Redefining Construction As-Built Plans to Meet Current Kentucky Transportation Cabinet Needs

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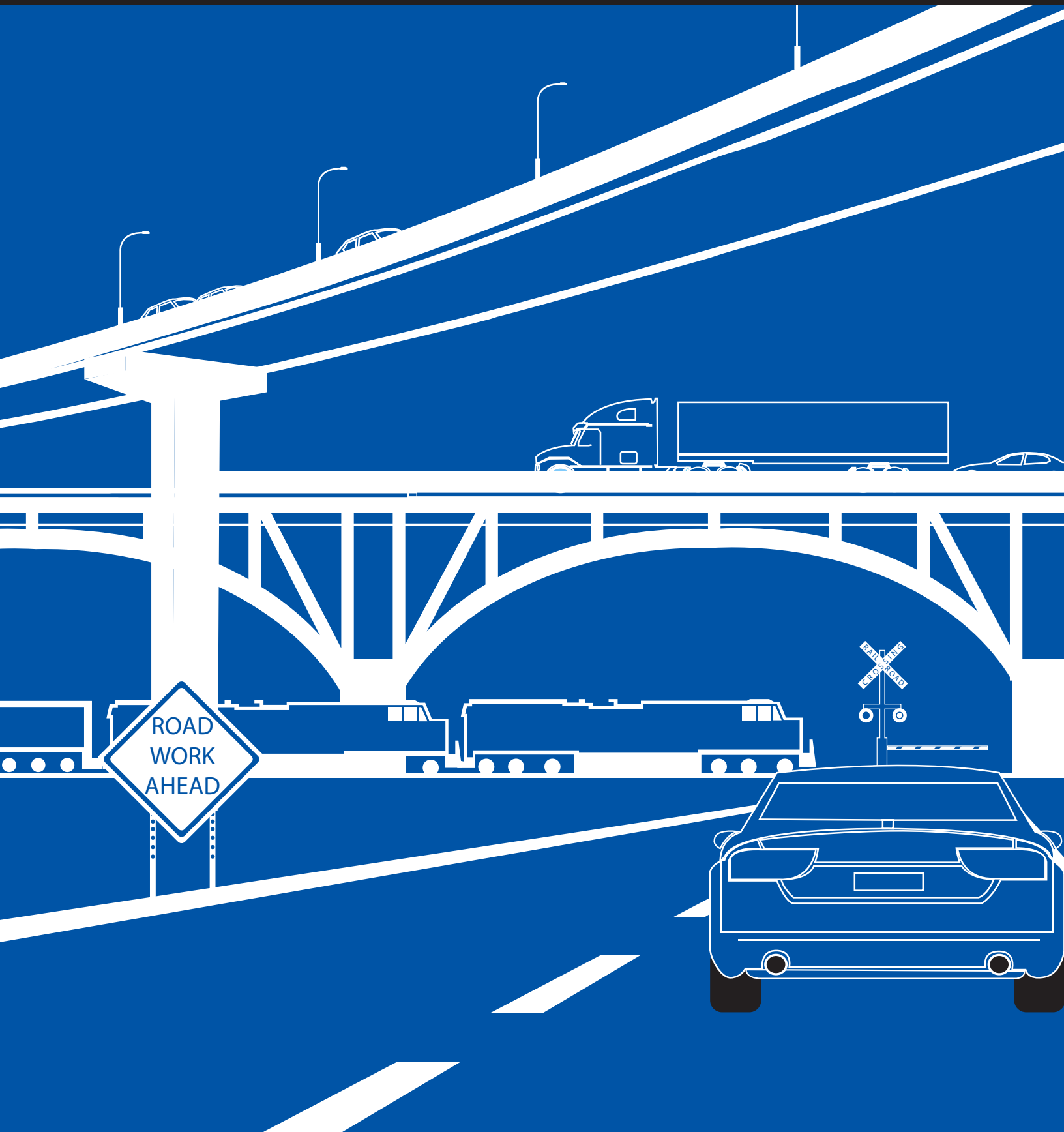

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College of Engineering, University of Kentucky, Lexington, Kentucky

in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

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Research Report
KTC-19-10/SPR18-555-1F

Redefining Construction As-Built Plans to Meet Current Kentucky Transportation Cabinet Needs

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16. Abstract

As-built plans have traditionally been used by construction industry practitioners to record changes made during construction. As-builts provide valuable information for new design projects as well as rehabilitation and remediation projects. The completeness and accuracy of these plans are essential for transportation industries and their success. While the importance of as-builts is widely recognized, preparing them can be difficult and time-consuming; many entities — especially public agencies — lack the resources necessary to produce accurate and detailed as-builts. After investigating the current as-built operations of state transportation agencies, Kentucky Transportation Center (KTC) researchers devised recommendations to improve the Kentucky Transportation Cabinet's (KYTC) as-built process. To develop their proposed process, researchers conducted in-depth interviews with as-built end users and developers. Along with describing the proposed as-built process, this report outlines a number of suggestions for improving current practices. First, it is imperative to preserve all as-builts in a central storage location that can be accessed by all stakeholders. The Cabinet will also benefit from guidance which standardizes the production of as-built plans/information and specifies what should be included in them. To ensure they are completed on time and accurately, as-built plans should be developed continually throughout the project using simple editing software on iPads. A PDF editor is ideal for as-built development as most end users prefer as-builts in a PDF format. Finally, to ensure this process is being followed, assigning a liaison to serve as a go-between to coordinate the activities of as-built developers and users is recommended.

17. Key Words as-builts, construction plans, construction management, design-construction integration, project documentation		**18. Distribution Statement** Unlimited with approval of the Kentucky Transportation Cabinet	
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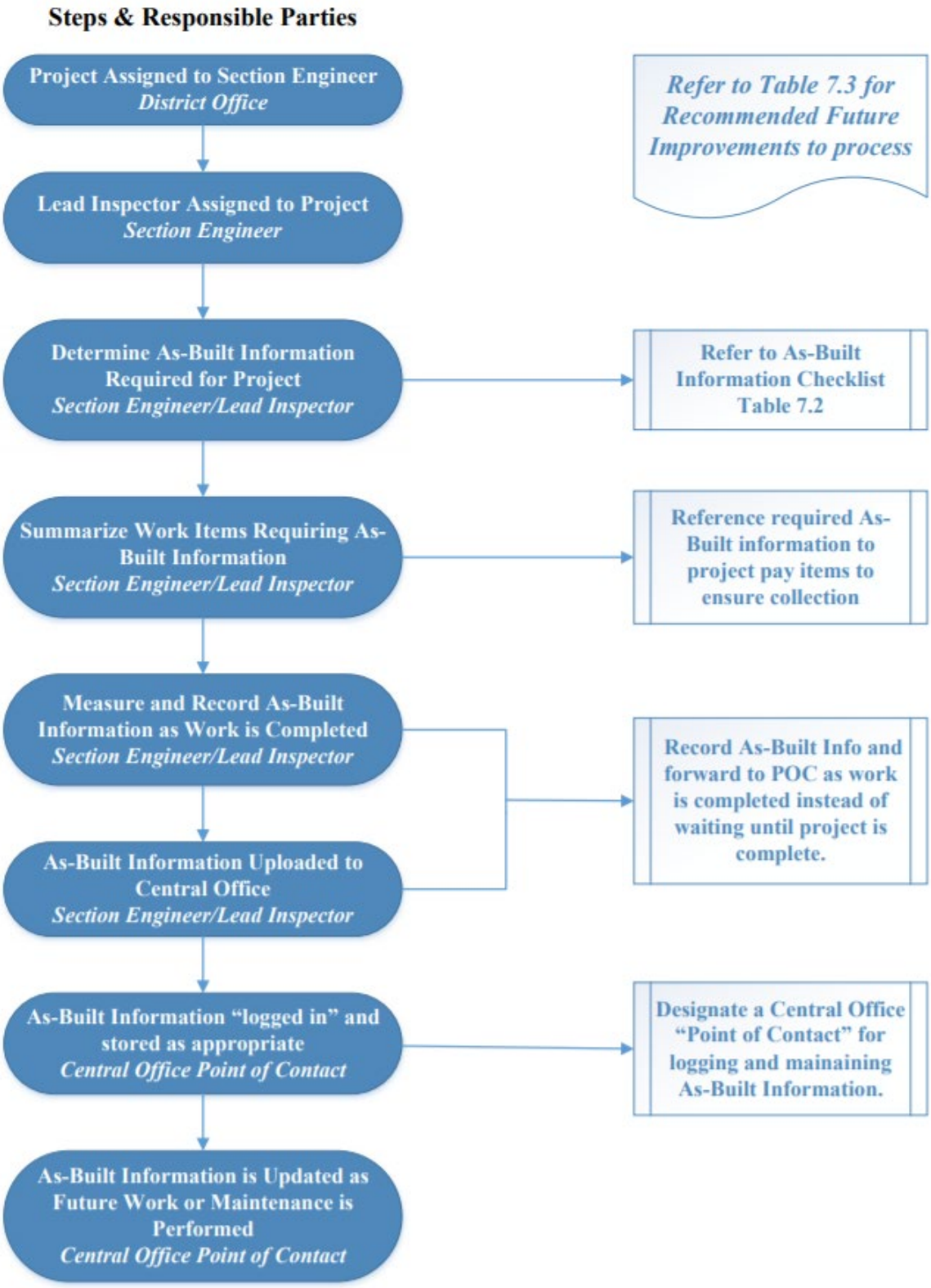
Executive Summary

Having accurate and complete as-built plans is critical for the Kentucky Transportation Cabinet's (KYTC) efforts to plan maintenance activities, future improvements, and design new projects. As-builts provide a wealth of information on transportation infrastructure and nearby facilities. (e.g., utilities located above- and belowground). Unfortunately, the emphasis on producing timely and accurate as-built plans has waned over the years. This has resulted in the Cabinet being reliant on outdated and ineffective practices for developing, maintaining, and storing as-builts. Approaches used to prepare as-built plans vary among Section Offices and are often haphazard and inconsistent. The current process for developing as-builts is also very time-consuming, and Section Offices lack the resources necessary to complete these tasks.

With KYTC engineers and technicians having access to many technologies (e.g., GPS, Lidar) not available when the current as-built process was established, it is now possible to easily develop informative, highly accurate, and consistently formatted as-builts. To develop recommendations for improving KYTC's as-built process, researchers at the Kentucky Transportation Center (KTC) reviewed and then synthesized practices used at other state transportation agencies for preparing as-built plans. Researchers also spoke with as-built developers and end users within the Cabinet to better understand the current as-built process and identify what those agency stakeholders believe are the most important steps that can be taken to improve the situation. Based on stakeholder input, researchers developed recommendations for a revised as-built process that were then presented at a workshop bringing together end users and developers with diverse subject-matter expertise. Leveraging feedback from this workshop, researchers finalized the proposed as-built process, which is summarized in the figure and table contained on the next two pages of this summary. The goal of the new as-built process is to bring about much-needed changes and to achieve standardization in how as-builts are developed throughout the Cabinet. Once formalized, KYTC will need to explore training options to facilitate implementation.


Steps & Responsible Parties
Project Assigned to Section Engineer
District Office
Lead Inspector Assigned to Project
Section Engineer
Determine As-Built Information Required for Project
Section Engineer/Lead Inspector
Summarize Work Items Requiring As-Built Information
Section Engineer/Lead Inspector
Measure and Record As-Built Information as Work is Completed
Section Engineer/Lead Inspector
As-Built Information Uploaded to Central Office
Section Engineer/Lead Inspector
As-Built Information "logged in" and stored as appropriate
Central Office Point of Contact
As-Built Information is Updated as Future Work or Maintenance is Performed
Central Office Point of Contact
Refer to Table 7.3 for Recommended Future Improvements to process
Refer to As-Built Information Checklist Table 7.2
Reference required As-Built information to project pay items to ensure collection
Record As-Built Info and forward to POC as work is completed instead of waiting until project is complete.
Designate a Central Office "Point of Contact" for logging and mainaining As-Built Information.

Step	Responsible Party	Action Items		
		Current Responsibilities	Proposed Responsibilties	Future Improvements
1	District PD&P	Project Assigned to Section Engineer's Office	Project Assigned to Section Engineer's Office	N/A
2	Section Engineer	Project assigned to Lead Inspector	Project assigned to Lead Inspector	N/A
3	Inspector/Section Engineer	N/A	Project Work Types summarized accorind to "pay book." Automated from SiteManager	Within the planset produce a summary sheet (or note for proposal-only) listing "Work Items Requiring As-Built Information"
4	Inspector/Section Engineer	N/A	Determine As-Built information required based on summary of work types	Upgrade to SiteManager highlight Pay Items linked to needed As-built Information. Pay estimate warning to the SE when running an estimate to ensure information is collected.
5	Inspector/Section Engineer	N/A	Refer to As-Built information matrix for information needed, level of detail, and format	Refined through use and evaluation
6	Inspector/Section Engineer	Record As-Built information is recorded within a planset during the project and in closing out the project. As-built plans are submitted to the DO.	Record As-Built Information is collected as specific work types are completed; not at conclusion of the project.	Use of technology aligned to As-built Information required.
7	Section Engineer/District PD&P	As-built plans are checked for completion copied with a District set stored in perpetuity with the originals submitted to CO Division of Construction.	Recorded As-Built Information is forwarded to the proper contacts or uploaded to the appropriate location in ProjectWise. CO is notified of there storage in ProjectWise.	There is substantial confusion regarding the details for checking, scanning, storage, and records retention for as-builts. Currently, the "keeper" of the as-builts is the Division of Highway Design. These processes should be refined and clearly defined for clarity. Recommendations are provided within this report.
8 (present)	CO Division of Construction	As-built plans received are scanned and saved in Project Wise as PDF or electronically submitted as DGNs. As-built plans are sent to CO Division of Highway Design.	As-built plans checked for access in Project Wise as PDF or electronically as DGNs. Division of Highway Design is notified of their storage in ProjectWise.	Revisions are needed to the Records Retention Schedule policy. The process to store and archive as-built inforation should be streamlined and standardized to facilitate an understandind of the information desired and an appropriate storage location for ease of future access.
9 (present)	CO Division of Highway Design	As-built plans are coverted to PDFs, logged into the electronic archived plans GIS application, microfilmed and sent to the State Archives for permanent retention.	As-built plans are coverted to PDFs and logged into the electronic archived plans GIS application. (Requires a revision to the Records Retention Schedule policy)	
8 (future)	CO Point of Contact (TBD, Recommended: Division of Maintenance)	N/A	N/A	As-Built Information verified to be in ProjectWise and uploaded the electronic archived plans GIS application. This is for permanent retention within both systems.
9 (future)	CO Point of Contact (TBD, Recommended: Division of Maintenance)	N/A	N/A	As-Built Information is updated as work is performed. Maintenance, Widening, Rehabilitation, etc. (Requires careful communication & coordination with Districts and Divisions)

1. Introduction and Background

The United States is facing an infrastructure crisis due to the deterioration and failure of its existing transportation infrastructure. The 2017 American Society of Civil Engineers (ASCE) Report Card gave America's overall infrastructure a score of a D+, with road and bridges receiving grades of D and C+, respectively (American Society of Civil Engineers 2017). As engineers begin to rebuild existing infrastructure, as-built plans can provide important insights into the configuration of infrastructure systems.

Historically, as-built plans have been used in the construction industry to capture and record construction changes and additions not represented in the original plan drawings. While the Federal Highway Administration (FHWA) and ASCE have no published definition of as-built plans, the Kentucky Transportation Cabinet (KYTC) defines as-builts as "the final plans reflecting all changes to the original plans" (Commonwealth of Kentucky Transportation Cabinet 2012). The accuracy and completeness of these plans are essential for the operations, maintenance, repairs, and rehabilitation of transportation infrastructure. As-builts also provide a baseline for new design projects by furnishing information on the physical infrastructure and other facilities such as underground and overhead utilities. While the importance of as-built plans is widely recognized, current as practices for developing as-builts are outdated and inefficient. According to a Virtual Design and Construction Engineer and Affiliate Member of ASCE, "Significant losses have been noted because of the difficulty in obtaining information about existing assets, such that over US$5.4 billion is wasted per year on operations and maintenance engineers verifying the accuracy of existing information and transferring information related to existing U.S. capital facilities" (Randall 2011).

Over the last decade, the construction and transportation industries have adopted advanced data collection methods using technologies such as Lidar, 3D information modeling, and ground penetration radar (GPR). These technologies have changed the format, accuracy, and level of detail required for transportation projects, enabling designers to include more accurate information in construction plans. However, the integration of these technologies into the development of as-builts has not been as quick and coordinated, making some information included in traditional as-builts inferior to the information collected with greater accuracy during design stages. While electronic and 3D technologies are becoming the norm for engineering practitioners, some entities still choose to draw as-built information by hand onto original construction plans.

At KYTC, the Section Engineer's Office is responsible for preparing as-built plans. This process is initiated after project completion. According to the 2009 edition of the *KYTC Construction Guidance Manual*, as-built plans are sent to the Division of Highway Design Microfilm section (which no longer exists) for review and are then transferred to the Department of Library and Archives for microfilming and permanent storage. Original as-built hard copy plans are then stored pursuant to their record and retention schedule (Commonwealth of Kentucky Transportation Cabinet 2009). While this process is clearly defined in the *Construction Guidance Manual*, the emphasis on preparing accurate as-built plans on time has gradually waned, and the process has evolved beyond what is stipulated in procedure and guidance. Available time, current resources, and new technologies have made the completion of as-builts challenging and different from how they were assembled in past decades. The current as-built process is time consuming, and section engineers lack the resources required to create accurate and complete as-builts in a reasonable amount of time. Also, new technology has changed the

format, accuracy, and level of detail considered for as-builts. As such, KYTC's current practices for developing as-builts need to be revised to ensure they are developed on time and provide the information needed by the KYTC end-users of as-built information.

A Kentucky Transportation Center (KTC) research team was assembled to address three tasks related to as-built plan development at the Cabinet. First, our team was to synthesize current practices at KYTC. To produce this synthesis, we conducted structured interviews with as-built end users and as-built developers. Structured interviews with as-built end users focused on what information they require of as-built plans, their preferred format for as-builts, and where as-builts should be stored. A structured interview with as-built developers focused on the current processes section engineers use to develop as-builts and obstacles they encounter while preparing these documents. Next, we examined practices at other state transportation agencies (STAs). Finally, we prepared recommendations to inform future procedures and practices related to as-built plans and information at KYTC.

This report examines current as-built practices at STAs and the private industry through a literature review and an in-depth study of KYTC. This document contributes to the existing body of knowledge by 1) studying current practices for developing as-built plans in the transportation industry, 2) identifying information as-built end users need to effectively manage road transportation networks, and 3) discussing the methods as-built developers can use to gather such information. Combining the information gathered on current practices and requested information, the report advances suggestions on data capture methods to procure such information while attempting to understand and maximize the resources available to as-built developers.

1.1 Project Scope and Objectives

The project scope was limited to an analysis of information gathered from published literature and structured interviews, with a focus on the needs and improvement of the as-built information collection and storage process at KYTC. The report:

- Synthesizes current practices at the Cabinet for preparing, distributing, and storing as-built plans;
- Summarizes the efforts and requirements of other STAs, to articulate an industry standard for how as-built plans are currently developed and used;
- Develop recommendations for developing and distributing as-built information at KYTC in the future; and
- Based on collaborations with Project Development and Project Delivery subject-matter experts, presents a design a process for collecting, developing, and distributing the newly defined as-built information.

The report highlights current practice so that efforts can be made to fill research gaps and establish a path to improvement. Some issues facing as-built development at KYTC include: IT challenges, a lack of technical staff, a lack of management support, uncertainty on where to begin, and insufficient technological resources.

1.2 Research Methodology

Primary data came from structured interviews with as-built developers and end-users at KYTC. During interviews, researchers asked respondents about as-built development, preservation, and usage for various delivery methods. The literature review focused on as-built development,

preservation, and use. Findings from the literature review informed the development of interview questions. Much of this review concentrates on publicly available manuals and guidance that outline as-built practices at STAs. But it also includes a review of as-built practices used throughout private industry. Following completion of the literature review and interviews, researchers organized a collaborative workshop with developers and end user subject matter experts to review and revise recommendations the team had devised.

1.3 Report Structure

Chapter 2 summarizes the literature review. Information presented in the literature review came from an examination of approaches and practices related to as-builts used adopted by STAs and private industry stakeholders. Chapter 3 discusses our interviews with KYTC as-built end users, while Chapter 4 turns our discussions with KYTC as-built developers. We developed interim recommendations based on analysis of these interviews; they are presented in Chapter 5. The interim recommendations were presented, discussed, and revised with an as-built task force. The formation of the task force and its participation in shaping the ultimate conclusions of this project are discussed in Chapter 6. Chapter 7 presents recommended as-built procedures, enhancements, and potential policy actions for KYTC to consider. These items are classified into two categories: short- and long-term strategies. Chapter 8 highlights conclusions from the research effort and suggests future research topics. The remainder of the report (appendices) contain supplemental documentation supporting the methodology and research findings.

2. Literature Review

The literature review focuses on methods used by STAs and other engineering and construction firms to conduct as-built operations. Focal points of the review include: entities responsible for as-built development, methods used to capture and record as-built information, platforms used to establish as-built plans, information recorded on as-built plans, accuracy and usefulness of as-built plans, format and location of as-built plans storage, and the use of as-built plans following approval.

2.1 As-Built Practices in State Transportation Agencies

We reviewed the current practices all 50 STAs to create a snapshot of how agencies deal with as-builts. Forty-two STAs document as-built related practices and requirements in manuals or specifications. This synthesis contains information on as-builts from 17 STA specifications, 28 construction manuals, 7 design manuals, and 8 other manuals and guides found on agency websites. The data summarized below are based on publicly available guidance. In some cases, current agency practices may differ from what has been captured here. Table 2.1 summarizes documented as-built practices for each STA. Appendix A links to the publicly available STA materials we relied on in assembling this synthesis..

Table 1 State Transportation Agencies' As-Built Practices

STA	Entity Responsible for As-Built Development	As-Built Development Process	Format of Stored As-Builts	Storage Location of Completed As-Builts	Additional Comments
AK	Project Engineer[1]	Updated by hand and either copied to mylar or used to redraft original drawings	Hard copy prints		Changes should be made immediately on as-built plans
AZ	Construction Administrator and As-Built Designer[2]	Three methods: (1) updated by hand and scanned to PDF, (2) updated electronically, or (3) updated by hand and transcribed electronically using Microstation or Adobe	PDF	ADOT Information Data Warehouse and Engineering Records	A 5-10 minute weekly recording driving through the site results in video as-builts.
CA	Resident Engineer and the District Design Unit or a consultant[2]	Full size drawings updated by hand or by a field CAD system then transferred to original CAD files by Design Unit or consultant.	TIFF file and microfilm	Document Retrieval System	
CO	Project Engineer[1]	Copy of original plans revised using Microstation, Redline Software, or similar software.	Hard copy prints and electronic	Electronic copies are retained by the Resident Engineer and hard copies are distributed.	
CT	Chief Inspector and/or Designer[2]	District Management decides how as-builts are developed and by whom.	PDF	ProjectWise	Field personnel may not attempt to maintain digital as-builts unless trained. Working as-builts must be updated monthly.

Table 1 (continued)

DE	Resident Engineer/Project Supervisor[1]	Updated by hand with a red pencil. These plans are used to update original construction plans.	Hard copy prints		As-builts must be kept up-to-date
FL	Project personnel and the District Finals Estimate Office or consultant[2]	Updated electronically. Project personnel mark changes in red, while the overviewer makes comments in green.	PDF	Electronic Document Management System.	As-built plans shall be updated as the project progresses.
GA	Project Personnel under the supervision of the Construction Manager[1]	Updated by hand in red and scanned.	Electronic	ProjectWise	
HI	Contractor[3]	Updated by hand. Changes are made with a red pencil and notes are made with a blue pencil.	Hard copy prints		Must be submitted to an engineer once a month for review.
ID	Resident Engineer or Contractor[4]	Plans should be updated using CAD if CAD was used to prepare the original project plans.	PDF	File360 Image Database	As-builts must be kept up-to-date throughout the duration of the project.
IL	Resident Engineer[1]	Updated by hand.	Microfilm	Microfilm Unit	
IN	District Office[1]		Hard copy prints or microfilm	Appropriate District Office	

Table 1 (continued)

IA	Project Engineer[1]	Full-size plans updated by hand or electronic plans updated using Spicer Imagination Software.	Hard copy prints or electronic	Records Management for hard copy prints or Electronic Record Management System for electronic plans.	A consultant is hired to complete as-builts for wetland projects.
KS	Field Engineer and Bureau Chief of Road Design[1]	Updated by hand with black ink and used to update the original tracings.	Hard copy prints	District Office Files	As-builts must be kept up-to-date.
KY	Section Engineer[1]	Updated by hand.	Microfilm	Department of Library and Archives	
LA	Project Engineer[1]	Updated by hand with red pen or pencil.	Hard copy prints		Operations and Maintenance Manuals shall contain certified as-built plans.
ME			Electronic	E-Plans Archive on MaineDOT Intranet Page	Project is not considered complete until as-builts are complete.
MD	Project Engineer[1]	Updated by hand in green. May be scanned if all groups agree.	Hard copy prints or electronic if approved		As-built changes should be recorded on a daily basis.
MI	Resident/Delivery Engineer[1]	Updated by hand with black ink or in CAD.	PDF	ProjectWise	
MN	Project Engineer[1]	Updated by hand in ink.	Microfilm		Information applies to as-builts for bridge projects.
MS	Project Engineer[1]	Half-size plans are updated with red ink.	Hard copy prints		

Table 1 (continued)

MO	Resident Engineer[1]	Should be updated using Microstation. If Microstation is not used, black ink or mylar pencils must be used.	CD		
MT			Hard copy prints or electronic	MDT Central Office if not available electronically	
NE	Consultant or Project Manager[2]	Full-size plans are updated with black ink. Half-size copies are made for districts.	Microfilm		
NV	Construction Field Crew[1]	Updated by hand with blue ink and scanned.	Hard copy prints and electronic.	Hard copy prints are stored in the District and Head Quarter Offices. Bridge project as-builts are stored in Central Records.	Survey crew chief adds survey information to as-builts. As-builts must be updated as the project progresses and they must be submitted to begin the final payment process.
NJ	Resident Engineer and Designer[2]	Updated by hand with red pencil then transferred to project mylars.	Mylars	Document Control	
NM	Contractor or Contractor's personnel[3]	Full-size plans updated with black ink.	Electronic and hard copy prints if electronic survey data are provided. If not, just hard copy prints.		As-built plans should be kept current.

Table 1 (continued)

NY	Regional Construction Engineer or Designee and Regional Construction Group[1]	Updated by hand and used to develop final as-builts in CAD.	PDF	ProjectWise	May develop final as-builts by hand based on availability of trained staff.
ND	Project Engineer[1]	Updated by hand or electronically with changes made in blue.	Microfilm		
OR	Project Manager[1]	Updated by hand in red then scanned.	PDF	FileNet	
PA	Department or consultant[2]		PDF	Electronic Document Management System	
SC	Resident Construction Engineer or Contractor[4]	Updated by hand or in CAD in red.	Hard copy prints or electronic	Plans Library	One copy of as-builts should be sent to the local Resident Maintenance Engineer. Plans shall be kept up-to-date. As-built checklists must also be submitted.
UT	Contractor[3]	Updated by hand in red and scanned or used to modify the original CAD files.	Electronic	ProjectWise	As-builts should be discussed in the preconstruction conference. Resident engineer should also keep track of changes. Utility as-builts are maintained by utility companies.

Table 2. 1 (continued)

VT	Resident Engineer and Finals Room Supervisor or their Designee[1]	Updated by hand in red ink and scanned or used to modify the original CAD files.	Hard copy prints and CAD or TIFF files	Digital Print Room	Changes should be recorded as they are made.
VA	Inspector[1]	Updated by hand and used to develop CAD files.	CAD file	Central Office Structure and Bridge File Room	If no changes are made, as-builts are not required and a letter can be sent to the District Structure and Bridge Office stating the project was built as bid.
WA	Project Engineer[1]	Full-size plans updated in red ink.	PDF	Oracle Content Management System	
WI	Project Leader[1]	Updated in red using Adobe Acrobat or equivalent Adobe software.	PDF	DOTView Image Drive	Changes must be made as the project progresses.
WY					As-built summaries must be included in as-built plans. Utility as-builts must go to the District Maintenance Technician.

[1] In-House completed as-builts
[2] In-House or design consultant completed as-builts
[3] Contractor completed as-builts
[4] In-House or contractor completed as-builts

We classified entities responsible for developing as-builts for STAs into one of four categories: in-house completed as-builts, in-house- or design consultant-completed as-builts, contractor-completed as-builts, or in-house- or contractor-completed as-builts. Thirty-five states identify the entity responsible for developing as-builts. Figure 2.1 summarizes our findings. At 23 STAs in-house employees create as-builts; 7 have in-house personnel or design consultants prepare as-builts; 3 have contractors produce as-builts; and 2 agencies list in-house personnel or the contractor as responsible for composing as-builts.

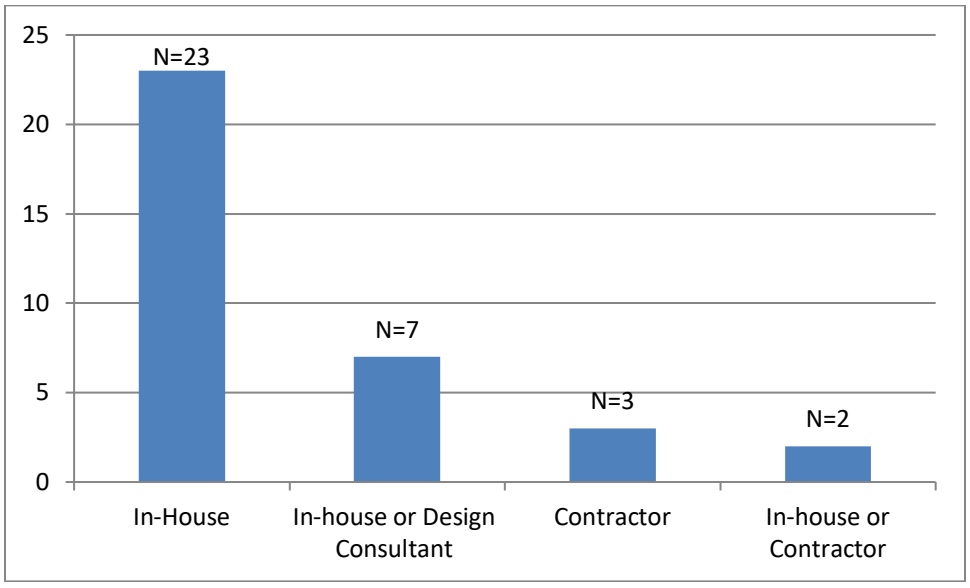


Figure 1 Entity Responsible for As-Built Development for STAs

While only 5 STAs list the contractor as the lead for as-built development, 19 agencies require contractors to develop some type of as-built drawings despite not being identified as the party responsible for as-built production. Most of these additional contractor-created as-builts are for specialty items such as electrical work, irrigation systems, or water and sewer systems (or other utilities installed by the contractor). However, in Colorado and Connecticut the contractor generates complete project as-built drawings to assist the responsible party in completing the official as-builts (Colorado Department of Transportation 2017, Connecticut Department of Transportation 2017). Table 2.2 lists what types of as-builts contractors are responsible for at each STA.

Table 2 Contractor Created As-Builts

STA	Contractor Created As-Builts
AL	Utilities
AK	Specialty items such as electric and structures
AZ	Survey information
CA	Irrigation systems, prestressed concrete structures, and electrical wiring diagrams
CO	All changes and deviations
CT	All changes and deviations
FL	Intelligent Transportation Systems (ITS), signals, conduits, and lighting
GA	Water and sewer facilities

IL	Electrical work
IN	Permanent earth retention systems and wiring diagrams
KS	Survey Information
MS	Roadway lighting systems and centerline elevations
NH	Inductive loops
NJ	Water, sewer, gas, highway lighting systems, ITS, fiber optic cables, and traffic signal systems
NC	Utilities and buried electrical circuits for roadway lighting systems
OR	Irrigation systems
VA	Topographic survey information
WA	Corrected shop drawings, schematic circuit diagrams, or other drawings necessary to help prepare final as-builts
WV	Drilled caisson as-builts, as-built utility surveys, and as-built shop drawings

While as-built plans have been the method used to document changes during construction projects for several decades, the processes and methods used to capture as-built information are continuously changing as new technologies emerge. Recently Lidar, information modeling, and GPS technologies have transformed how the transportation industry collects data and develops plans; use of these technologies results in more accurate and detailed plans. While some construction firms and companies use these technologies for as-built development, according to published manuals, several STAs are not. We retrieved information on the methods used to record as-built information at 33 STAs. According to publicly available guidance, 21 STAs still require the initial set of as-built plans to be developed by hand. Several STAs then scan or copy these initial as-builts and convert them to electronic file formats such as PDF or CAD. Eight STAs permit the manual or electronic development of as-builts; only four STAs require that as-builts be developed electronically from a project's outset. Our findings are summarized in Figure 2.2. See Table 2.1 for the processes used to record as-built information at the 33 STAs that have documented their practices in publicly available manuals.

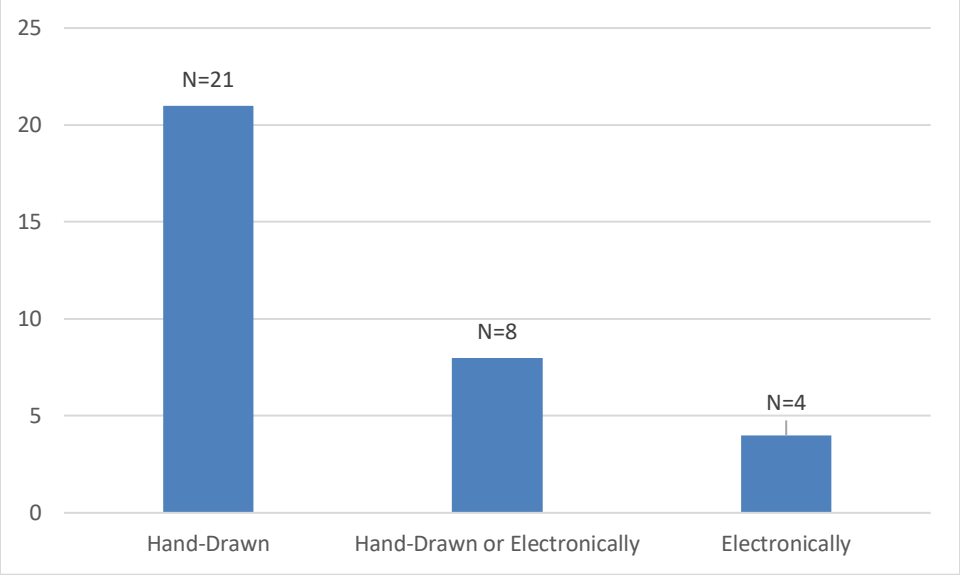


Figure 2 Method Used to Record As-Built Information for STAs

We also examined how agencies store as-builts. Information was available for 37 states. Formats were grouped into five categories: microfilm, hard copy prints, electronically stored plans, multiple formats, or varying format options. The breakdown is as follows: 5 STAs store as-builts as microfilm, 7 store as-builts as hard copies, 15 store as-builts electronically, 5 require the storage of as-builts in more than one format, and 5 provide a variety of options for as-built storage. Figure 2.3 illustrates these results.

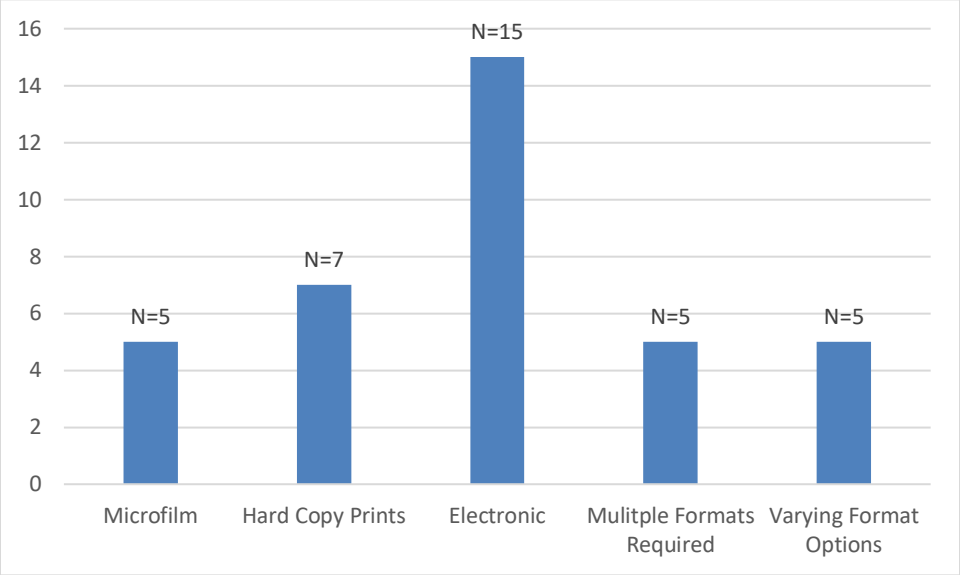


Figure 3 Format of Stored As-Builts for STAs

Ten STAs that store as-built plans electronically require they be in PDF format. In addition to its PDF as-built plans, the Arizona Department of Transportation captures a five- to ten-minute video recording of project sites each week. Recordings serve as video as-builts of a project. These unofficial video as-builts document the progression of work in a time-lapse fashion by displaying the changing positions of equipment, personnel, material, and construction (Arizona Department of Transportation 2015).

The location where as-built plans are stored refers to the storage format. Most STAs that are storing as-builts electronically preserve them in Electronic Document Management Systems (EDMS), while storage locations for the other formats vary by STAs. Table 2.1 contains further details on formatting and storage location for each agency.

If as-builts are to be useful in the future, it is imperative to identify what information about the project operators, maintenance crews, designers, and others will need. To accomplish this, ideally, the individuals or entities responsible for maintaining the facility or infrastructure would have a say in what information is included in as-built plans (Whyte et al. 2016). Several agency manuals and specifications detail what information should be recorded on as-built drawings. Some common required revisions recorded on as-built plans across STAs include:

- Changes in horizontal and vertical alignment
- Grade revisions
- Corrections and adjustments to stationing
- Changes in typical sections

- Utility locations, depths, elevations, offsets, and clearances
- Changes to right-of-way lines, distances, and markers
- Changes to drainage structures such as length, flow line elevation, station or offset dimensions, sizes, thicknesses, and types of inlets and manholes.
- Location and elevation of monuments, benchmarks, freeway fences, and gates
- Locations and dimensions of all structures
- Foundation elevations and subsurface structural details

2.2 As-Built Practices in the Private Industry

Information provided in STA construction manuals, design manuals, and specifications provide insight into how as-builts should be developed and appropriate storage techniques. However, most of these documents lack specifics on the handover of as-built plans from developers to potential users, or how they are used after completion. The process of developing and storing as-builts according to guidance, and accessing them several years later, may not be an issue with hand-drawn as-builts developed according to agency standards. However, given the changing technological landscape and the lack of attention to detail often paid in as-built development, it is critical to develop protocols which communicate the accuracy of as-builts as well as handover methods for getting as-built plans from developers to end users. A review of private industry as-built practices offered insights into the importance of communication between as-built developers and end users during the as-built development process. It also highlighted the potential for 3D technologies, such as Building Information Modeling (BIM) and Lidar, in as-built development (Randall, 2011). No STA mentioned the use of these technologies in their publicly available manuals and guidelines.

As technology improves and as-builts become digital and more detailed, the handover process will grow in complexity. The transfer of as-built data will require "attention to sequence, timing, passing technique and communication within a time-constrained window of opportunity" (Whyte at el. 2016). Improving the transfer of as-built information will enable owners, operators, maintenance workers, designers, and any others who will need as-built information in the future to better manage and maintain the infrastructure. This can require meeting with all current and future project teams to discuss the handover procedure and what data each group needs at the end of construction. The handover phase must be planned and practiced before it arrives (Whyte at el. 2016). The Utah DOT practices such a handover method. Contractors and engineers participate in a preconstruction conference where the engineer clearly defines what they expect of as-builts for a project (Utah Department of Transportation 2016). Without proper and planned transfers, information is likely to be lost or misinterpreted.

Timing handovers correctly is arguably the most important aspect of the handover process. If insufficient time is allotted for handovers, mistakes are more likely to be made. The physical act of handing over as-built data can only occur once a project is complete and all information has been updated. However, the build-up to handovers should begin during the design phase. This involves continually updating plans and digital data to reflect as-built conditions throughout the project. If changes to a project are not recorded until its end, as-builts are often rushed and mistakes are likely to creep in (Whyte at el. 2016). Fourteen STAs require the update and maintenance of as-builts throughout a project's duration. Information on which agencies require continual updates can be found in the *Additional Comments* column of Table 2.1.

Another major challenge in data handover is the accuracy and completeness of the data collected. In the past, as-built plans have been developed through an error-prone manual process (Abdel-Monem and Hegazy, 2013). As-builts often consist of hundreds of plan drawings of unknown accuracy (Randall, 2011). However, if as-built data are to be trusted for use in decision making, it is imperative they be accurate and of the highest quality. Because of the potential for inaccuracies, as-built information is often not used even when available (Whyte et al. 2010). For example, when asked about the trustworthiness of data on built infrastructure an Olympic Delivery Authority grounds work and services manager commented, "Unless you're really on top of it, once the data is no longer trusted people stop using it and then it just is a waste [and] completely falls away" (Whyte et al. 2016). Few STA guidance documents mention the required accuracy of as-built plans. Most only contain vague descriptions (e.g., "The as-built plans should be carefully and accurately prepared."). The Connecticut DOT requires that field personal receive training from engineers before they develop electronic as-builts to ensure accuracy, high quality, and consistency (Connecticut Department of Transportation 2017).

Technological advancements will facilitate improvements in the quality and accuracy of as-builts. BIM is a 3D representation of a facility's physical and functional features. As of 2011, nearly half of the architecture, engineering, and construction sector used BIM. It offers several benefits over traditional 2D designs, such as improved life cycle management of buildings. Laser scanning technologies perform thousands of measurements per second in 3D coordinates of a designated area. The 3D surface model created by these scans is significantly more accurate than traditional surveys. By combining BIM with laser scanning technologies, as-built conditions can be accurately captured and fully represented in a 3D model and updated as a project moves forward. When a project is complete, the project site should be scanned and transferred to the as-built BIM file to assist with facility management (Randall 2011).

Another technology that could potentially benefit as-built development is Interactive Voice Response (IVR). A case study analyzed this technology and suggested next steps to implement it on a larger scale (Abdel-Monem and Hegazy 2013). An IVR system was used to collect project data from supervisors each day (or more frequently if initiated by the supervisor). The system called the supervisors at the end of the workday and asked if any work has been completed. Based on the supervisor's response, the system posed follow-up questions, such has what percentage of the expected daily work was completed; the supervisor could also leave comments. The system then sent an e-mail to the project e-mail account with the information recorded during the phone call. Finally, a reporting tool logged all communication and updated the schedule. For this case study Ifbyphone, Microsoft Office, and Microsoft Project were used as the IVR system, e-mail tool, and scheduling tool, respectively. Individuals participating in the case study stated the system was easy to use, had high sound quality, and was practical. But they also mentioned challenges, including the potential issues of construction noise on sound quality and having less time to think about answers when being asked over the phone. This case study used the IVR system to track progress of the project. Future steps on the project included adding as-built information such as changes to materials and dimensions to the IVR system (Abdel-Monem and Hegazy 2013).

The literature, guidance, and policy we reviewed indicates new strategies and approaches are needed to improve the creation, storage, and use of as-builts. The emergence of these new methods may signal that the era of marking up construction award/record plans by hand is coming to an end. With the use of technology and the needs of end users evolving, they require

as-built information in a different form and format. A better understanding of the needs and next steps were derived from interviews with KYTC subject-matter experts.

3. Kentucky Transportation Cabinet End User Interviews

We conducted structured interviews with representatives (i.e., engineers and technicians) of six end user groups at KYTC. Included among the interviewees were three engineers and one technician from Bridge Maintenance, two engineers from Pavement Design, two engineers and one technician from Highway Design, four engineers and one technician from the Structural Design/Geotechnical Division, one engineer from Utilities, and one engineer from Permits. We posed the same interview questions to members of the six groups. They were:

- How are you currently using as-builts when designing/preparing bid plans and proposals?
- How are as-builts currently delivered to your work area?
- What would a perfect-world set of as-builts look like?
- How important do you feel as-builts are to the project development process?
- How do you think the as-built process can be improved and is there anything you would like to add that we have not asked?

As interviews progressed, we asked end users more specific questions about their as-built needs.

3.1 Current Uses

In response to our question about how as-builts are currently being used, the consensus was that as-builts are rarely used. Interviewees cited a number of reasons for this:

- As-builts are not being completed,
- As-builts are unreliable or of unknown accuracy,
- New technologies for collecting field information supply better quality and accuracy than hand drawn as-builts,
- As-builts are not required for permitting, and
- Some end users, such as utilities, are involved too late during design stages to effectively use as-built information.

End users more involved in asset management and maintenance functions noted they attempt to use as-builts, and that when accurate as-builts are available they save time and money. For example, Bridge Maintenance uses as-builts for scour assessments, however, there is currently no indication of their accuracy level. The resultant uncertainty often prompts the use of the most conservative estimates. Of the last 500 scour assessments completed by Bridge Maintenance, as-builts were available for just three projects. When personnel lack as-builts they have no idea of the accuracy of the information, they must take an even more conservative approach when estimating attributes, either increasing inspection frequencies or posting bridges at reduced load limitations, which has negative economic impacts. Pavement Design representatives stated that after using unreliable as-builts they no longer trust the few as-builts they receive. Because of this, they perform more forensics than necessary. Last year the division spent $217,000 on 10 projects that forensically investigated pavement structures. If the as-builts were trustworthy, interviewees felt Pavement Design would only have spent 50% of that amount. For optimal use of as-built information, standards for as-built accuracy should be adopted (e.g., the new ASCE as-built standards indicating quality and accuracy levels).

3.2 As-Built Delivery

According to the Bridge Maintenance and Structural Design/Geotechnical groups, the few as-built plans they receive are delivered via e-mail. Pavement Design representatives stated that any as-builts they find demand time-consuming searches through the KYTC project database system (ProjectWise). As-builts are typically delivered as PDF files.

Most end users believe as-builts should be stored in a central storage location everyone has access to. ProjectWise was the common storage location mentioned by end users but there are multiple file folder locations used for storing as-builts. One engineer suggested only giving a few individuals write access to appropriate as-built folders in ProjectWise; everyone else would have read only access. Most end users prefer storage in a PDF format. Bridge Maintenance, Pavement Design, and Structural Design/Geotechnical preferred red-lined plans, while Highway Design was partial to using Lidar files of the completed project for as-built plans.

3.3 Perfect World As-Builts

Table 3.1 lists what information end users want include in as-built plans. For example, Bridge Maintenance personnel indicated they would benefit from as-builts containing data on pile tip elevations, concrete cylinder breaks, beam seat information, x-dimensions, culvert fill heights, and foundation layouts. Interviewees also suggested the use of as-built plans may be an antiquated approach and that as-built information could be a more appropriate representation of data needs. Table 3.1 also describes current methods used to collect as-built information as well as potential new methods (when known or applicable) that might be used to collect these data. The methods listed as current may not always be standard practice, or the information recorded with these methods may be lost in transition from developers to end users. Shaded cells in the new method column represent areas in which future research is necessary to establish a new method for collecting as-built data or if current methods will suffice. Information noted as being measured indicates that it is measured to tolerances specified within the project specifications. Information noted as being surveyed indicates it is measured to universal accuracy tolerances using total stations or other surveying equipment. Surveys are location-dependent; measurements are not.

Table 3 Summary of End User Requested As-Built Information

End User	As-Built Information Requested	Current Method to Collect and Record Data	New Method to Collect and Record Data
Bridge Maintenance	Pile tip elevations	Pile logs[1]	
	Concrete cylinder breaks	Cylinder break log[2]	
	Beam seat information	Surveyed[1]	
	X-Dimensions	Surveyed[1]	
	Culvert fill heights	Measured[1]	
	Foundation layouts	Surveyed[1]	
Pavement Design	Actual courses placed	Measured[1]	
	Typical sections	Measured[1]	

	Substructure details	Measured[1]	
	ADA tamps	Measured[1]	Mobile Carts and Phone Application
	Intersection grades	Measured[1]	Lidar and/or Photographs
	Maintenance history	Maintenance Database[2]	
	As-Built for proposal only projects	Measured[3]	Lidar and/or Photographs
Highway Design	Right-of-Way Plans	Survyed[1]	Google Earth
	Picture and Lidar Scan of Completed Project	Pictures and GPS Rover[2]	Google Earth
	Basic Project Information	Pictures[2]	Google Earth
Structural Design/Geotechnical	Footing Information	Measured[1]	
	Pile Lengths	Pile Logs[2]	
	X-Dimensions	Surveyed[1]	
	Bearing Details	Surveyed[1]	
Utilities	Subsurface Utility Information	Measured or Surveyed[1]	Use of ASCE 38-02
	Utility Conflict Information	Maintenance Database[2]	Use of SHRP2 R01A
	Alignments, Depths, and Clearances	Measured and Surveyed[1]	GPS/Asset Management Devices/Other Location Devices
Permits	Permitted Facilities shown on As-Builts	Visual Inspection[1]	GPS/GIS Asset Management System
	Scaled Drawings of Permitted Facilities	Hand-Drawn Red-Lined Plans[1]	Red-Lined Plans Using PDF Editor

[1] Recorded on Plans
[2] Recorded in Transportation Enterprise Database
[3] Recorded on Proposal Sheet

3.4 Importance of As-Builts

Interviewees made it clear that the traditional definition of as-builts needs to evolve. Highway Design personnel, for example, indicated that traditional red-line plan set as-builts are no longer relevant when information is available through resources such as Google Earth. However, what they referred to as a post-construction survey is very important to the design process. While each group had different views on the importance of traditional red-lined as-builts, all groups found some form of post-construction information important to them. End users also mentioned that the importance of as-builts depends on their accuracy (no current KYTC standard exists for classifying the information collected). If as-builts are accurate they are

invaluable, however, if they are inaccurate or their level of accuracy is unknown, they are worthless because the information cannot be trusted.

3.5 As-Built Process Improvement

End users provided several ideas for improving the as-built process. All groups agreed that in order to improve the process it is essential that end users are specific about what information they need and the required level of accuracy. This will save time, money and encourage as-built developers to collect the as-built data as needed. Another suggestion was establishing a liaison who serves as a go-between for as-built developers and end users. The Structural Design/ Geotechnical group plans to hire a technician who will help in this regard and organize as-builts according to staff needs. Other suggestions included hiring a licensed surveyor to survey completed projects and developing confidence levels for as-builts. Confidence levels would give end users a rating informing them how confident they can be in the as-builts' accuracy. The confidence level would be contingent on the accuracy level as-built developers achieve while completing the as-builts.

4. Kentucky Transportation Cabinet As-Built Developer Interviews

After interviewing end users and summarizing our findings, we spoke with the four section engineers responsible for preparing as-built drawings. These engineers work in different KYTC districts throughout the state. The section engineers were asked the following questions:

- How often are you currently developing/producing as-built plans on your construction projects?
- Do you feel project managers utilize as-built plans when developing projects? If no, why not?
- What are the biggest obstacles your office face when developing as-built plans?
- Are you currently developing as-built plans electronically?
- How do you think the current process can be improved?
- What would a perfect-world procedure for developing as-built plans look like?
- Do you have anything you would like to add that we have not asked or discussed?

4.1 Current As-Built Development

Interviewees said that all section engineers are developing as-built plans for major projects, specifically bridge projects. Items often recorded on bridge as-built plans include seat elevations, x-dimensions, and piling depth and length. However, as-built plans are lacking for drain and grade projects. Only major alterations are being recorded for grade and drain projects, such as changes in typical sections. Two section engineers mentioned their districts treat construction revisions on projects as the only needed information on grade and drain for as-built plans, and they use these revisions as the as-built plans but do not develop as-builts separately.

4.2 Utilization of As-Built Plans by Project Managers

None of the interviewees believe that project managers use as-built plans. Their assertion stems from the fact that section engineers are not confident on where to store as-builts and are never asked about them. They submit as-builts to different locations because there is insufficient guidance on where to send and store as-builts. Since all as-builts are being stored in different locations, the section engineers do not think the project engineers know where to find as-builts when needed.

The section engineers felt that project managers not typically using as-builts explains why the emphasis on creating them has waned over the past several years. They agreed that if they were certain project engineers use as-builts, they would be more diligent about collecting and recording as-built information.

4.3 Biggest Obstacles When Developing As-Builts

The section engineers identified the following obstacles to developing as-built plans:

- Insufficient guidance on where to store as-builts once they are complete,
- Insufficient guidance on what as-built plans should capture,
- Limited inspector capabilities,
- Limited time to complete as-builts,
- Lack of resources needed to develop as-builts, and
- Difficulty transferring as-built notes into a format that can be used by end users.

After the interviews we found a document titled, "Guidance for the Use of ProjectWise in Section Offices for Construction Administration." It states that as-builts should be stored in ProjectWise after completion and provides the naming convention to use when storing them (Commonwealth of Kentucky Transportation Cabinet 2017). However, given that section engineers were unsure of storage location, we recommend placing this information in other manuals and guidance to establish a consistent message across all documents on where as-built plants are to be stored. The lack of consistency on as-built procedures throughout manuals and documents is not unique to KYTC. At the 2018 American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Design Annual Meeting, STAs were asked how their agency handles as-built plans. The handling of as-built procedures mentioned at the meeting differed from as-built procedures found in publicly available manuals for four STAs (2018, June 10-14).

Current inspector capabilities limit the technology that can be used to create as-builts. Many section engineers have found that inspectors lack the skills to use Adobe and Blue Beam when recording as-built changes. This forces as-builts to be hand drawn on half-set plans, which is more time-consuming than using PDF editing software. In addition to inspector capabilities, current KYTC workloads are a time resource issue when developing as-builts. As-builts were previously developed in the construction off season; however, today's engineers have no downtime available to generate as-builts for the previous year's projects. Without a designated period for producing as-builts, section engineers have trouble making time for their development. Additionally, resources that would facilitate as-built development are not always available to Section Offices. A GPS rover would be greatly beneficial to as-built development. But it is difficult for every office to have access to a rover and the technical expertise to operate it when needed. Finally, section engineers informed said that recording as-built notes is fairly easy and reasonable, however, putting this information into a format that amenable end users is time-consuming and often difficult.

4.4 Format and Storage Location of As-Built Plans

The format used to create as-builts varies according to inspectors and their abilities. If the inspector has a working knowledge of Blue Beam, Adobe, or Microstation, as-builts are developed using these software packages. The section engineers find developing as-builts this way was more efficient. However, often their inspectors lack the skills to use these programs. When this is the case, half-set plans are marked with red pencil and scanned to develop the as-built plans. To build consistency and move toward electronic development of as-builts, training should be developed for and delivered to as-built developers.

Storage location of as-builts was also mentioned in the context of this question. We received different answers on where the section engineers send as-builts for storage. ProjectWise was the common storage location mentioned but the specific folder location varied. Other section engineers send their as-builts to the construction liaison or Structures Division. Some of the engineers keep a set of as-builts in their section office, in either an electronic format or as paper copies stored in filing. The lack of a standard process and uniform storage location is a major issue and concern with KYTC's approach to as-builts.

4.5 As-Built Process Improvement

The section engineers proposed several ideas for improving the as-built development process. First and foremost, they want better guidelines on what information to collect and what to do with as-built plans after their completion. Guidance would eliminate the ambiguity in as-built development and provide all section engineers with the same checklist when developing as-builts. They also suggested uploading as-built plans to the GIS project archives system, noting that in ProjectWise, plans can be difficult to find because of their competing project identifiers. When different numbers are used to identify a single project, it becomes difficult to find projects by their identifying numbers. However, if as-builts were uploaded to a GIS-referenced archive, finding as-builts would be as simple as knowing the project location.

While the storage location of as-built plans is a major issue with KYTC's as-built development process, the development of as-builts also needs improvement. Section engineers listed time as one of the biggest obstacles in the as-built development process. To address this issue, interviewees suggested developing as-builts as the project progresses. Fourteen of the other 41 STAs we studied require the preparation of as-builts throughout the project duration. If as-builts are developed as a project progresses, section engineers could submit partial as-builts once an activity is complete (e.g., submitting storm sewer as-builts as soon as the storm sewer construction is finished). Developing as-builts as the project progresses will require in-field editing capabilities. The section engineers suggested a PDF editor available on iPads to complete as-builts in the field. Training inspectors creating digital as-builts on the iPads may be necessary in order to implement this change. The Connecticut DOT does not let field personnel maintain digital as-builts unless properly trained. This has ensured the consistency and accuracy of as-built drawings (Connecticut Department of Transportation 2017).

Finally, the section engineers proposed having design consultants or contactors assist with as-built development. Suggestions included contractors collecting as-built information and providing it to KYTC, design consultants prefabricating quantity and summary templates to help with timely data collection, and consultants or contractors developing all as-built plans. Twelve STAs currently have contractors or design consultants produce as-built plans for their projects.

5. Interim Recommendations

After speaking with KYTC personnel we reviewed our interview data and prepared high-level interim recommendations. Recommendations were formed using input from as-built developers and end users. The goal of the recommendations was to outline procedures to capture and store requested as-built information, while understanding and maximizing the resources available to as-built developers. These recommendations also guided the creation of a task force and a subsequent workshop dedicated to proposing an as-built development procedure (see Chapters 6 and 7 for details). The interim recommendations were as follows:

- Reframe *As-Built Construction Plans* as *As-Built Construction Information.* The minor change in wording represents a major paradigm shift in how as-built construction information is perceived by developers and end users. All end users agreed the emphasis should be on collecting accurate and appropriate as-built *information* — not on development of a formal *red-line* plan set.
- Establish a central storage location for as-builts known to all Section Offices and end users. Although a process for submitting and storing as-builts currently exists, there appears to be confusion, especially among end users, over where and how the final as-builts are stored.
- Develop a file naming convention for as-built plans that makes locating as-builts in the storage location straightforward. Files containing as-built information should be named in a clear and consistent format so that end-users can easily locate and determine the most recent update.
- Develop clear and specific lists of requested as-built information for each end user. Specify the required level of accuracy for different end users. The current process for developing as-built plans is very time-consuming for already-overworked Section Office staff. Providing a list of as-built information needed by end users will prevent the use of resources to collect information that may not be used. Knowing how collected information will be utilized also helps Section Offices appreciate the importance of accurate and complete as-builts.
- Ensure as-builts are developed ***during a project*** — not after it is finished. There is no justification for waiting until a project is finished to begin collecting and submitting as-built information. In fact, waiting until the project is complete may make the task appear even more onerous and increase the possibility of collecting inaccurate information. Collect and submit as-built information as respective work items are completed.
- Deliver as-builts in PDF format. There was much discussion during the interviews about the various methods available for collecting and recording as-built information. The unanimous recommendation was that for the time being as-built information should be stored and delivered in PDF format.
- Establish a liaison who serves as a go-between for construction and end users who ensures as-builts are completed and stored properly. This liaison should represent all end users and their respective divisions and understand each area's information needs and required level of data accuracy.
- Form a task force to facilitate the above tasks (see Chapter 6).

6. Task Force Development and Workshop

After preparing interim recommendations, a task force composed of five end users and five as-built developers reviewed them. End users were from Bridge Maintenance, Highway Design, Structural Design, and Project Development. The five as-built developers came from two district offices, Highway Design, and the Central Office Construction Section. Once task force participants examined the interim recommendations they took part in a workshop with our research team to refine and revise them. The workshop helped establish what as-built information should be collected based on the project work type, level of detail required, preferred method of collecting as-built information, and the format and storage location of finished as-built information. The as-built process from development through storage was discussed in great detail.

6.1 Task Force Workshop

The workshop brought as-built developers and end users together to discuss the topics listed above. Throughout this project it was clear that the needs of end users must be balanced against the demands placed on developers, who have limited resources and time to spend creating as-builts. The purpose of bringing these stakeholders together in dialogue was to reach a compromise solution and begin development of an official procedure for recording and storing as-built information.

Table 6.1 was summarizes the workshop's outcomes. At the beginning of the workshop, attendees received a blank table with only the requested as-built information listed by end user group. The workshop proceeded in the following manner. First, the project team introduced a new topic under the requested as-built information. Next, end users explained the importance of that information and their preferred methods of collection and delivery. Then developers talked about their abilities to gather such information. Finally, a compromise was reached between end users and developers on a specific item; additional comments were also recorded.

Table 4 End User and Developer Workshop Table

End User	Requested As-Built Information	Collection Method	Additional Comments
Bridge Maintenance	**Pile tip elevations**	Drawn on piling sheets, scanned, and stored in ProjectWise. One developer uses spreadsheets to capture this data.	Developers are uploading to ProjectWise or sending to the Construction Liaison.
			The format is not important to end users as long as they know where to get the information.
			Suggested using iPads to record changes.
	Concrete cylinder breaks	This information is in SiteManager. Draw a bubble on the plans indicating where the concrete did not meet specifications, or noting in as-builts that all concrete met specifications.	Whoever determines the numbering system for cylinder locations should record this information on the as-built plans.

Table 4(continued)

End User	Requested As-Built Information	Collection Method	Additional Comments
Bridge Maintenance (continued)	**Beam seat information**	Drawn on plans, scanned, and stored in ProjectWise.	
	X-Dimensions	Drawn on plans, scanned, and stored in ProjectWise.	
	Culvert fill heights	Drawn on plans, scanned, and stored in ProjectWise.	Culverts should be treated as structures and all changes should be recorded.
	Foundation layouts	Drawn on plans, scanned, and stored in ProjectWise.	
Pavement Design	**Actual courses placed**	Should be marked on a PDF of the proposal and uploaded to the archive. (This solution is just a start and needs to be revisited.)	Undercutting will be hard to represent on the proposal sheets.
	Typical sections	Should be marked on a PDF of the proposal or original plans and uploaded to the archive. (This solution is just a start and needs to be revisited.)	
	Subgrade details	Should be marked on a PDF of the proposal and uploaded to the archive. (This solution is just a start and needs to be revisited.)	The information needs to be captured when they are stabilizing. Also need to capture edge drain details.
	ADA ramps	Collected on an app and is a required process separate of as-builts.	
	Intersection grades	Mobile Lidar or drones is ideal for collection.	Design consultants should be gathering cross slopes, cut slopes, and intersection grades. This would need to be part of the contract.
	Maintenance history	Same requirements as those of typical sections.	

Table 4 (continued)

End User	Requested As-Built Information	Collection Method	Additional Comments
Pavement Design (continued)	**As-Builts for proposal projects only**	Should be marked on a PDF of the proposal and uploaded to the archive. (This solution is just a start and needs to be revisited.)	
Highway Design	**Right-of-Way plans**	No additional collection information given.	Not an as-built issue at this point. This information would only be included in as-builts if right-of-way changes during the course of the project.
			The Cabinet is now using a licensed surveyor to collect this information, so it is much more accurate than before.
	Picture and Lidar scan of completed project	No additional collection information given.	
	Basic project information	No additional collection information given.	Anything underground, alignments, and anything a designer would care about.
Structural Design/ Geotechnical	**Footing information**	Same requirements Bridge Maintenance described.	
	Pile lengths	Same requirements Bridge Maintenance described.	
	X-Dimensions	Same requirements Bridge Maintenance described.	
	Stationing information	Same requirements Bridge Maintenance described.	Need to know stationing equations for where bridges and roads meet.
			Need to know if bridge changes in length.
			Need to know if peers get built at the wrong skew.

Table 4 (continued)

End User	Requested As-Built Information	Collection Method	Additional Comments
Structural Design/ Geotechnical (continued)	**Bearing details**	Same requirements Bridge Maintenance described.	
	Rock cut slopes	By drone	
	Cut and fill slopes	Drawn on plans.	
Utilities	**Subsurface utility information**	No additional collection information given.	
	Utility conflict information	No additional collection information given.	
	Alignments, depths, and clearances	No additional collection information given.	
Permits	**Permitted facilities**	Scaled drawings	

Along with the information in Table 6.1, we recorded several comments about general as-built procedures:

- End users want structure plans that are separate from the general plans because every change to a structure is important and must be recorded.
- Each district needs to ensure it has a couple of inspectors capable of collecting and recording as-built information.
- Information on right of way is scarce but should be collected.
- Structural Design is working to develop a group focused on collecting as-built information and assisting section offices in completing as-builts.
- Construction has used rent-a-techs for as-built development in busy periods.
- Shop drawing changes need to be tracked. This may be the responsibility of the shop inspectors; more research is needed in this area.
- Every change to a structure must be recorded even if there is no drawing number.
- Pavement Design staff have no faith in as-builts and are doing forensics on everything.
- Construction does not have plans on pavement rehabilitation projects, so they are unsure about where to record as-built information.
- Proposal-only projects should also entail the capture of as-built information. This information should also be used to update any existing as-built files from previously constructed projects within the Project Archives system.
- It is neither reasonable nor practical for Construction to attempt to go back and gather as-built information on previously built facilities. Any new procedures adopted should only be applied to projects moving forward.
- If design consultants are used for as-built development, their contract should be kept open until as-builts are complete (e.g., the consultant would receive 90% of contract amount at the end of design and the remaining 10% would be awarded after as-built development is complete. However, the 10% should not be considered outstanding work within their eligibility.)
- Construction would prefer a list of as-built information they need to record.
- With current staff and resources, Construction still needs to hand draw as-builts on plans.
- End users want as-builts stored on the archive website for mass use.
- A next step is to establish a liaison between Construction and end users to ensure as-builts are being stored uniformly.

Information gathered through the workshop underwrote the development of a proposed procedure for as-built development at KYTC. Chapter 7 narratively and graphically describes the recommended procedure. The recommendations are written based on current resources available at KYTC. As resources and staffing availability evolve, revisions to the procedure can be made. Such future opportunities at KYTC for as-built development are mentioned but have not been fully researched, as they were beyond the scope of this project.

7. Recommended As-Built Procedures

Following the workshop, our research team developed a recommended procedure for as-builts based on interviews and task force recommendations. We anticipated that some of the recommendations could be immediately implemented at the Cabinet. Others will require policy changes or KYTC to dedicate additional time and resources to their implementation. This chapter first presents the Cabinet's existing as-built process and policies as a baseline from which KYTC can progress. The next section chapter discusses recommendations that can be implanted right away to improve the as-built process. The final section looks at future implementation strategies and concepts for long-term improvement of the collection, storage, and use of as-built information.

7.1 Existing As-Built Process

KYTC's current as-built process is not standardized. Multiple documents and policies manuals reference as-built plans sets or data collection; and multiple ad hoc approaches have emerged from practices handed down through informal mentoring. Because ad hoc approaches vary even at the crew level, describing the existing as-built process is best done through reviews of the following KYTC documents: *Highway Design Guidance Manual*, *Construction Guidance Manual*, *Section Engineer Reference Guide*, *Guidance for the Use of ProjectWise in Section Offices for Construction Administration*, and the *Records Retention Schedule*.

The *Highway Design Guidance Manual* has few details about as-built information. Section HD-211.3 (Post Construction) notes that a copy of a project's plans shall be placed in the Project Archives website, "Project Plan Archive (1909-Present)." However, it should be noted that structure plans should ***not*** be included in the publically available Project Plan Archive due to security concerns. The records retention schedule provides guidance on the retention of project documents (HD-211.5). The only guidance for developing as-built information is in HD-210.4 (Construction Revision), which indicates Project Development staff may be needed to capture and coordinate the development of construction revisions.

The *Construction Guidance Manual* provides a bit more information on as-built plans. It specifies that the original roadway plans delivered to the section engineer will eventually serve as the as-built plans set. Items of record for these as-builts are construction revisions, permits, correction of errors or omissions, and grade/excavation sections compared to those designed. As-builts are to be provided along with the final project estimate; they are then transferred to the Division of Highway Design Microfilm Section (which no longer exists) and submitted to the Department of Library and Archives for microfilming and storage according to the records retention schedule.

The *Section Engineer's Reference Guide* notes that construction revisions are necessary for any right-of-way change, typical section changes, or major design feature change. Changes should be recorded on mylar, according to the document, but Construction Memorandum 02-11, which stipulates changes are to be submitted to ProjectWise electronically, phased out this requirement. As-builts should be sent in soon after the final estimate to the Central Office Division of Construction (mylar or electronically, MicroStation files). The document also contains several checklists for the items to be completed along with the final estimate and as-built plans. Specifics provided about as-built plans pertain to checking quantities, indicating subgrade drainage, structures submitting foundation sheets, construction elevations, and any adjustments to original plans.

Guidance for the Use of ProjectWise in Section Offices for Construction Administration contains no details about collecting information for as-builts. The guide details the location and file naming nomenclature for as-built files in ProjectWise. It also highlights the security restrictions, rights, and responsible parties with respect to these files.

KYTC's *Records and Retention Schedule* is a collection of retention and storage policies used and maintained by the Cabinet. This document is one of the most detailed we found, yet it appears outdated and disjointed when read in light of current practices. Information regarding as-built plans is spread across several sections, including those focused on the Division of Construction, the Division of Highway Design, and District Offices. Figure 7.1 highlights relevant sections of the retention policy. The section pertaining to the Division of Construction indicates that as-built files are transferred to the Division of Design following the verification of pay quantities and that the Division of Design retains all as-built plans permanently. A portion this section refers to structure plans, which are to be retained until a structure is rehabilitated or demolished. The section on District Offices notes that as-builts are not only sent to the Division of Highway Design but are retained permanently in the District Office (Figure 7.2). Finally, the section in for the Division of Highway Design states that as-builts are retained permanently by the Division but has no reference to microfilming (Figure 7.3).

Because these documents are disjointed they — coupled with the ad hoc approaches for capturing as-built data — can be a source of confusion about how the as-built process works. Based on feedback from as-built developers, the typical process for developing as-built plans is documenting information on hand-drawn markups of a plan set or electronically in PDF versions of the plans (the CAD format has been used as well). Information prioritized for collection is generally related to structures — foundation details, elevations and x-dimensions, and significant changes to the original design. Beyond structural elements, the focus is on capturing changes to the right of way or boundaries, followed by typical sections and cross sections (if those changes were documented). The reason given for emphasizing certain items during data collection was that end users had asked for them on one occasion or another. The remaining sections of this chapter present recommendations for standardizing the development of as-builts in a way that meets the needs of the end users while not exceeding the capabilities of the developers.

04795	**As-Built Plans and Profile Sheets (V)**	This series documents plans related to construction projects that involve earth work; for example, grades and drains; bridge construction; and structure replacements such as culverts. It represents "as-built" construction and documents all pay quantities, i.e., all materials used on a project. The series is used to verify that the cost of all pay quantities (materials) has been paid to the contractor by the Department of Highways, in compliance with contract plans and specifications. Audits are generally completed during the life of the projects. Original transparent "as-built" plans are received from the project engineer and forwarded to the Division of Design, after final pay quantities have been checked, which typically take 30 days. The plans are microfilmed and retained permanently by the Division of Highway Design.
	Access Restrictions	None
	Contents	Series contains: Project plan sheets
	Retention and Disposition	Transfer to the Division of Design after verification of all pay quantities. NOTE: The Division of Design retains "as-built" plans permanently.

Figure 4 Excerpt from KYTC Records Retention Schedule for the Division of Construction

04796	**Cross-Section and Structure Sheet File (V)**	This series documents the amount of earth work (grades, drains, etc.) associated with a construction project. The structure sheets show the amount of dirt and rock removed from a site in order to build a structure, such as a bridge or culvert. The cross-sections show the depth and width of rock and dirt removed from the site, in order to complete the project. Series reflects the plan of the project, as it was built. It is also used to verify that all materials costs have been paid by the Department for Highways, in compliance with contract plans and specifications. Audits are generally completed during the life of the projects. *Not all projects involve earth work.
	Access Restrictions	None
	Contents	Series contains: Project plan sheets, pipe sheets, structure sheets (drawings of actual structure), bridge plans and drawings
	Retention and Disposition	Retain Cross-Section three (3) years after voucher is paid. Retain Structure Sheet until structure is rebuilt or demolished.

Figure 5 Excerpt from KYTC Records Retention Schedule for the District Offices

05920	**As-Built Plans**	This series documents plans related to construction projects. For example, grades and drains, bridge construction and structure replacements such as culverts. It represents "as-built" construction and documents all pay quantities, i.e., all materials used on a project. This series is used to verify that the cost of all pay quantities (materials) have been paid to the contractor by the Department of Highways in compliance with contract plans and specifications. Audits are generally completed during the life of the projects. Original transparent "as-built" plans are sent by the project engineer to the Division of Highway Design after final pay quantities have been checked. The plans are microfilmed and also retained permanently by the Division of Highway Design series 05801.
	Access Restrictions	Agencies should consult legal counsel regarding open records matters.
	Contents	Series may contain: Plan sheets from roadway, traffic, utilities; structural plans, county project correspondence and related documents and correspondence.
	Retention and Disposition	Retain in District Office Permanently.

Figure 6 Excerpt from KYTC Records Retention Schedule for the Division of Highway Design

7.2 Immediate Implementation Opportunities for the As-built Process

The proposed as-built process can be readily implemented in KYTC's current operating environment. Figure 7.4 visualizes the proposed process.

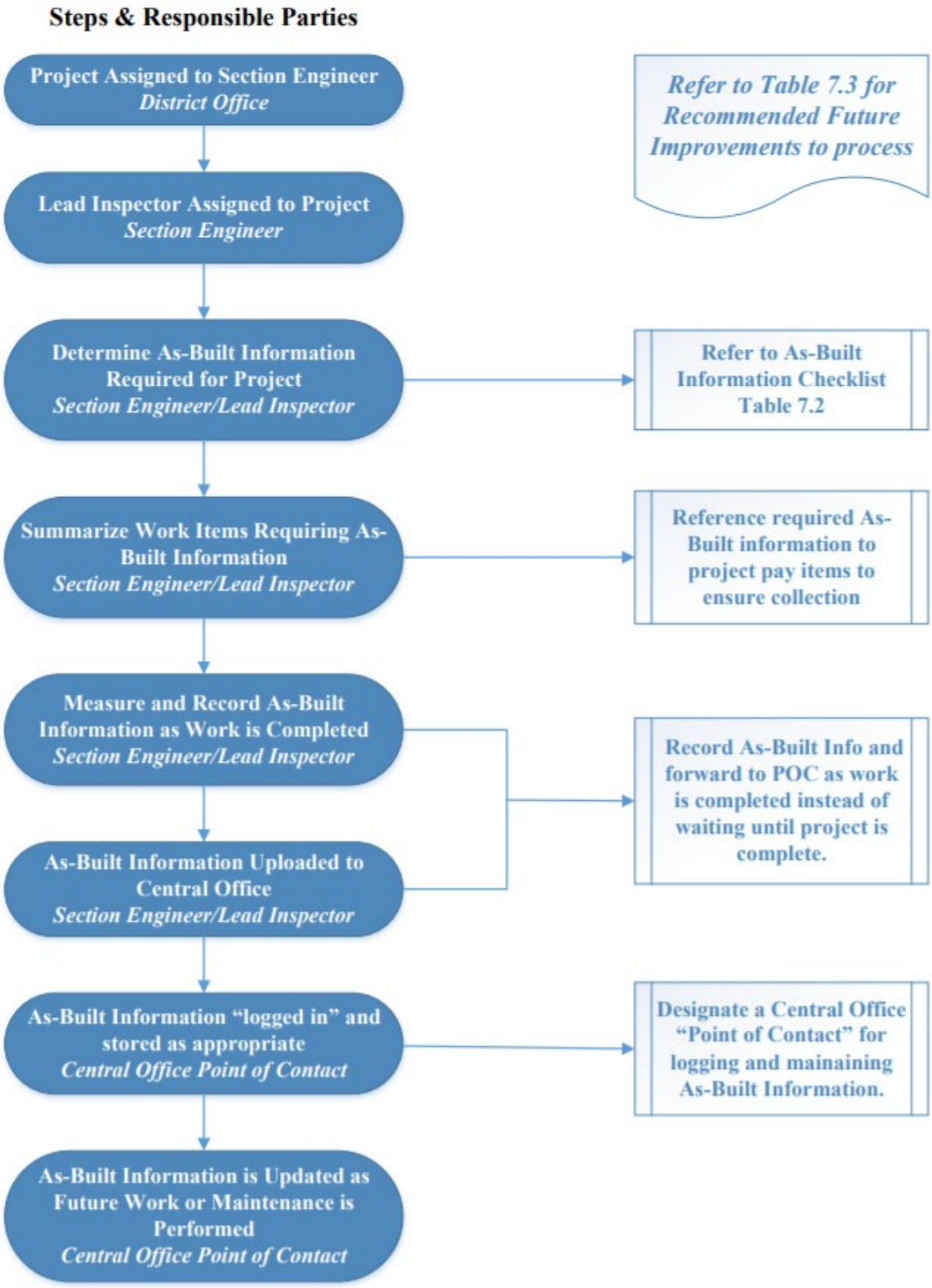


Figure 7 Proposed Process for Development of As-Built Construction Information

The process begins with the Section Engineer assigning the project to a Lead Inspector. The Section Engineer and/or the Lead Inspector determines and then summarizes work items that require as-built information. We developed an As-Built Information Checklist to assist in the performance of these steps; its lists the as-built information needed for each category of end users (Table 7.1). It also describes the minimum acceptable recording method for required as-built information. Table 7.2 is a checklist of necessary as-built information broken down according to work type. Projects with these work items require as-built information. If the as-built developer has access and possesses the skill to record as-built information at a greater level accuracy than what is listed in the table, it is acceptable. All as-built information is converted to PDF format before its submission.

Table 5 As-Built Information Checklist by End User

End User	Required As-Built Information	Minimum Acceptable Recording Method
Bridge Maintenance	Pile tip elevations	Hand drawn
	Concrete cylinder breaks	Hand drawn
	Beam seat information	Hand drawn
	X-Dimensions	Hand drawn
	Culvert fill heights	Hand drawn
	Foundation layouts	Hand drawn
Pavement Design	Actual courses placed	Hand drawn
	Typical sections	Hand drawn
	Subgrade details	Hand drawn
	ADA ramp information	APP
	Intersection grades	Mobile LiDAR
Highway Design	Anything underground	Hand drawn
	Alignments	Hand drawn
	Picture of completed project	Camera
	LiDAR scan of completed project	Mobile LiDAR
Structural Design/Geotechnical	Footing information	Hand drawn
	Pile lengths	Hand drawn
	Stationing equations for where bridges and roads meet	Hand drawn
	Changes in bridge length	Hand drawn
	Peers built at wrong skew	Hand drawn
	Bearing details	Hand drawn
	Rock cut slopes	Drone
	Cut and fill slopes	Hand drawn
Utilities	Subsurface utility information	Hand drawn
	Utility conflict information	Hand drawn
	Alignments	Hand drawn
	Depths	Hand drawn

	Clearances	Hand drawn
Permits	Permitted facilities	Hand drawn

Table 6 As-Built Checklist Information by Work Product

Major Work Product	Work Product Components	Individual Work Items	Required As-Built Information	Collection & Recording Method - (Current Recommendation))	Future Collection & Recording Methods
STRUCTURES			Concrete Cylinder Breaks	Test & Record in SiteManager	
	Foundation	Piles	Pile Tip Elevations/Lengths	Direct Measure & Record on Pile Logs	
			Measured Bearing	Direct Measure & Record on Pile Logs	
		Foundation Layout	Bottom of Footer Elevations	Direct Meaure & Record on Plans	
	Substructure	Abutment/End Bent	Beam Seat Elevations	Direct Meaure & Record on Plans	
			Beam Seat Layout	Direct Meaure & Record on Plans	
			Wing Wall Dimensions	Direct Meaure & Record on Plans	
		Piers	Beam Seat Elevations	Direct Meaure & Record on Plans	
			Beam Seat Layout	Direct Meaure & Record on Plans	
	Superstructure	Bridge Deck	X-Dimensions	Surveyed & Record as PDF	
			Finished Grade	Direct Meaure & Record on Plans	
	Culvert		Culvert Fill Heights	Direct Meaure & Record on Plans	
			Wing Wall Dimensions	Direct Meaure & Record on Plans	
		Foundation Layout	Bottom of Footer Elevations	Surveyed & Record as PDF	
ROADWAY		Right of Way	Actual R/W Monuments & Lines	Survey & Record on Plans	Google Earth
		Completed Project		Picture & GPS and Record on ArcGIS	Google Earth
	Subgrade	Stablization method	Cement/Lime/Rock Roadbed	Record Method Used as PDF	
	Asphalt/Concrete Pavement	Base Courses	Actual Courses & Thickness Plac	Direct Meaure & Record on Plans	
PERMITTED FACILITIES		Entrances	Permitted Facilities	Visual Inspection & Record on Plans	GPS/GIS Asset Management System
			Scaled Drawings	Record on Plans	PDF Red-Line Editor
UTILITIES		Underground Utilities	Subsurface Information	Measured or Surveyed & Record on Plans	As per ASCE 38-02
			Conflict Information	Record in Maintenance Database	As per SHRP2 R01A
			Alignments, Depths, & Clearanc	Measured or Surveyed & Record on Plans	GPS/Asset Management

For Proposal Only projects the Proposal should be cosnidered as the plans.
Only submit relevant plans sheets in PDF format. Do not submit an entire set of plans

Data collection using these checklists should be done throughout project construction as work is completed. The information is then uploaded to ProjectWise using the appropriate procedures and naming conventions. Uploaded files can include individual plan sheets; the file name should include the date of data collection and the sheets involved. This process could potentially evolve, improving standardization and the quality of the as-built information.

7.3 Future Implementation Opportunities for the As-built Process

The proposed process and tools will streamline the as-built process using existing methods and resources. We recommend that KYTC continue exploring methods to simplify the development of as-built information for Section Offices and increase its accuracy and reliability for end users. What follows is a list of recommended process improvements for the Cabinet to consider. This list is not exhaustive. It prioritizes ideas that can be implemented with existing resources and technologies. These are *recommendations* only and the final decision about implementation rests solely with KYTC.

- Include a list of required as-built information with the project plans and/or proposal. Using the information provided in Tables 7.1 and 7.2, a table could be developed and included on the General Notes page of project plans. For a proposal-only project, this could be included as Special Note in the appropriate section of the proposal.
- Link the required as-built information to the appropriate bid items in SiteManager. For example, if the bid item for steel H-Piles is part of a project it would be flagged in SiteManager to alert a Section Office when the bid item was paid and that the Record of Piles Driven needs to be completed and sent in. This procedure could be developed to link appropriate bid items with the required as-built information using the bid item codes and Tables 7.1 and 7.2.
- Develop end-user driven guidelines on the required level of detail for the components of each major work product. These guidelines would stipulate the required accuracy needed when measuring and recording as-built. This would guarantee end users access to consistent and reliable as-built information at the appropriate level of detail. As a starting point, KYTC could use the guidelines currently used by the Minnesota Department of Transportation[1], ASCE 38-02 – Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data[2], and the ASCE utility as-built guidance currently in development.[3]
- Establish a Central Office point of contact to track the development, storage, and updating of as-built information. Currently the responsibility for ensuring as-built information is collected begins in the Division of Construction and ends in the Division of Highway Design, which is responsible for storing and maintaining the information. A centralized point of contact that would track as-built information from start to finish. Work across all Department of Highway divisions would greatly improve the consistency of as-built plan development and ensure this information is readily accessible to end-users.
- In conjunction with a Central Office point of contact, the final storage location of as-built information should be in centrally located within the KYTC database. All Department of Highways divisions would have easy access on a read-only basis.
- Develop a process for updating existing as-built information when maintenance work or construction work is performed. These updates would be added as separate PDF files to the original as-built information in a tree format. This would be similar to the method for recording Construction Revisions in the Division of Construction. Each update would be tagged with a date, informing end users of the most current date they can assume the as-built information is correct.
- Change the term *As-Built Plans* to *As-Built Information*. Revise the definition in the specifications to read: "The final Plans and/or Proposal reflecting all changes to the original documents."
- Update the KYTC's *Records Retention Schedule* so it matches current/new storage procedures for as-built information. Ensure consistency among the various entities within

[1] http://www.dot.state.mn.us/gisspec/
[2] https://ascelibrary.org/doi/book/10.1061/9780784406458
[3] https://www.asce.org/uploadedFiles/Technical_Areas/Construction_Engeering/Content_Pieces/as-built-standards-whitepaper.pdf.

the Department of Highways. Determine if a copy should still be forwarded to the Department of Archives.

- Continue training maintenance personnel to use iPad cameras to photograph completed maintenance activities and forward to the as-built information point of contact.
- Explore the cost and feasibility of utilizing mobile Lidar to conduct a photographic post-construction survey of all completed projects in the Six Year Plan.
- Increase training of Section Office personnel on the use of BlueBeam so they can capture as-built information when individual work items are completed in field.

Table 7 As-Built Process and Future Recommendations

Step	Responsible Party	Action Items		
		Current Responsibilities	**Proposed Responsibilties**	**Future Improvements**
1	District PD&P	Project Assigned to Section Engineer's Office	Project Assigned to Section Engineer's Office	N/A
2	Section Engineer	Project assigned to Lead Inspector	Project assigned to Lead Inspector	N/A
3	Inspector/Section Engineer	N/A	Project Work Types summarized accorind to "pay book." Automated from SiteManager	Within the planset produce a summary sheet (or note for proposal-only) listing "Work Items Requiring As-Built Information"
4	Inspector/Section Engineer	N/A	Determine As-Built information required based on summary of work types	Upgrade to SiteManager highlight Pay Items linked to needed As-built Information. Pay estimate warning to the SE when running an estimate to ensure information is collected.
5	Inspector/Section Engineer	N/A	Refer to As-Built information matrix for information needed, level of detail, and format	Refined through use and evaluation
6	Inspector/Section Engineer	Record As-Built information is recorded within a planset during the project and in closing out the project. As-built plans are submitted to the DO.	Record As-Built Information is collected as specific work types are completed; not at conclusion of the project.	Use of technology aligned to As-built Information required.
7	Section Engineer/District PD&P	As-built plans are checked for completion copied with a District set stored in perpetuity with the originals submitted to CO Division of Construction.	Recorded As-Built Information is forwarded to the proper contacts or uploaded to the appropriate location in ProjectWise. CO is notified of there storage in ProjectWise.	There is substantial confusion regarding the details for checking, scanning, storage, and records retention for as-builts. Currently, the "keeper" of the as-builts is the Division of Highway Design. These processes should be refined and clearly defined for clarity. Recommendations are provided within this report.
8 (present)	CO Division of Construction	As-built plans received are scanned and saved in Project Wise as PDF or electronically submitted as DGNs. As-built plans are sent to CO Division of Highway Design.	As-built plans checked for access in Project Wise as PDF or electronically as DGNs. Division of Highway Design is notified of their storage in ProjectWise.	Revisions are needed to the Records Retention Schedule policy. The process to store and archive as-built inforation should be streamlined and standardized to facilitate an understandind of the information desired and an appropriate storage location for ease of future access.
9 (present)	CO Division of Highway Design	As-built plans are coverted to PDFs, logged into the electronic archived plans GIS application, microfilmed and sent to the State Archives for permanent retention.	As-built plans are coverted to PDFs and logged into the electronic archived plans GIS application. (Requires a revision to the Records Retention Schedule policy)	
8 (future)	CO Point of Contact (TBD, Recommended: Division of Maintenance)	N/A	N/A	As-Built Information verified to be in ProjectWise and uploaded the electronic archived plans GIS application. This is for permanent retention within both systems.
9 (future)	CO Point of Contact (TBD, Recommended: Division of Maintenance)	N/A	N/A	As-Built Information is updated as work is performed. Maintenance, Widening, Rehabilitation, etc. (Requires careful communication & coordination with Districts and Divisions)

8. Conclusions

Our investigation of KYTC's current as-built process revealed the development of as-builts does not align with the needs of end users. At the Cabinet, as-builts are only sporadically used, and their development often occurs in an ad hoc manner. Staff responsible for preparing as-builts observed that few people requested them when they were not completed, suggesting they are not being used. End users, conversely, noted that they often could not find as-built plans in ProjectWise and therefore assumed they were never finished. Arguably, the current process for as-built development is antiquated and needs to be revised to leverage new technologies and survey methods. Doing so will help KYTC meet specific needs for as-built information without marking up an entire plan set by hand.

Our literature review, interviews with Cabinet stakeholders, and discussions with the task force deepened our understanding of the current issues with KYTC's as-built process and guided us in recommending possible solutions. Twenty-three STAs assign in-house employees to create as-built plans; seven allow consultants to create as-builts, and three have contractors producing as-builts. Fifteen STAs store as-built plans electronically rather than using traditional hard copy plans. End users prefer that PDF as-builts be housed in a central storage location accessible to all as-built developers and end users. STA and private industry guidelines listing what information to include on as-builts and the required level of accuracy also proved informative.

Our examination of private industry offered insights into new technologies and practices for data handovers. While many companies use BIM and Lidar, state agencies are generally less advanced on this front. However, agencies are using GPS to gather as-built information (e.g., GPS rovers, mentioned by KYTC engineers). While our review of STA guidance turned up little information on data handovers, journal articles on as-built development in the private industry emphasized the importance of the as-built data handover. While the physical handover of data only happens after a project is complete, there should be continual preparation for the handover throughout a project. As-built developers and end users should continually discuss the information being recorded on as-builts throughout a project.

To make recommendations for improving KYTCs as-built process, we identified the main hurdles engineers confront when developing as-builts. These include: lack of guidance on what as-builts should contain and where to store them, limited inspector capabilities, limited time to work on as-builts, lack of resources, changing technology, and difficulty formatting as-builts into useful plans. Our recommendations address the obstacles faced by as-built developers and take advantage of evolving technologies in the transportation industry. We have recommended two procedures: 1) developing checklists as-built developers can use, specifying a point of contact where all as-builts are sent, adopting a common storage location, and preserving as-builts in PDF format; and 2) requiring that as-built information for a specific project be indicated within SiteManager, and that it corresponds to pay items rather than a generic checklist applicable to all projects. The first recommendation will not require additional time or resource investments to implement, whereas the second will.

KYTC's retention process demands additional consideration. The Central Office Division of Highway Design is currently the default location for retaining as-built plan sets. Paper plan sets are scanned and uploaded to the Project Archives website, while electronic plan sets are uploaded to Project Archives and a copy printed. The paper version is sent to the State Library and Archives warehouse location for permanent storage in perpetuity (pursuant to the retention policy). This process is redundant and archaic. The retention policy should be revised to

eliminate the storage of paper as-built plans — electronic files are more useful and efficient. Given the cyclical nature of design, construction, and maintenance activities, the Division of Highway Design may not be the ideal location for storing as-built information. The storage of as-builts and the preparation of revisions following maintenance or the issuance of permits are more appropriately asset management functions. KYTC leadership should further investigate the potential of these solutions.

8.1 Existing Research and Future Research Needs

Despite thoroughly reviewing as-builts guidance from other state transportation agencies and investigating KYTC's practices in depth, our study has a few limitations. First, some of the published manuals and guidance we examined appeared outdated however, we did not contact other STAs directly to procure further information. Second, our observations about private industry was based on a limited number of articles and may not be representative of the entire private sector. Third, we only spoke with a small number of KYTC engineers, and it is possible they were not representative of how all Cabinet engineers approach the as-built process.

Future research may want to focus on interviewing or surveying all 50 STAs to gain a better picture of their as-built processes and how they are evolving as well as common obstacles personnel at these agencies face. Another potential research topic is looking at how this study's recommendations are being implemented to determine whether they are proving successful. It will also be critical to keep abreast of how emerging technologies will influence the future of as-built processes.

Appendix A: Links to State Transportation Agencies' As-Built Procedures

State	Document Title	Link
AL	Standard Specifications for Highway Construction	https://www.dot.state.al.us/conweb/pdf/Specifications/2012%20DRAFT%20Standard%20Specs.pdf
AK	Construction Manual	http://www.dot.state.ak.us/stwddes/dcsconst/assets/pdf/constman/2017/acm_17.pdf
AZ	Construction Manual	https://azdot.gov/docs/default-source/businesslibraries/CMchapter-12.pdf?sfvrsn=25
CA	Construction Manual	http://www.dot.ca.gov/hq/construc/constmanual/construction_manual.pdf
	Project Development Procedures Manual	http://www.dot.ca.gov/design/manuals/pdpm/chapter/chapt15.pdf
CO	Construction Manual	https://www.codot.gov/business/designsupport/bulletins_manuals/cdot-construction-manual/cdot-construction-manual.pdf/view
	Standard Specifications	https://www.codot.gov/business/designsupport/cdot-construction-specifications/2017-construction-standard-specs/2017-specs-book/standard-specifications-2017-final.pdf/view
CT	Construction Manual	http://www.ct.gov/dot/lib/dot/documents/dconstruction/construction_manual/CM_ver_3.0.pdf
DE	Construction Manual	http://constructionmanual.deldot.wikispaces.net/Part+C+-+Contract+Administration
FL	Construction Project Administration Manual	https://www.fdot.gov/construction/manuals/cpam/CPAMManual.shtm
GA	Construction Manual	http://www.dot.ga.gov/PartnerSmart/Business/Source/construction/cm001.pdf
HI	Standard Specifications	http://hidot.hawaii.gov/highways/files/2013/01/648A__Field-Posted_Drawings.pdf
ID	Roadway Design Manual	http://apps.itd.idaho.gov/apps/manuals/RoadwayDesign/files/Roadwaydesignprintable.pdf
	Standard Specifications for Highway Construction	http://apps.itd.idaho.gov/apps/manuals/SpecBook.pdf
IL	Construction Manual	http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Construction/Construction-Manual/Construction%20Manual.pdf
	Standard Specifications for Road and Bridge Construction	http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Construction/Standard-Specifications/Standard%20Specifications%20for%20Road%20and%20Bridge%20Construction%202016.pdf
IN	Design Manual	http://www.in.gov/dot/div/contracts/design/IDM%20Complete%202013.pdf
	Standard Specifications	http://www.in.gov/dot/div/contracts/standards/book/sep17/2018Master.pdf
IA	Construction Manual	https://iowadot.gov/erl/current/CM/content/CM%202.70.htm
KS	Construction Manual	https://www.ksdot.org/Assets/wwwksdotorg/bureaus/burConsMain/Connections/ConstManual/2014%20Construction%20Manual-Parts%20I%20-%20IV.pdf

	Standard Specifications for State Road and Bridge Construction	https://www.ksdot.org/Assets/wwwksdotorg/bureaus/burConsMain/specprov/2015/802.pdf
KY	Construction Guidance Manual	https://transportation.ky.gov/Organizational-Resources/Policy%20Manuals%20Library/Construction.pdf
LA	Construction Contract Administration Manual	http://wwwsp.dotd.la.gov/Inside_LaDOTD/Divisions/Engineering/Misc%20Documents/Construction%20Contract%20Administration%20Manual/Construction%20Contract%20Administration%20Manual%207-13-17%20Revised.pdf
	Standard Specifications for Roads and Bridges	http://wwwsp.dotd.la.gov/Inside_LaDOTD/Divisions/Engineering/Standard_Specifications/Standard%20Specifications/2016%20Standard%20Specifications%20for%20Roads%20and%20Bridges%20Manual/00%20-%202016%20-%20Standard%20Specification%20(complete%20manual).pdf
ME	Highway Design Guide	http://www.maine.gov/mdot/hdg/docs/hdg-revised%202-2015.pdf
MD	State Highway Administrative Office of Construction Sub-recipient Construction Manual	http://www.roads.maryland.gov/OOC_Forms/_OOC%20LPA%20Manual.pdf
MI	Road Design Manual	https://mdotcf.state.mi.us/public/design/englishroadmanual/
MN	Bridge Construction Manual	http://www.dot.state.mn.us/bridge/pdf/constrmanual/bridgeconstructionmanual.pdf
MS	Construction Manual	http://sp.mdot.ms.gov/Construction/Manuals/Construction%20Manual%20July%202017.pdf
	Standard Specifications for Road and Bridge Construction	http://sp.mdot.ms.gov/Construction/Standard%20Specifications/2017%20Standard%20Specifications.pdf
MO	Engineering Policy Guide	http://epg.modot.org/index.php?title=Category:239_Construction_Inspection_Guidelines_for_Final_Plans
MT	Road Design Manual	http://www.mdt.mt.gov/other/webdata/external/cadd/RDM/50-RDM-COMPLETE.pdf
NE	Construction Manual	http://dot.nebraska.gov/media/6913/cst-ma-1.pdf
NV	Construction Manual	https://www.nevadadot.com/home/showdocument?id=9196
	Documentation Manual	https://www.nevadadot.com/home/showdocument?id=9274
	Structures Manual	https://www.nevadadot.com/home/showdocument?id=1733
NH	Standard Specifications for Road and Bridge Construction	https://www.nh.gov/dot/org/projectdevelopment/highwaydesign/specifications/documents/2016NHDOTSpecBookWeb.pdf

NJ	Construction Procedure Handbook	http://www.state.nj.us/transportation/eng/construction/pdf/Sec7SubSecH2.pdf
	Standard Specifications for Road and Bridge Construction	http://www.state.nj.us/transportation/eng/specs/2007/pdf/StandSpecRoadBridge.pdf
NM	Standard Specifications for Highway and Bridge Construction	http://dot.state.nm.us/content/dam/nmdot/Plans_Specs_Estimates/2014_Specs_For_Highway_And_Bridge_Construction.pdf
NY	Contract Administration Manual	https://www.dot.ny.gov/main/business-center/contractors/construction-division/construction-repository/CAM_Sect91.pdf
NC	Standard Specifications for Roads and Structures	https://connect.ncdot.gov/resources/Specifications/2012StandSpecsMan/PDF/2012%20Standard%20Specifications%20Manual%20with%20ASTM.pdf
ND	Construction Records Manual	https://www.dot.nd.gov/manuals/construction/constr-records/2014/completemanual.pdf
	CADD Standards Manual	https://www.dot.nd.gov/manuals/design/caddmanual/caddmanual.pdf
OR	Construction Manual	http://www.oregon.gov/ODOT/Construction/Doc_ConstructionManual/cm_all.pdf
	Standard Specifications for Construction	http://www.oregon.gov/ODOT/Business/Documents/2018_STANDARD_SPECIFICATIONS.pdf
PA	Design Manual Part 3: Plans Presentation	http://www.dot.state.pa.us/public/pubsforms/Publications/PUB%2014M.pdf
SC	Construction Manual	https://www.dot.state.sc.us/business/scdot-construction-manual.aspx
	Manual of Instructions for the Preparation of As-Built Plans	http://www.dot.state.sc.us/business/pdf/asBuilt_Forms/asBuilt_manual.pdf
	Roadway Design Manual	http://www.dot.state.sc.us/business/pdf/roadway/2017_SCDOT_Roadway_Design_Manual.pdf
	As-Built Construction Plans Supplemental Specifications	http://www.dot.state.sc.us/business/pdf/asBuilt_Forms/asBuilt_Plans_SuppSpech.pdf
UT	Completing and Archiving As-Built Construction Plans	http://www.udot.utah.gov/main/uconowner.gf?n=10486916241566300
	Construction Manual of Instruction	https://www.udot.utah.gov/main/uconowner.gf?n=23155926721402429
	Standard	http://www.udot.utah.gov/main/uconowner.gf?n=31730316757114651

	Specifications for Road and Bridge Construction	
VT	Construction Manual	https://outside.vermont.gov/agency/vtrans/external/docs/construction/2017%20Construction%20Manual%20Addendum.pdf
VA	Construction Manual	http://www.virginiadot.org/business/resources/const/ConstructionManual.pdf
	Post Construction Manual	http://www.virginiadot.org/business/resources/const/pc_manual.pdf
WA	Construction Manual	https://www.wsdot.wa.gov/publications/manuals/fulltext/M41-01/Construction.pdf
WV	Standard Specifications for Roads and Bridges	http://transportation.wv.gov/highways/contractadmin/specifications/2017StandSpec/Documents/2017_Standard.pdf
WI	Construction and Materials Manual	http://wisconsindot.gov/rdwy/cmm/cm-01-65.pdf#cm1-65.14
WY	Construction Manual	ftp://wydot-filestore.dot.state.wy.us/construction/constructionmanuals/2018%20Construction%20Manual/2018%20Construction%20Manual.pdf

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