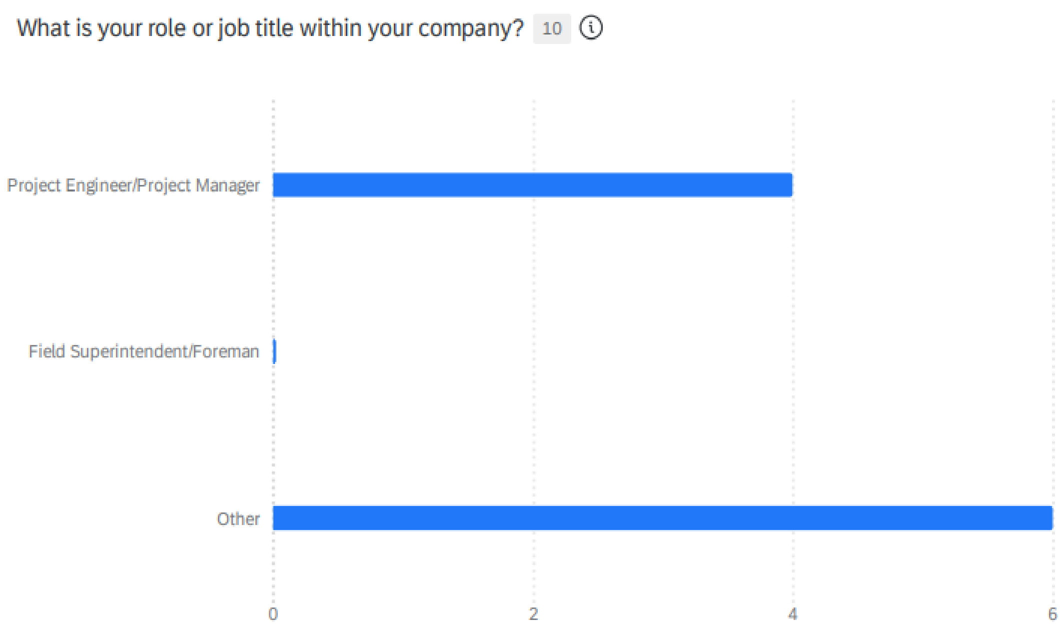
APPENDIX B. KAHC/PAIKY SURVEY

1. What is your role or job title within your company?

    a. Project Engineer/Project Manager

    b. Field Superintendent/Foreman

    c. Other?

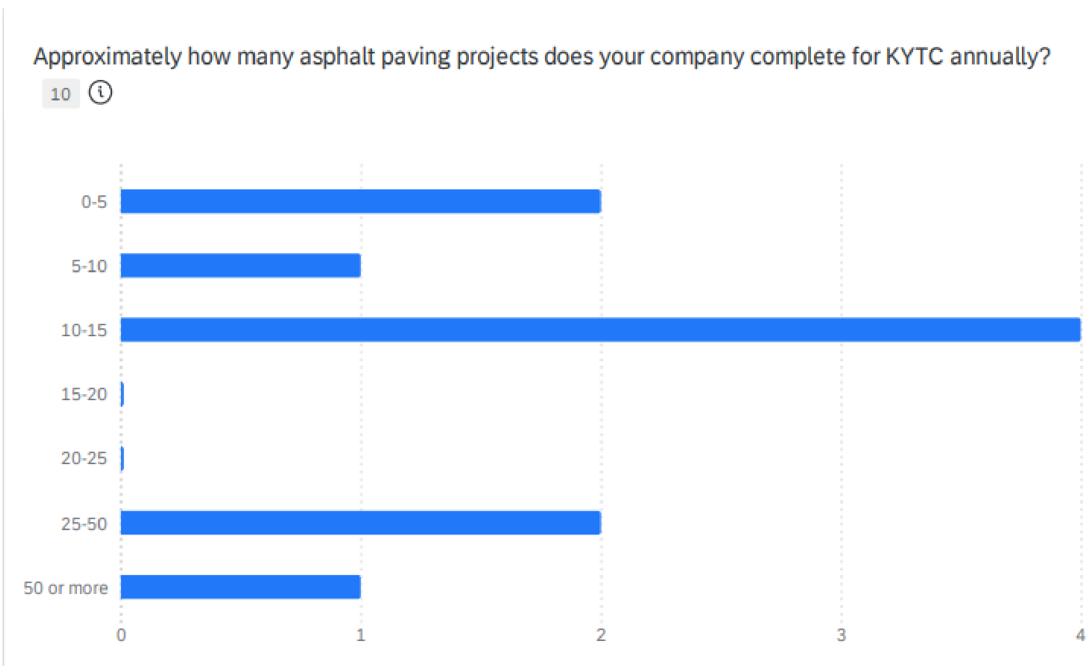


What is your role or job title within your company? 10

What is your role or job title within your company?	Average	Minimum	Maximum	Count
Project Engineer/Project Manager	1.00	1.00	1.00	4
Field Superintendent/Foreman	-	-	-	0
Other	3.00	3.00	3.00	6

Sales Manager
QC Manager
CFO

2. Approximately how many asphalt paving projects does your company complete for KYTC annually?
    a. 0-5
    b. 5-10
    c. 10-15
    d. 15-20
    e. 20-25
    f. 25-50
    g. 50 or more



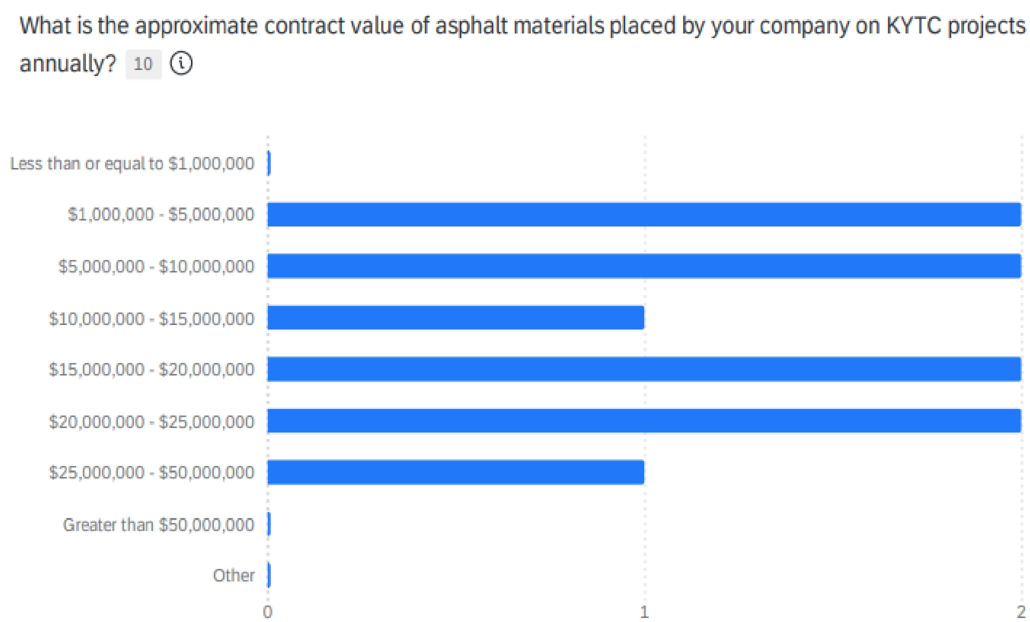
Approximately how many asphalt paving projects does your company complete for KYTC annually?

10 ⓘ

Q2 - Approximately how many asphalt paving projects does your company complete for KYTC annually?	Percentage	Count
0-5	20%	2
5-10	10%	1
10-15	40%	4
15-20	0%	0
20-25	0%	0
25-50	20%	2
50 or more	10%	1

3. What is the approximate contract value of asphalt materials placed by your company on KYTC projects annually?

   a. Less than or equal to $1,000,000
   b. $1,000,000 - $5,000,000
   c. $5,000,000 - $10,000,000
   d. $10,000,000 - $15,000,000
   e. $15,000,000 - $20,000,000
   f. $20,000,000 - $25,000,000
   g. $25,000,000 - $50,000,000
   h. Greater than $50,000,000
   i. Other?

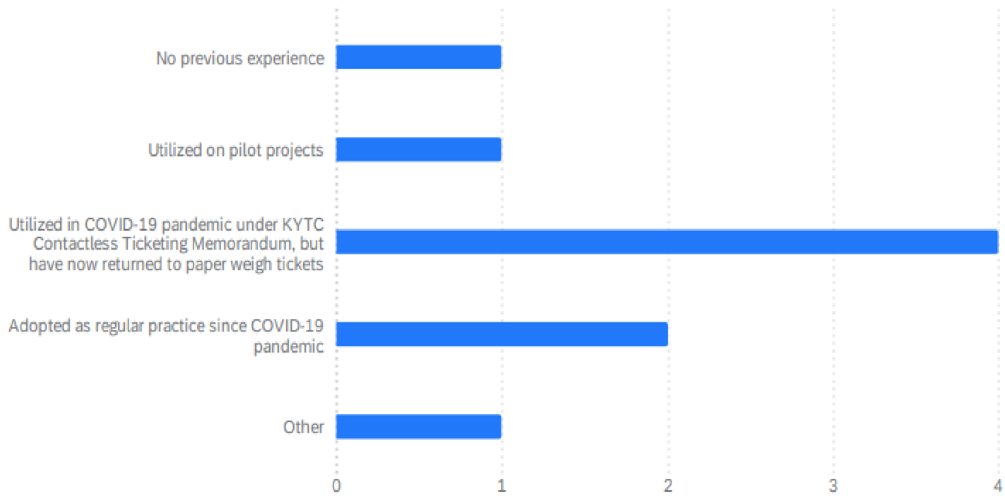


What is the approximate contract value of asphalt materials placed by your company on KYTC projects annually? 10

Q3 - What is the approximate contract value of asphalt materials placed by your company on KYTC projects annually? - Selected Choice	Percentage	Count
Less than or equal to $1,000,000	0%	0
$1,000,000 - $5,000,000	20%	2
$5,000,000 - $10,000,000	20%	2
$10,000,000 - $15,000,000	10%	1
$15,000,000 - $20,000,000	20%	2
$20,000,000 - $25,000,000	20%	2
$25,000,000 - $50,000,000	10%	1
Greater than $50,000,000	0%	0
Other	0%	0

4. What previous experience best describes how your company has utilized e-ticketing system(s) for asphalt operations?
    a. No previous experience
    b. Utilized on pilot projects
    c. Utilized in COVID-19 pandemic under KYTC Contactless Ticketing Memorandum, but have now returned to paper weigh tickets
    d. Adopted as regular practice since COVID-19 pandemic
    e. Other?

What previous experience best describes how your company has utilized e-ticketing system(s) for asphalt operations? 9



What previous experience best describes how your company has utilized e-ticketing system(s) for asphalt operations? 9

Q4 - What previous experience best describes how your company has utilized e-ticketing system(s) for asphalt operations? - Selected Choice	Percentage	Count
No previous experience	11%	1
Utilized on pilot projects	11%	1
Utilized in COVID-19 pandemic under KYTC Contactless Ticketing Memorandum, but have now returned to paper weigh tickets	44%	4
Adopted as regular practice since COVID-19 pandemic	22%	2
Other	11%	1

5. What e-ticketing system(s) has your company utilized on past projects?

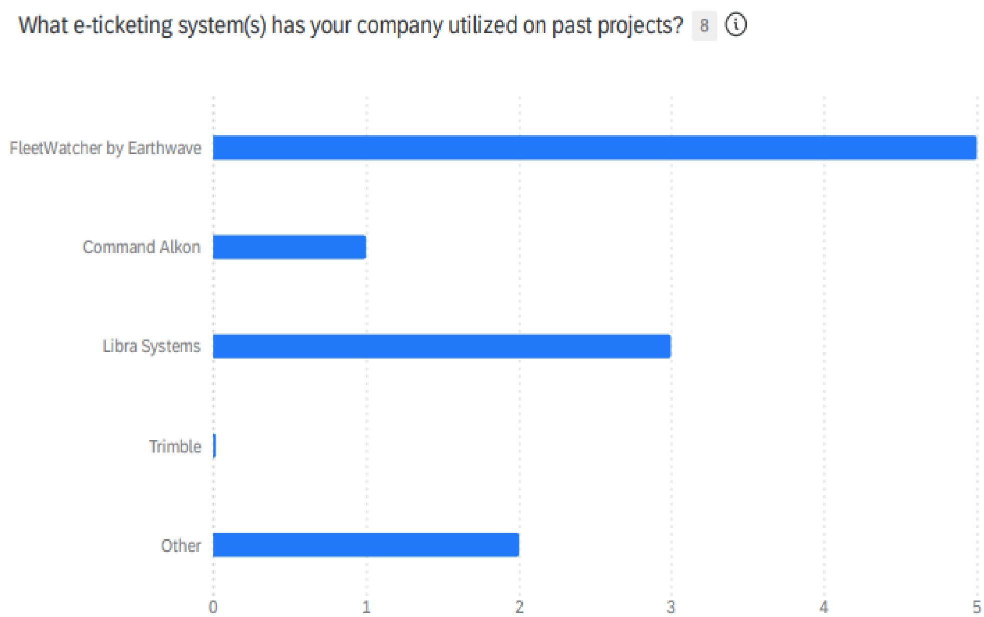
   a. FleetWatcher by Earthwave

   b. Command Alkon

   c. Libra Systems

   d. Trimble

   e. Other?



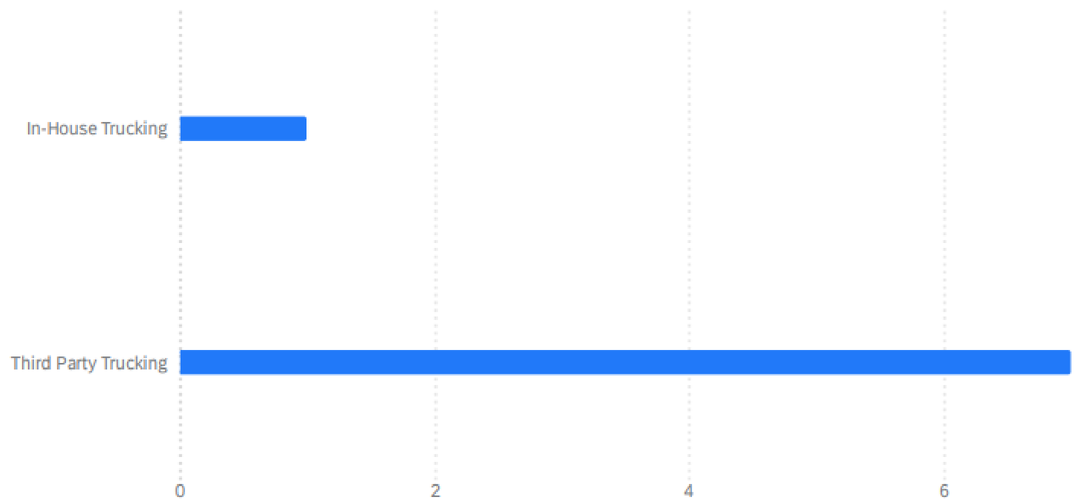
What e-ticketing system(s) has your company utilized on past projects? 8

Q5 - What e-ticketing system(s) has your company utilized on past projects? - Selected Choice	Percentage	Count
FleetWatcher by Earthwave	63%	5
Command Alkon	13%	1
Libra Systems	38%	3
Trimble	0%	0
Other	25%	2

broadloop

6. Does your company primarily utilize in-house trucking or third party trucking to haul asphalt materials?
   a. In-house trucking
   b. Third-party trucking

Does your company primarily utilize in-house trucking or third party trucking to haul asphalt material?
8 ⓘ



Does your company primarily utilize in-house trucking or third party trucking to haul asphalt material?
8 ⓘ

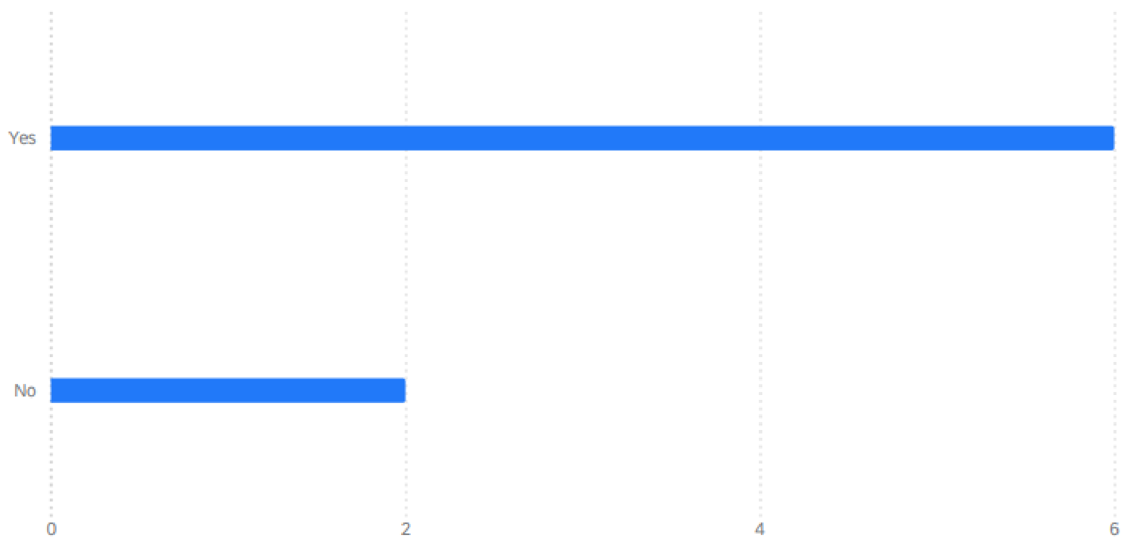
Q6 - Does your company primarily utilize in-house trucking or third party trucking to haul asphalt material?	Percentage	Count
In-House Trucking	13%	1
Third Party Trucking	88%	7

7. Were the e-ticketing system(s) previously listed utilizing GPS capabilities for haul vehicles?

   a. Yes

   b. No

Were the e-ticketing system(s) previously listed utilizing GPS capabilities for haul vehicles? 8



Were the e-ticketing system(s) previously listed utilizing GPS capabilities for haul vehicles? 8

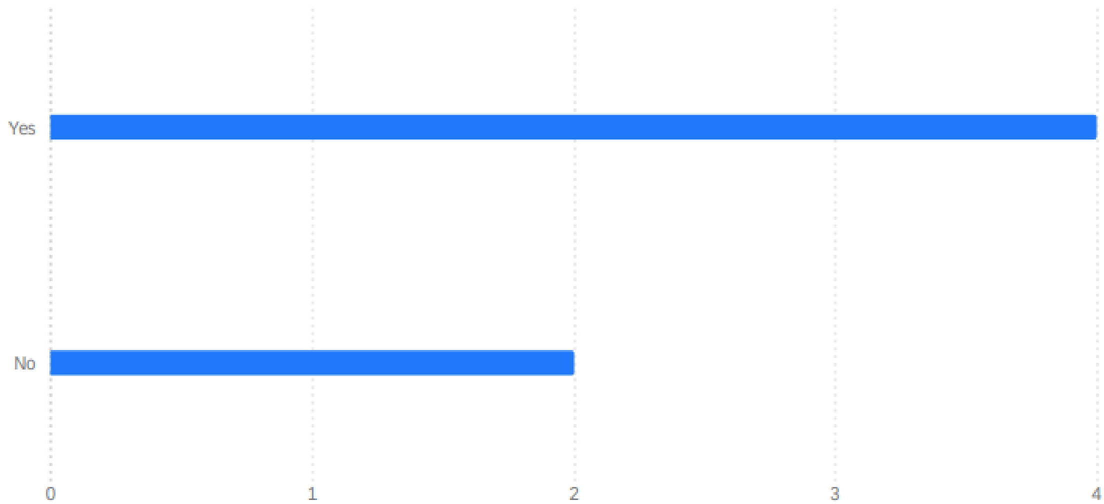
Q7 - Were the e-ticketing system(s) previously listed utilizing GPS capabilities for haul vehicles?	Percentage	Count
Yes	75%	6
No	25%	2

8. If the e-ticketing system(s) utilized GPS capabilities for haul vehicles, were haul fleets able to be optimized during the shift (i.e., did tracking haul vehicles allow some trucks to be sent to different jobs)?

   a. Yes

   b. No

If e-ticketing system(s) utilized GPS capabilities for haul vehicles, were haul fleets able to be optimized during the shift (i.e., did tracking haul cycles allow some trucks to be sent to different jobs)? 6



If e-ticketing system(s) utilized GPS capabilities for haul vehicles, were haul fleets able to be optimized during the shift (i.e., did tracking haul cycles allow some trucks to be sent to different jobs)? 6

Q8 - If e-ticketing system(s) utilized GPS capabilities for haul vehicles, were haul fleets able to be optimized during the shift (i.e., did tracking haul cycles allow some trucks to be sent to different jobs)?	Percentage	Count
Yes	67%	4
No	33%	2

9. If haul fleets were optimized through using e-ticketing system(s), what were the approximate savings? Please approximate savings as an average number of trucks reallocated per paving project.

do not have that info

I dont think there was a huge savings but it is helpful to keep us on budget.

UnKnown

10. What monetary savings could be realized by your company through the elimination of printing paper weigh tickets for asphalt loads? Please approximate savings as an average cost per printed ticket.

do not have this info

We still print tickets for all projects

Unknown

We would still print tickets for our trucks, due to having a plethora of third-party haulers keeping their own records.

Minimal

0

I'm not sure it will be cheaper. It may end up being more convenient but not cheaper. I guess eventually we will save the money we spend on paper tickets.

11. How have the deployed e-ticketing system(s) affected your field personnel duties (i.e., increased personnel safety, increased time spent on production related activities, etc.)?

have not seen an impact

Has not changed

Yes

Increased workload of having to serve as IT support for the DOT personnel when new users accounts or training is needed.

We use it for two reasons. Tracking of positions for trucks in route and during the pandemic to decrease touch points.

No longer requires truck drivers to get out of their trucks to approach the scale house.

12. How have the deployed e-ticketing system(s) affected your project management duties (i.e., fleet optimization, tracking on-site production, decreased time to review pay estimates, lower fuel costs, etc.)?

no impact

Has not changed other than being able to stay up to date on daily plant logs.

UnKnown

The impact has been minimal. Due to the current trucking shortage, the business intelligence has been that we need more trucks to reach optimal efficiency. This was already apparent.

due to the fact that we use 3rd party trucks, it is difficult to assure 100% coverage of the GPS units in each truck. We rely on the paperless aspect of the connection to the scales. We deem the GPS visibility as a "bonus" to the extent we can keep the transponders in the 3rd party trucks.

E-ticketing makes sharing information between satellite locations and our main office much easier.

13. What are the greatest benefits for highway contractors utilizing e-ticketing system(s) on KYTC projects?

i do not see a great benifit

Staying on budget, job tracking.

SAFETY !!!!!

The retrieval of lost tickets.

We adopted e-ticketing for pilot projects. We kept the system because it provides company wide transparency for daily shift process. This coincided with COVID. We wanted to decrease paper touch points. While we understand how smaller contractors may object to universal e-ticketing, we believe that KYTC adoption of e-tickets would make the cabinet more efficient in processing pay items. We believe that this would be a net positive for taxpayers. While we use fleetwatcher, we do not think it would be appropriate for the cabinet to narrowly restrict the e-ticket suppliers. They, rather, should specify the type and manner of information provided by the e-ticketing system.

Not having to keep up with paper tickets is better for us but our truckers don't necessarily like it.

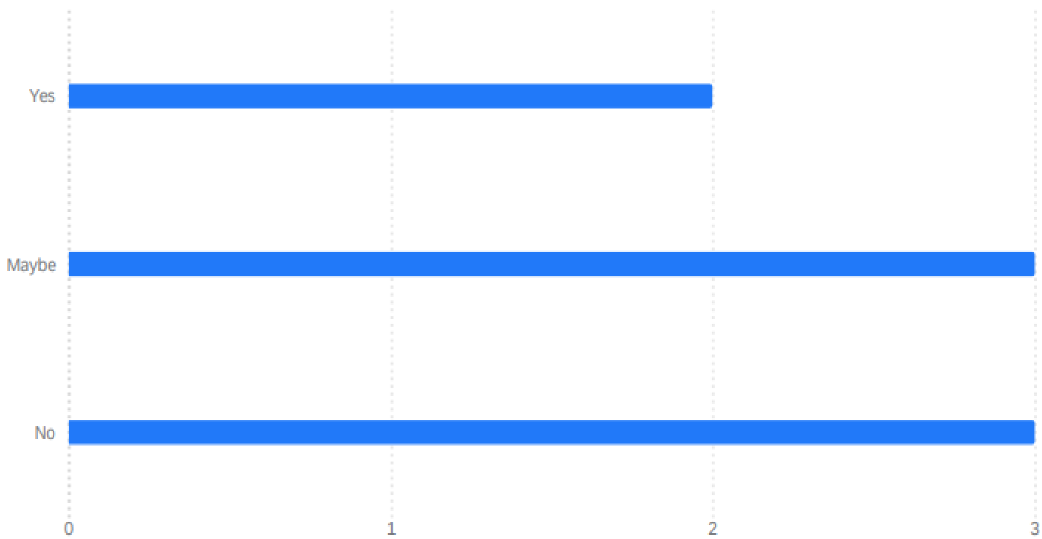
14. Does your company plan to or currently utilize e-ticketing system(s) on non-KYTC projects?

    a. Yes

    b. Maybe

    c. No

Does your company plan to or currently utilize e-ticketing system(s) on non-KYTC projects? 8



Does your company plan to or currently utilize e-ticketing system(s) on non-KYTC projects? 8

Q14 - Does your company plan to or currently utilize e-ticketing system(s) on non-KYTC projects?	Percentage	Count
Yes	25%	2
Maybe	38%	3
No	38%	3

15. What is your overall satisfaction with e-ticketing processes currently utilized on KYTC projects?

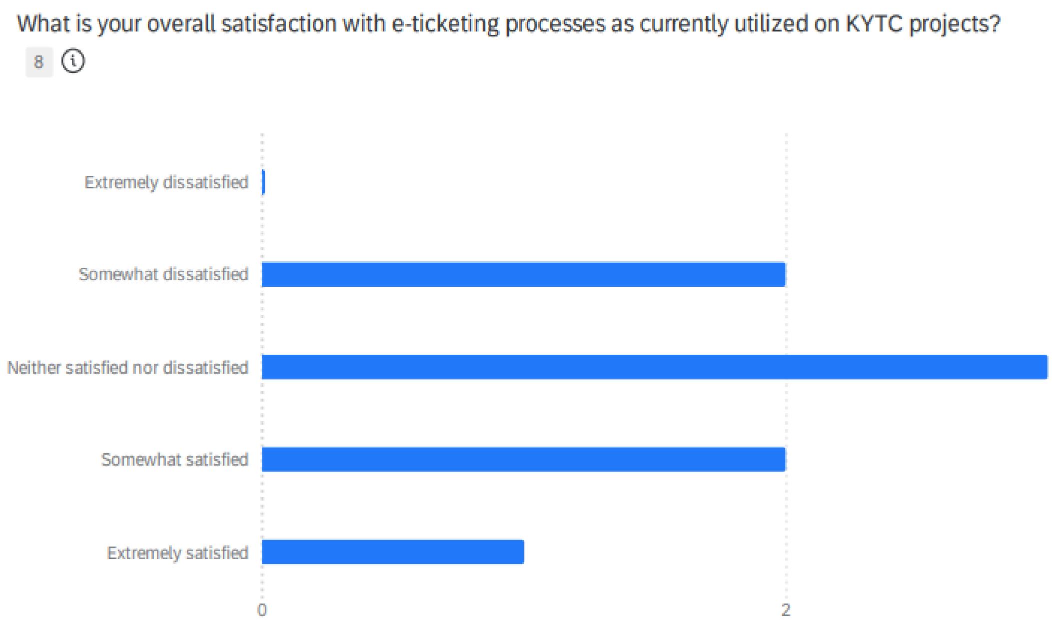
    a. Extremely dissatisfied

    b. Somewhat dissatisfied

    c. Neither satisfied nor dissatisfied

    d. Somewhat satisfied

    e. Extremely satisfied



What is your overall satisfaction with e-ticketing processes as currently utilized on KYTC projects?

8

Q15 - What is your overall satisfaction with e-ticketing processes as currently utilized on KYTC projects?	Percentage	Count
Extremely dissatisfied	0%	0
Somewhat dissatisfied	25%	2
Neither satisfied nor dissatisfied	38%	3
Somewhat satisfied	25%	2
Extremely satisfied	13%	1

16. What feedback do you have regarding how e-ticketing processes have currently been deployed on KYTC projects?

The state still requests paper tickets even if they have the e tickiting system.
We are looking to go Fleetwatcher w/ Full GPS & all Capabilities
The GPS tracking portion of previous specifications was an administrative nightmare.
We would prefer that the cabinet start with the e-delivery of scale tickets first. The GPS aspects of the e-ticketing systems are very difficult to manage with the prevalence of 3rd party trucker who work for multiple contractors.
We operate in remote areas of Kentucky and consistent connection is a problem.

17. What concerns do you still have regarding full-scale adoption of e-ticketing process on KYTC projects?

None

Only that we may have to run a different system for KYTC projects than Fleetwatcher

None if KYTC continue to drop the GPS portion of the specification.

see about. I am cautious about requiring 100% coverage of GPS.

GPS and Cell signal availability

We have internet and cellular connection issues that are a concern. Also, many of our truck drivers are older and don't have the proper technology or knowledge.

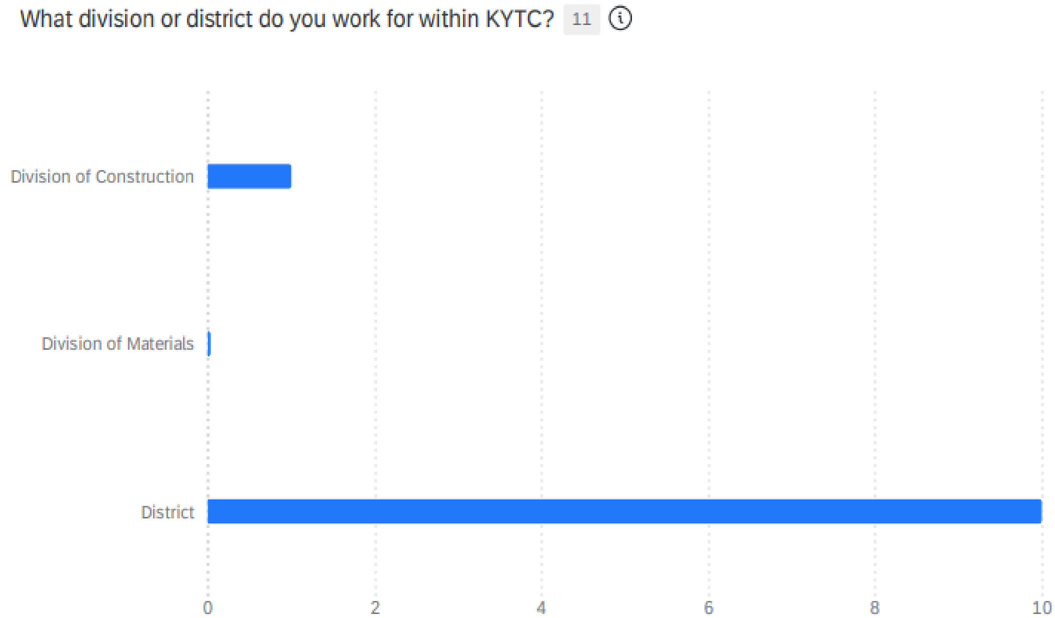
APPENDIX C. KYTC DPD SUBCOMMITTEE SURVEY

1. What division or district do you work for within KYTC?

    a. Division of Construction

    b. Division of Materials

    c. District?



What division or district do you work for within KYTC? 11

Q1 - What division or district do you work for within KYTC? - Selected Choice	Percentage	Count
Division of Construction	9%	1

Q1 - What division or district do you work for within KYTC? - Selected Choice	Percentage	Count
Division of Materials	0%	0
District	91%	10

11
3
3
4
3
9
6
9

2. What is your role or job title within KYTC?

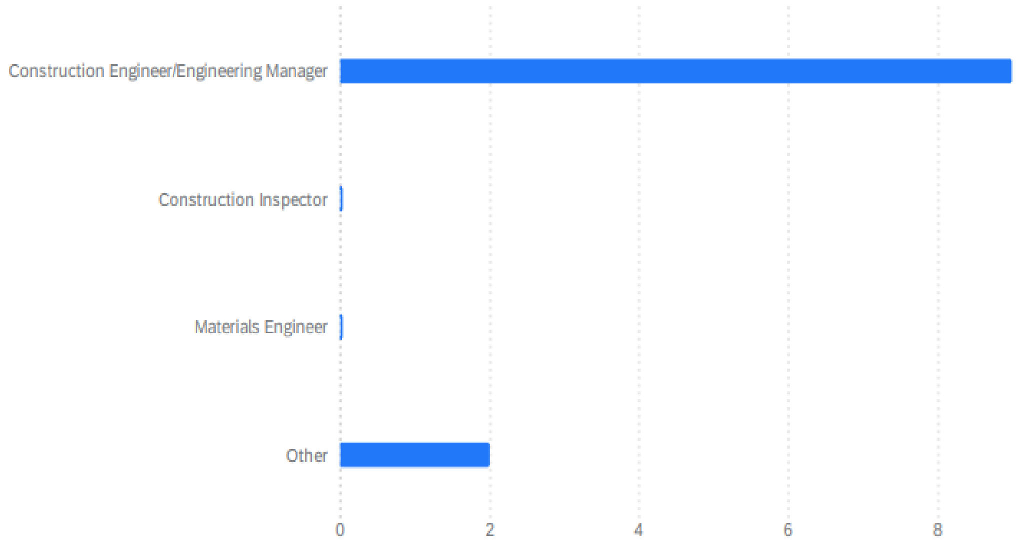
    a. Construction Engineer/Engineering Manager

    b. Construction Inspector

    c. Materials Engineer

    d. Other?

What is your role or job title within KYTC? 11



What is your role or job title within KYTC? 11

Q2 - What is your role or job title within KYTC? - Selected Choice	Percentage	Count
Construction Engineer/Engineering Manager	82%	9
Construction Inspector	0%	0
Materials Engineer	0%	0
Other	18%	2

Project Development Branch manager
Director of Construction

3. How long have your worked for KYTC?

    a. 0-5 years

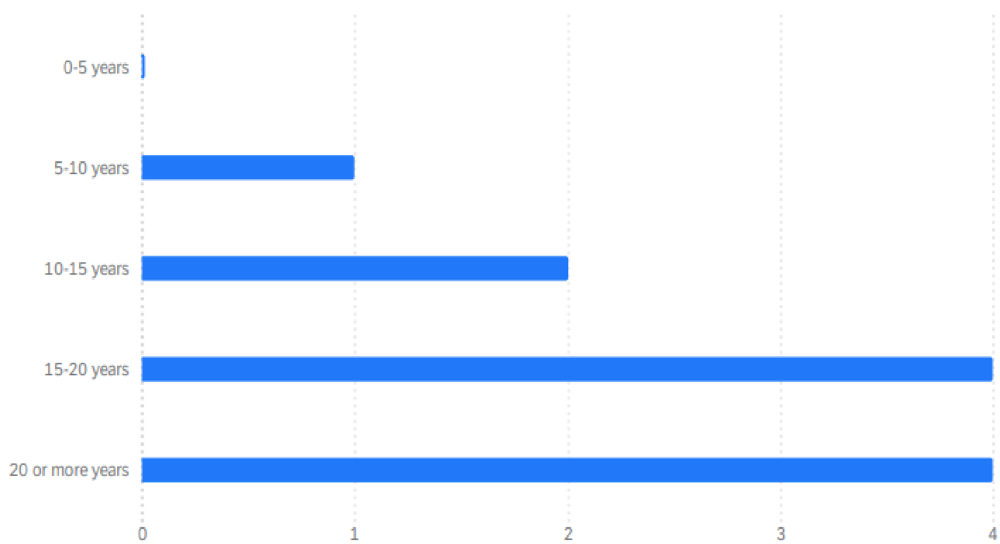
    b. 5-10 years

    c. 10-15 years

    d. 15-20 years

    e. 20 or more years

How long have you worked for KYTC? 11



How long have you worked for KYTC? 11

Q3 - How long have you worked for KYTC?	Percentage	Count
0-5 years	0%	0
5-10 years	9%	1
10-15 years	18%	2
15-20 years	36%	4
20 or more years	36%	4

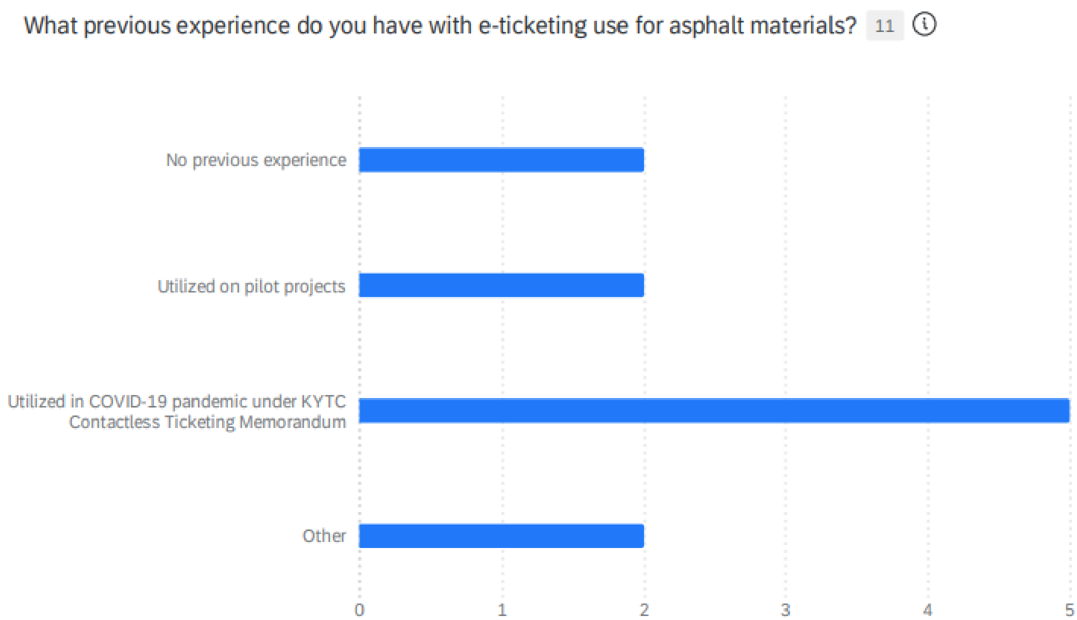
4. What previous experience do you have with e-ticketing use for asphalt materials?

    a. No previous experience

    b. Utilized on pilot projects

    c. Utilized in COVID-19 pandemic under KYTC Contactless Ticketing Memorandum

    d. Other?



What previous experience do you have with e-ticketing use for asphalt materials? 11

Q4 - What previous experience do you have with e-ticketing use for asphalt materials? - Selected Choice	Percentage	Count
No previous experience	18%	2
Utilized on pilot projects	18%	2
Utilized in COVID-19 pandemic under KYTC Contactless Ticketing Memorandum	45%	5
Other	18%	2

Development of future specs
Pilot projects and Covid Memo

5. Which e-ticketing system(s) have you utilized on past projects?

    a. FleetWatcher by Earthwave

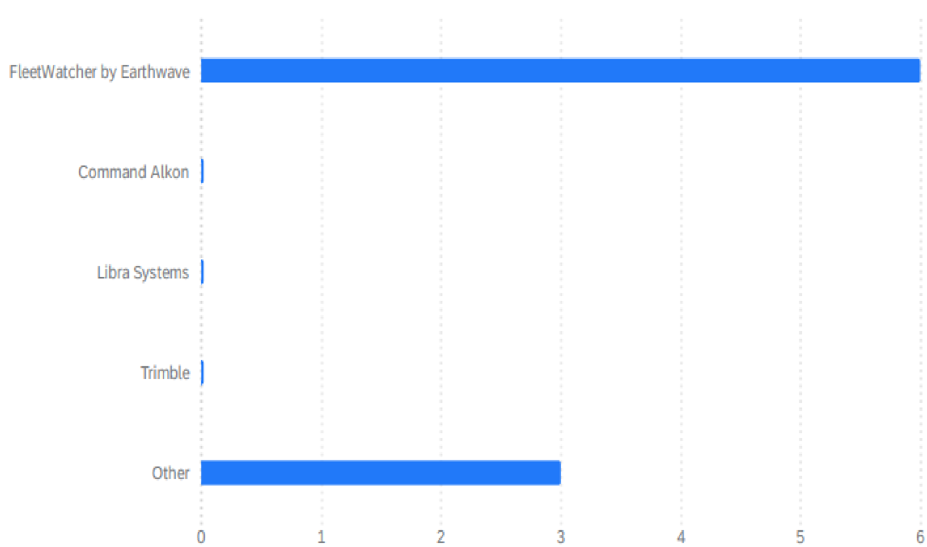
    b. Command Alkon

    c. Libra Systems

    d. Trimble

    e. Other?

Which e-ticketing system(s) have you utilized on past projects? 8



Which e-ticketing system(s) have you utilized on past projects? 8

Q5 - Which e-ticketing system(s) have you utilized on past projects? - Selected Choice	Percentage	Count
FleetWatcher by Earthwave	75%	6
Command Alkon	0%	0
Libra Systems	0%	0
Trimble	0%	0
Other	38%	3

Mountain Enterprises developed a in house version of E-ticketing due to the Pandemic

DOC is currently working on Pilots with Command Alkon and Haul Hub

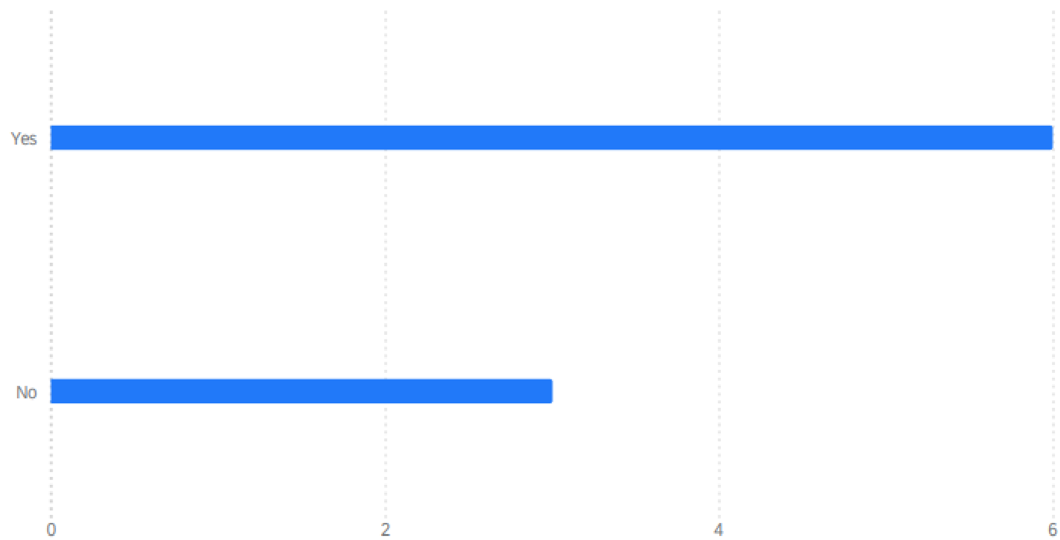
FastWeigh

6. Were these e-ticketing system(s) utilizing GPS capabilities for haul vehicles?

    a. Yes

    b. No

Were these e-ticketing system(s) utilizing GPS capabilities for haul vehicles? 9



Were these e-ticketing system(s) utilizing GPS capabilities for haul vehicles? 9

Q6 - Were these e-ticketing system(s) utilizing GPS capabilities for haul vehicles?	Percentage	Count
Yes	67%	6
No	33%	3

7. How have the deployed e-ticketing system(s) affected field personnel duties (i.e., increased personnel safety, increased time spent on QA/QC activities, etc.)?

Does increase safety due to not having to get the tickets from the truck, and ideally provide additional time for inspection. However, inspectors were lost most of the time by not knowing what the current tonnage was to calculate the yield. Voided / rejected loads of material was a big problem by being on the report and no good way to get it off the list.

Increased safety due to the inspectors not having to climb on the dump trucks or be close to them. Makes keeping track of how the contractor is running on tonnage (too heavy or too light) more difficult. In our area, we still have large areas without cell coverage. Learning curve for the inspectors who are use to looking at the tickets. Inspectors have to keep up with trucks to know, who has dumped and not dumped. Or at least that is the way with Mountain's app. Since they didn't have GPS. Thiers's was just linked to the computer system at the plant.

I can not say to date. Implementation during the pandemic has been widely variable and no one had truly what the full product will supply.

Primarily using Fleetwatcher for asphalt material delivery. Allows a single inspector to monitor material placement and compaction without having to stay close to the truck to make sure tickets aren't missed. Assists with laying out random cores. Also provides a factor of safety by not having to walk along the trucks/traffic.

It has removed the need to place an employee in potential danger locations to obtain tickets from the drivers and increased the reliability of retaining the ticket records.

The fleetwatcher program was cumbersome and hard to navigate and get what was needed. Ended up just requesting tickets as a PDF most times.

---

8. How have the deployed e-ticketing system(s) affected project management duties (i.e., improved project documentation, decreased time for pay estimate review/processing, etc.)?

Increased the duties. Found the electronic ticketing to be inaccurate several times. Therefore, additional checking was required. Changes in the field were not processed well by the contractor.

Yes. I feel the app helps me insure, we have the correct tickets. Sometimes the inspectors lose tickets or step out to lunch and miss a truck, etc.

I do not know at this time.

Reduces/eliminates missed tickets. Especially tack oil or milling tickets when trucks may not return to the project. Allows engineer to quickly monitor progress on multiple projects remotely. Allows an inspector to monitor multiple operations at once and manage material testing for the separate materials. Resolve last load disputes when loads are unused on project. Easily generates legible load tickets in digital format for records.

It has improved the documentation reliability by eliminating missed tickets.

Helped in getting all tickets were before missing tickets took time to track down. Harder to verify ticket to physical truck with cumbersome navigation and poor cellular service. Also Fleetwatcher required a unique email address for each contractor so had to choose between contractors and not have access to the other.

9. What feedback do you have regarding how e-ticketing has currently been deployed on KYTC projects?

It is the learning stages. The contractor nor KYTC is sure how to use it. E-Ticketing mistakes and update information on the projects are huge problems.

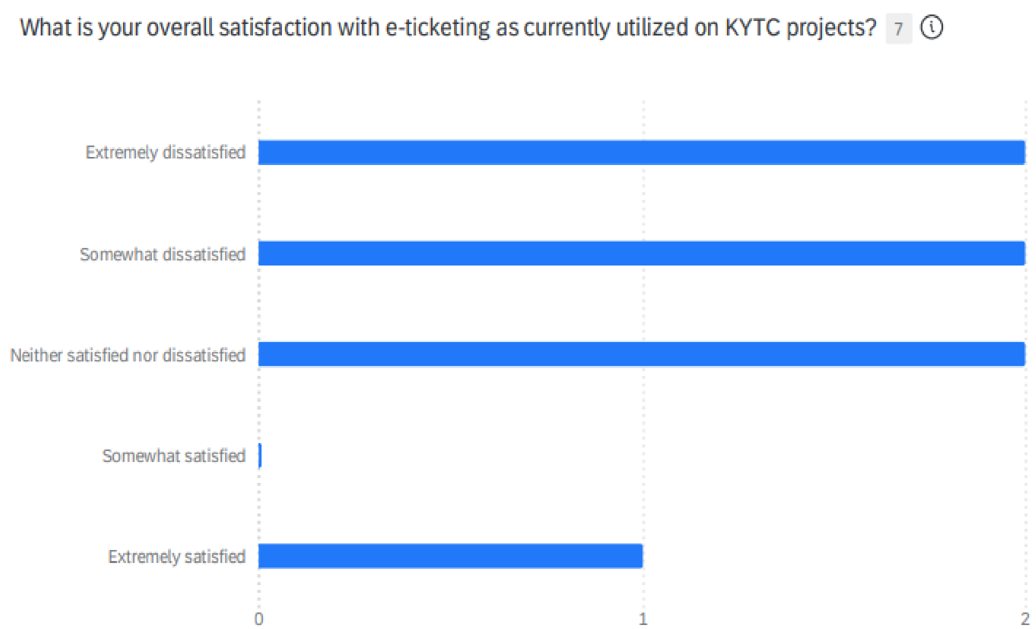
It is widely varied. The few cases where they were truly implemented have seemed to run well.

Works great. Rock quarries seem to use the GPS capable tracking platforms the least. I'd like all ticketed material transported to the job be accessible through Fleetwatcher style software.

There are issues with regard to access for KYTC personnel if you work with multiple asphalt companies. Each company has provided login access to the E-ticketing system and you are not able to reference data across companies. This requires the inspector to remember which login is associated with the proper company for the respective projects.

Need better more intuitive program that makes it easier navigate and match ticket to truck to material used.

10. What is your overall satisfaction with e-ticketing as currently utilized on KYTC projects?
    a. Extremely dissatisfied
    b. Somewhat dissatisfied
    c. Neither satisfied nor dissatisfied
    d. Somewhat satisfied
    e. Extremely satisfied



What is your overall satisfaction with e-ticketing as currently utilized on KYTC projects? 7

Q10 - What is your overall satisfaction with e-ticketing as currently utilized on KYTC projects?	Percentage	Count
Extremely dissatisfied	29%	2
Somewhat dissatisfied	29%	2
Neither satisfied nor dissatisfied	29%	2
Somewhat satisfied	0%	0
Extremely satisfied	14%	1

11. What concerns do you have regarding full-scale adoption of e-ticketing on KYTC projects?

Not accurate, real time information on the project, availability of electronic devices for the inspectors, Service in remote areas, Correcting mistakes in the e-tickets, Overweight ticket deductions, inspectors and management needing to chase down information at the end of the day's production, obtaining asphalt cores at the correct tonnage due to not knowing the current real time totals, etc.
Cell signal coverage in our area.
Training, program support
Device battery life and signal strength on the project site are the only downsides I have noted. I would still like to see e=ticketing required as standard for all ticketed materials delivered to KYTC projects with the option to supplement with paper tickets in locales known for poor signal strength.
My concern is that inspectors will further use the system to permit them to not properly inspect the projects as the work is performed. This already happens too much when inspectors stay all day sitting in the truck while they should be watching the paving mat being laid.
Needs a better program than fleetwatcher.

APPENDIX D. KYTC ENGINEER DAILY SURVEY

1. Project CID?

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21-1049
21-1049
21-3162
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21-1035
21-1035
21-1035
21-3162
204206
211342

2. Project County?

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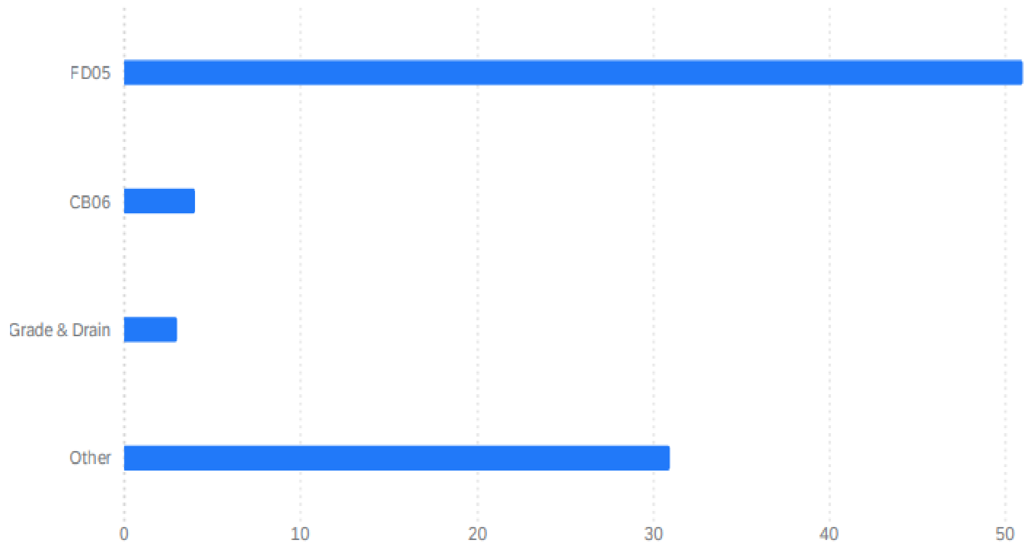
Allen
Hardin

3. Project Scope?
    a. FD05
    b. CB06
    c. Grade & Drain
    d. Other?

Project Scope? 89



Project Scope? 89

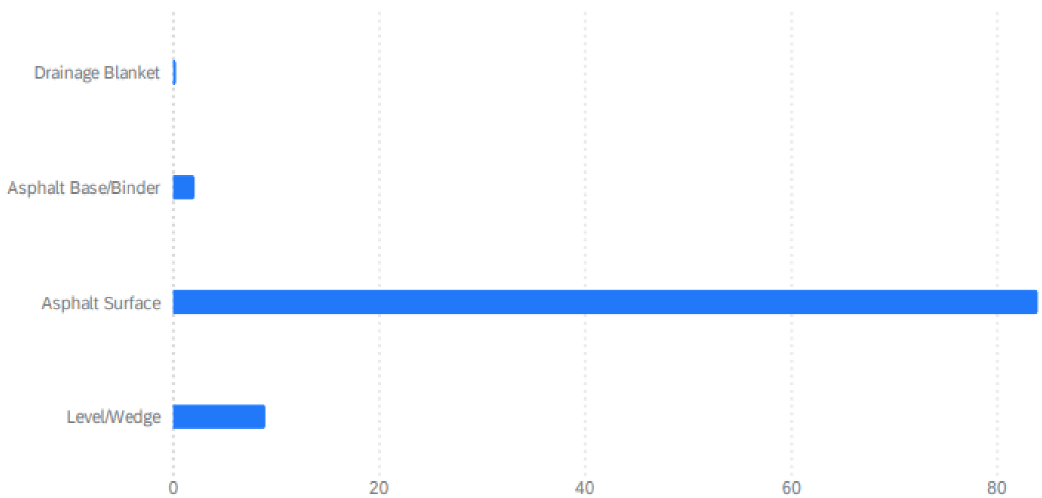
Q3 - Project Scope? - Selected Choice	Percentage	Count
FD05	57%	51
CB06	4%	4
Grade & Drain	3%	3
Other	35%	31

Other Responses (Text)
HSIP
HSIP
HSIP
HSIP
HSIP
Preventative Maintenance
Preventative Maintenance
Rehab
Rehab
Rehab
Rehab
Rehab
Rehab
Rehab
Preventative Maintenance
Sidewalk

Sidewalk
FD52
FD52
FD52
FD52
Preventative Maintenance
Preventative Maintenance
Rehab
Rehab
Rehab
LFUCG Project
LFUCG Project
LFUCG Project
HSIP
FD04

4. What is the asphalt operation for the day? If multiple asphalt mix types were placed on the project, please select all that apply.
   a. Drainage Blanket
   b. Asphalt Base/Binder
   c. Asphalt Surface
   d. Level/Wedge

What is the asphalt operation for the day? If multiple asphalt mix types were placed on the project, please select all that apply. 89



What is the asphalt operation for the day? If multiple asphalt mix types were placed on the project, please select all that apply. 89

Q4 - What is the asphalt operation for the day? If multiple asphalt mix types were placed on the project, please select all that apply.	Percentage	Count
Drainage Blanket	0%	0
Asphalt Base/Binder	2%	2
Asphalt Surface	94%	84
Level/Wedge	10%	9

5. How many loads were received on the project for the day? If multiple asphalt mixes were placed, please separate loads by mix type.

29
45
28
60
52
52
25
29
30
49
1
37
47
38
37
38

16
34
3 loads CL2 Surface 16 loads CL3 Surface
41 loads CL2 Surface 16 loads CL3 Surface
49 loads CL2 Surface 14 loads CL3 Surface
29 loads CL2 Surface
29 loads CL3 Surface
59 loads CL3 Surface
37 loads CL3 Surface
14 loads CL3 Surface
45 loads CL3 Surface
1
8
20
1
3
6 loads Level/wedge 21 loads CL3 Surface

1 Load CL3 surface 9 Loads level/wedge
54 loads CL3 Surface
45 loads CL3 Surface
13 loads CL3 surface
80 loads CL3 Surface 8 loads level/wedge
45 loads CL3 Surface
26 loads CL4 Surface
43 loads CL4 Surface
52 loads CL4 Surface
22 loads CL4 Surface
17 loads CL4 Surface
46 loads CL4 Surface
9 loads CL4 Surface 6 loads level/wedge
12 loads CL4 Surface
8 loads CL4 surface
6 loads CL4 surface
5 loads CL4 surface

40 loads surface
19 loads surface
25
30
53
52
81
46
25
9 loads CL4 Surface 0.38A 76-22
62 loads CL4 Surface 0.38A 76-22 4 loads Level/Wedge
16 loads CL4 Surface 0.38A 76-22 1 load Level/Wedge
62 loads CL4 Surface 0.38A 76-22
33 loads CL4 Surface 0.38A 76-22
21 loads CL4 Surface 0.38A 76-22
3 loads CL4 Surface 0.38A 76-22
53 loads CL4 Surface 0.38A 76-22

41 loads CL4 Surface 0.38A 76-22
30 loads CL2 Surface No. 4D 64-22
17
10
25
30
53
52
31 loads Surface
35 loads Surface
78
45
47 - CL4 Surface 0.38A 76-22
36 loads Surface
37 loads Surface
7 loads Level/Wedge, 26 loads Surface
10

17
1
3 loads Level/Wedge, 36 loads Surface
14
41

6. How many tons were placed on the project for the day? If multiple asphalt mixes were placed, please separate tonnage by mix type.

729.94
1144.77
708.27
1525.99
1319.75
1325.3
368.28
746.72
761.17
1229.01
10

946.76
688.93
972.76
946.76
744.7
358.57
845.29
74.31 tons CL2 Surface 402.73 tons CL3 Surface
1027.53 tons CL2 Surface 394.64 tons CL3 Surface
1226.38 tons CL2 Surface 350.78 tons CL3 Surface
725.62 tons CL2 Surface
709.69 tons CL3 Surface
1478.82 tons load CL3 Surface
924.76 tons CL3 Surface
352.85 tons CL3 Surface
1022.16 tons CL3 surface
26.24

207.65
513.51
25.64
79.4
150.89 tons level/wedge 525.41 tons CL3 surface
25.47 tons CL3 Surface 212.43 tons level/wedge
1333.74 tons CL3 Surface
1130.66 tons CL3 Surface
325.73 tons CL3 Surface
1990.07 tons CL3 Surface 202.03 tons level/wedge
1130.95 tons CL3 Surface
653.50 tons CL4 Surface
1080.08 tons CL4 Surface
1295.44 tons CL4 Surface
549.43 tons CL4 Surface
429.53 tons CL4 Surface
1166.07 tons CL4 Surface

213.28 tons CL4 surface 153.31 tons level/wedge
296.00 tons CL4 Surface
204.28 tons CL4 surface
152.40 tons CL4 surface
125.36 tons CL4 surface
1015.31 tons surface
466.46 tons surface
635.66
762.87
1349.56
1311.89
2050.76
1172.86
633.36
231.82 tons surface
1567.84 tons surface 101.80 tons level/wedge
406.72 tons surface 25.00 tons level/wedge

1567.84 tons surface
833.08 tons surface
532.11 tons surface
76.17 tons surface
1341.98 tons surface
1037.80 tons CL4 Surface
739.06 tons surface
429.74
255.51
635.66
762.87
1349.56
1311.89
777.93 tons Surface
892.43 tons Surface
1992.25
1143.81

1187.61 - CL4 Surface 0.38A 76-22
929.83 tons Surface
951.23 tons Surface
181.12 tons Level/Wedge, 669.01 tons Surface
255.51
429.74
26.50
62.21 tons Level/Wedge, 912.82 tons Surface
338.19
1024.43

7. How much time (in minutes) was spent reviewing hard copy weigh tickets in the traditional documentation method (i.e., verifying all documentation turned in and last load ticket paid on Daily Work Report)?

15
25
15
32
26

27
13
18
25
28
5
10
15
15
25
27
12
15
2
4
5
2

2
4
2
1
2
0
0
0
0
0
3
1
4
3
2
5
4

2
2
3
2
2
3
2
1
1
1
1
4
3
0
0
0
0

0
0
0
2
6
3
6
4
3
1
9
4
5
0
0
0
0

0
0
3
2
0
0
0
2
2
3
10
10
20
3
N/A

8. How much time (in minutes) was spent reviewing tickets utilizing the selected e-ticketing system?

0
9
8
5
1
0
1
0
1
0
5
8
1
0
1
0

2
4
4
5
5
5
4
5
1
1
1
1
1
1
1
1
1

2
3
3
2
3
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1
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1
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1
1
1
1
4
4
4
5
5
4
5
1
1

1
1
1
1
1
1
1
1
18
20
10
10
10
10
1
1
10

15
20
1
1
1
9
9
18
1
N/A
30

9. How much time (in minutes) was spent filing hard copy weigh tickets in office records using traditional documentation methods (i.e., placing tickets in project folder in section office, scanning last load ticket and placing in electronic project folder or ProjectWise)?

8
10
10

8
9
12
8
10
10
15
2
9
8
7
10
10
5
5
2
2

2
2
2
2
2
2
2
0
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0
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0
2
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0
2
2
2
0
0
0
2
N/A

5

10. How much time (in minutes) was spent transferring tickets from selected e-ticketing system to electronic project folder or ProjectWise?

2
2
2
2
2
2
2
2
2
3
1
2
2
1
2

2
1
1
1
1
1
1
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2
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2
1
1
1
1
1
1
1

1
1
1
5
5
5
5
4
5
1
1
5
5
10
1
1
1

1
1
2
1
N/A
5

APPENDIX E. KYTC INSPECTOR DAILY SURVEY

1. Project CID?

221035
221035
212495
212495
224403
224403
224403
224403
224403
224403
224403
224403
224403
224403
224403

224403
224403
224403
224403
222190
222190
222190
222190
222190
222228
222228
222228
222228
222228
222228
222094
222094

222228
222228
222228
222228
222228
222372
222372
222372
22-2372
22-2372
22-2372
222306
222306
222306
222306
222306
22-2372

22-2372
22-2372
22-2372 2
2-2372
22-2131
22-2131
212495
222185
222257
222257
22-1035
22-1035
22-2257
22-2257
21-1049
21-1049
21-1049

222317
2223117
21-1049
21-1049
211040
21-2459
21-1049
21-1049
21-1049
21-1049
22-2016
22-2016
21-1049
21-1049
21-1049
211049
21-1049

21-1049
21-1049
21-1049
21-1049
21-3162
213162
213162
213162
21-1035
21-1035
21-1035
20-4206
211342
211342

2. Project County?

Fayette

Fayette
Jessamine
Jessamine
Fayette
Fayette
Fayette
Fayette
Fayette
Fayette
Fayette
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Fayette
Fayette
Jessamine
Jessamine county
Fayette
Fayette
Fayette
Fayette
Fayette
Fayette
Fayette
Fayette
Fayette
Bath
Bath
Fayette
Fayette

warren
Warren
Fayette
Fayette
Fayette
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Fayette
Fayette
Fayette
Allen
Hardin
hardin

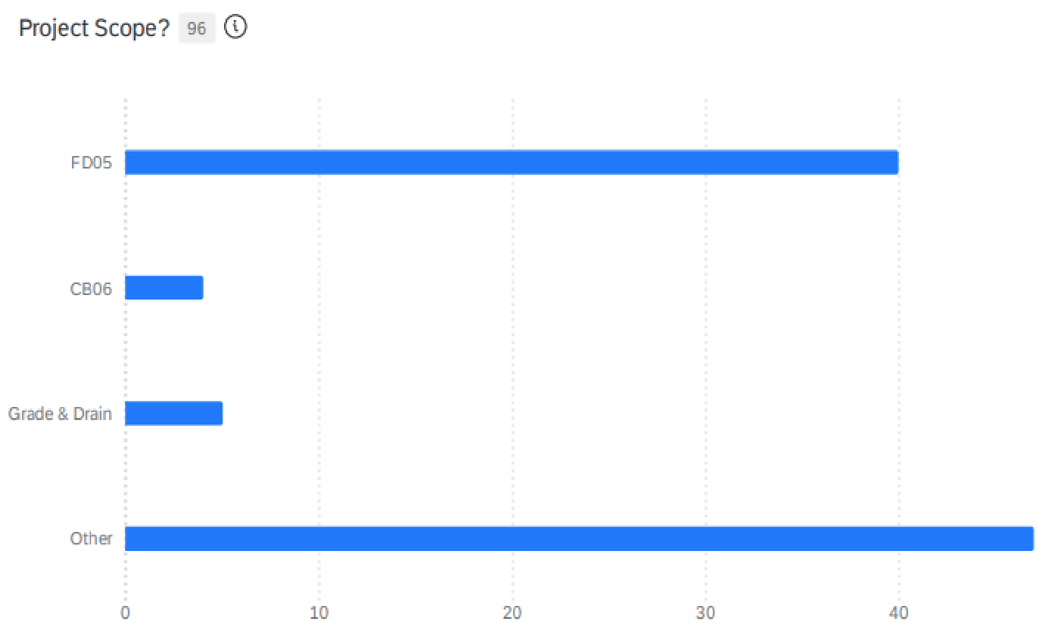
3. Project Scope?

   a. FD05

   b. CB06

   c. Grade & Drain

   d. Other?



Project Scope? 96

Q3 - Project Scope? - Selected Choice	Percentage	Count
FD05	42%	40
CB06	4%	4
Grade & Drain	5%	5
Other	49%	47

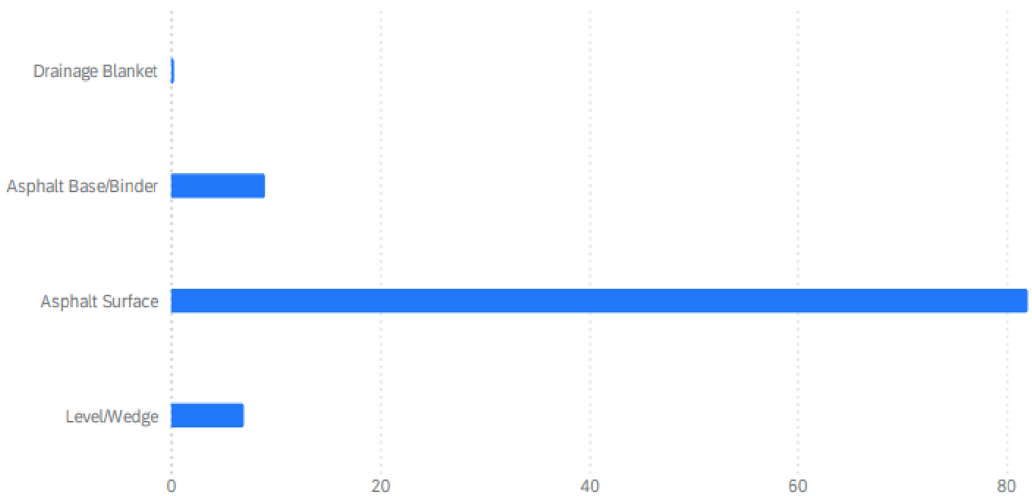
Other Responses (Text)
Hsip
Hsip
Hsip
Hsip
Hsip
Hsip
Hsip
Hsip
Hsip
Hsip
Hsip
Hsip
Hsip
Hsip
Hsip
PMA

PMA
PMA
PMA
PMA
PMA
PMA
Mill & Fill
Mill & Text
Mill & Fill
Mill & Fill
Mill & Fill
Mill & fill
Mill & Fill
Mill and fill
Mill & Fill
Preventative Maintenance
Preventative Maintenance

Mill and Fill
Mill and Fill
Mill and Fill
Mill and Fill
Milling and Fill
Milling & Fill
Mill and Fill
Mill and Fill
Milling and Fill with asphalt, as well as Concrete work
FD04
FD04

4. What is the asphalt operation for the day? If multiple asphalt mix types were placed on the project, please select all that apply.
    a. Drainage Blanket
    b. Asphalt Base/Binder
    c. Asphalt Surface
    d. Level/Wedge

What is the asphalt operation for the day? If multiple asphalt mix types were placed on the project, please select all that apply. 97



What is the asphalt operation for the day? If multiple asphalt mix types were placed on the project, please select all that apply. 97

Q4 - What is the asphalt operation for the day? If multiple asphalt mix types were placed on the project, please select all that apply.	Percentage	Count
Drainage Blanket	0%	0

Q4 - What is the asphalt operation for the day? If multiple asphalt mix types were placed on the project, please select all that apply.	Percentage	Count
Asphalt Base/Binder	9%	9
Asphalt Surface	85%	82
Level/Wedge	7%	7

5. How many loads were received on the project for the day? If multiple asphalt mixes were placed, please separate loads by mix type.

47
38
16
34
66
24
1
1

20
8
20
18
2
7
13
11
2
6
3
25
29
12
67
1
5

29
29
29
59
37
37
38
54
13
8
80
45
26
43
52
17
22

46
9
52 loads
24 loads
33 loads
64 loads
9
9
12
8
6
Surface-40
Surface- 19 Loads
34
30
52 loads
52 loads surface

Level & Wedge 76-22
Level & Wedge 76-22 38 loads
29
45
38
57
81
Mix- CL2.38 D SURF 64-22 Loads- 66
Product- LW38D64 23 Loads
52
49
66
55
75
53
30
68

31
33
34
52
78
69
85
34
60 Loads
45
47 loads
38 loads of surface.
39 loads of surface. On 06/30/22
28 loads of surface and 7 loads of Level & wedge.
38 surface and 3 L & W.
10
1 load - Base, 1 load - surface

17
301 mix 14 loads
41
41

6. How many tons were placed on the project for the day? If multiple asphalt mixes were placed, please separate tonnage by mix type.

688.93
744.7
358.57
845.29
1690.25
613.98
25.64
26.24
513.51
207.65
514.38

441.05
51.69
185.96
339.71
289.74
52.33
154.57
79.4
638.28
736.72
761.17
1229.01
10
125.64
726.19
725.62
709.69

1478.62
924.76
946.76
972.69
1333.74
325.73
202.03
1990.07
1130.95
653.50
1080.07
1295.44
429.53
549.43
1166.07
231.82ton
1311.05ton

607.79ton
834.54ton
1621.36tons
213.28
213.28
296.00
204.28
152.40
Surface-1015.31 Tons
Surface- 466.46 Tons
845.29
739.06 tons
1319.75 Tons
1325.30 tons CL3 0.38A PG64-22
916.10 tons.
847.47 tons.
729.94

1144.77
962.50
1451.99
2050.76
Mix- CL2.38 D SURF 64-22 Tonnage- 1703.59 tons
Product- LW38D64 574.69 Tons
1311.89
1243.69
1602.26
1350.03
1914.21 tons
1,349.56 Tons
762.87
1,723.25 Tons
752.07
841.33 tons
853.12 tons

1,319.04 tons
1992.25 tons
1,761.64 tons
2165.62 Tons
871.75 Tons
1,526.99 Tons
1,143.81 tons
1187.61 tons
929.83 tons of surface.
951.23 tons of surface mix.
181.12 ton L & W and 669.01 ton of surface.
912.82 surface and 62.21 L & W.
255.51
20.22 tons Base, 26.5 tons Surface
429.74
338.16
1024.43

1024.43

7. How much time (in minutes) was spent during the shift collecting tickets in the traditional method (i.e., receiving paper ticket from the haul vehicle driver)?

18
12
15
120 min
55 min
15 min
15 min
55 min
38 min
45 min
55 min
20 min
40 min
45

55 min
20 min
40 min
20 min
10
10
10
10
5
None
None
None
None
None
None
11
11 hours

None
None
None
None
None
None
None
None
None
None
None
5
50
35
45mins
90mins
None

None
None
None
None
30 Minutes
30 minutes
120 min
120 minutes
13 hours
8 hours
No tickets collected after the first one to verify the correct mix.
No tickets being collected after the first one to verify the correct mix. Foreman is called to verify tonnage during paving operations.
None
None
None
None
None

66 minutes
25
None
None
540
0
None
None
None
None
90
90
None
None
None
None
None

None
None
None
None
30 minutes
2 minutes per load/ticket.
2 minutes per load/ticket.
Approximately 70 minutes to collect all the tickets for today’s production.
2 minutes per truck average.
15
5
20
4hrs
0
0

8. How much time (in minutes) was spent during the shift reviewing tickets utilizing the selected e-ticketing system for the project?

4
3
5
4 min
3 min
1 min
2 min
2 min
2 min
2 min
2 min
2 min
3 min
3 min
4 min
2 min

3 min
2 min
0
29
0
0
0
2 minutes
None
None
10
10
10
0
0
10
5

5
20
10
10
10 minutes
10
5 minutes
10
30 minutes
1
40
20
30min
60mins
15
2 minutes
5 minutes

5 minutes
10 minutes
0 Minutes
0 Minutes
2 min
2
5 minutes
5 minutes
No access to real time tickets in the field.
I have no real time access to tickets in the field.
10 minutes
10
20 minutes
15 minutes
20 minutes
Zero minutes
None

30 minutes
25
0
10
30
40
30
30
1
1
30
30
30
30 minutes
30 minutes
30 minutes
30 minutes

30 minutes
1 minute
Less than a minute
No real time access to tickets.
No access to real time tickets.
0 no access to real time tickets.
No access to real time e-tickets, I have to wait on contractor to email them
2
<1
5
1hrs
30
30

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