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REDEFINING CONSTRUCTION “AS-BUILT” PLANS TO MEET CURRENT KENTUCKY TRANSPORTATION CABINET NEEDS

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THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering in the College of Engineering at the University of Kentucky

By

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ABSTRACT OF THESIS

REDEFINING CONSTRUCTION “AS-BUILT” PLANS TO MEET CURRENT KENTUCKY TRANSPORTATION CABINET NEEDS

As-built drawings are the traditional method used by the construction industry 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, the process of creating them has proven to be difficult. It is a time consuming process and entities often lack the resources necessary to complete accurate and detailed as-builts. After an investigation of current as-built operations within State Transportation Agencies, recommendations have been made to redefine construction "as-built" plans to meet current state transportation needs. First, the importance of a central storage location accessible to all stakeholders cannot be overemphasized. Along with a central storage location, standard guidelines should be developed regarding what information is required to be included within as-built plans. This study's approach to developing such guidelines included meeting with as-built end users and formulating a list of requested information. To ensure as-builts are being completed on time and accurately, it is recommended that as-built plans be developed throughout the project using simple to use editing software on iPads. A PDF editor is ideal for as-built development as PDF is the requested format by most end users. Finally, to ensure this process is being followed by construction, a liaison between as-built developers and users is recommended.

KEYWORDS: As-Builts, Construction Plans, Construction Management, Design-Construction Integration, Project Documentation

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1. Introduction and Background

The United States is facing an infrastructure crisis as current transportation infrastructure is deteriorating and failing. 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 the current infrastructure, as-built plans can provide important insight into existing infrastructure systems.

Over the years, as-built plans have been the method used by the construction industry to capture and record construction changes and additions that are 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 defines as-built plans 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 operations, maintenance, repairs, and rehabilitation of current transportation infrastructure. As-builts also provide a baseline for new design projects by providing information on current transportation infrastructure and other facilities such as underground and overhead utilities. While the importance of as-built plans is widely recognized, current as-built development practices 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 industry has adopted advanced data collection methods utilizing technologies such as LiDAR, 3D information modeling, and Ground Penetration Radar. These technologies have changed the format, accuracy, and level of detail required for transportation projects, and have allowed designers to include more accurate information on construction plans. However, the use of these technologies in as-built development has not been as quick and coordinated, making some information included in traditional as-builts inferior to information collected with higher accuracy. While electronic and 3-D technology is becoming the norm for engineering practices, some entities still choose to hand draw as-built information on the original construction plans.

Within the Kentucky Transportation Cabinet (KYTC), the Section Engineer's Office is responsible for preparing as-built plans. This process is initiated after the completion of the project. According to the 2009 KYTC Construction Guidance Manual, the as-built plans are sent to the Division of Highway Design Microfilm section to be reviewed and then transferred to the Department of Library and Archives for microfilming after they are developed. The original as-built hard copy plans will then be stored according 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 slowly waned over the past several years. Available time, current resources, and new technology have made the completion of as-builts difficult. The current as-built process is time

consuming and the section engineers do not have 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 required for as-builts. Because of these reasons, the current practices used at KYTC to develop as-builts need to be revised to ensure as-built plans are being developed on time.

A research team was assembled to accomplish three tasks in regards to as-built development at KYTC. First, the team was to synthesize the current state-of-the-practice at KYTC. This synthesis included structured interviews with as-built users and as-built developers. Structured interviews with as-built end users focused on what information users required on as-built plans, what format they wanted as-builts in, and where they wanted as-builts stored. A structured interview with as-built developers focused on the current processes used by section engineers to develop as-builts and obstacles they encounter while developing as-builts. Next, the team conducted a synthesis on the current state-of-the-practice at other STAs. Finally, recommendations were made for future procedures and practices regarding as-built plans at KYTC.

This work examines current as-built practices within State Transportation Agencies (STAs) and the private industry through a literature review and an in depth study with the Kentucky Transportation Cabinet. The contribution of the current work to the existing body of knowledge is to examine the current practice regarding as-built development procedures within the transportation industry, to identify relevant information that is needed by as-built end users to effectively manage road transportation networks, and to identify methods for as-built developers to gather such information. Combining the information gathered on current practices and requested information,

suggestions will be provided on methods to capture such information, while understanding and maximizing the resources available to as-built developers.

1.1 Project Scope and Objectives

The scope of this research project is confined to the analysis of information collected from literature and interviews.

The objective of this report is to synthesize the current state-of-the-practice at KYTC regarding as-built plans, summarize the efforts and requirements of other STAs to determine the industry standard for how as-built plans are currently developed and utilized, develop recommendations for the future needs and direction regarding the development and distribution of as-built information at KYTC, and collaborate with Project Development and Project Delivery to design a process for development and distribution for the newly defined as-built information.

The report highlights the state of the practice so that efforts can be made to fill research gaps and establish a path to improvement. Some issues facing as-built development include IT issues, a lack of technical staffing, a lack of management support, uncertainty on where to begin, and a lack of available technology.

1.2 Research Methodology

The fundamental aspect of the research methodology is the interviews with as-built developers and end users at KYTC regarding as-built development, preservation, and usage for various delivery methods.

To support the development of the interview questions and the compilation of this report, a literature review was conducted on topics related to as-built development, preservation, and usage. Much of this review focused on as-built practices at STAs found

in publicly available manuals and guidelines, but it also included a review of as-built practices throughout the private industry.

2. Literature Review

During the research time, a literature review was conducted to analyze the methods in which the State Transportation Agencies (STAs) and other engineering and construction firms conduct as-built operations. Information of focus included: the entity responsible for as-built development, the methods used to capture and record as-built information, the platforms used to establish as-built plans, the information recorded on as-built plans, the accuracy and usefulness of as-built plans, the format and location in which as-built plans are stored, and the use of as-built plans after they are approved.

2.1 As-Built Practices in State Transportation Agencies

A web review of all 50 STAs was conducted to summarize the state-of-the-practice regarding as-built procedures for each STA. Forty-two STAs documented as-built related practices and requirements in their manuals or specifications. The final synthesis included as-built information from 17 STA Specifications, 28 Construction Manuals, 7 Design Manuals, and 8 other manuals and guides found on STA websites. The data summarized below is based on publicly available STA guidelines, and does not necessarily describe current practices. Table 2.1 summarizes each STA's as-built practices. Appendix A lists links to the publicly available STA documents used to develop Table 2.1.

Table 2.1: 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]	One of 3 ways: (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 2.1 (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 2.1 (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 will be 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 2.1 (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 in order 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 is provided. If not, just hard copy prints.		As-Built plans should be kept current.

Table 2.1 (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

The entity who develops as-builts for STAs was grouped into one of the following 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 identified the entity responsible for developing their as-builts. The categorical breakdown was as follows: 23 STAs have in-house employees creating as-builts, 7 have in-house personnel or design consultants creating as-builts, 3 have contractors creating as-builts, and 2 STAs list in-house personnel or the contractor creating as-builts. Results are displayed in Figure 2.1.

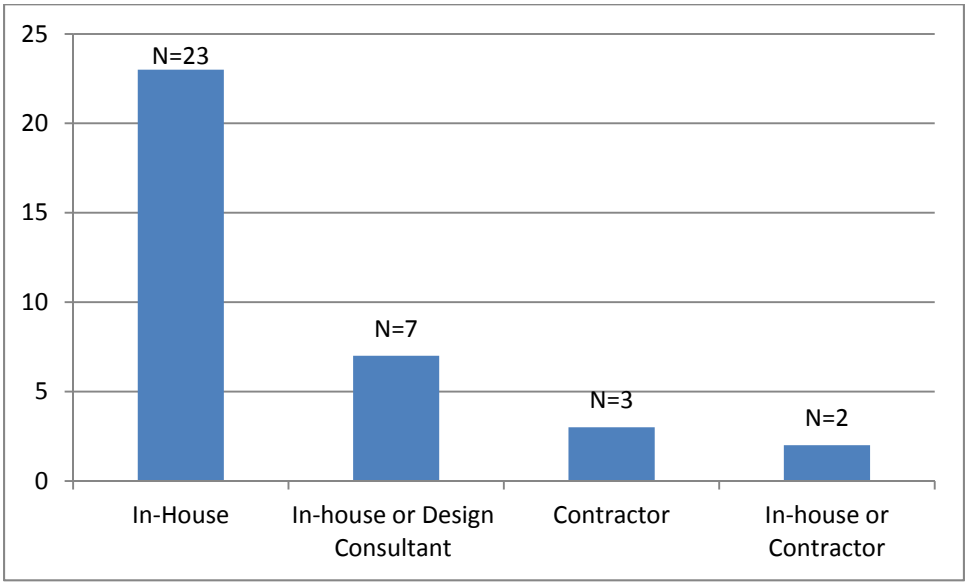

Figure 2.1: Entity Responsible for As-Built Development for STAs

While only 5 STAs assign the contractor as the lead for as-built development, 19 have the contractor developing some type of as-built drawings even though they are not identified as the party responsible for as-built development. Most of these additional contractor created as-builts are for specialty items such as electrical work, irrigation systems, or water and sewer systems. However, Colorado and Connecticut have the

contractor developing complete project as-built drawings to assist the responsible party in the completion of the official as-builts (Colorado Department of Transportation 2017, Connecticut Department of Transportation 2017). Table 2.2 lists as-builts required to be completed by contractors for corresponding STAs.

Table 2.2: 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 over several decades, the processes and methods used to capture as-built information are continuously changing as new technology emerges. Recently LiDAR, information modeling, and GPS technologies have changed the way the transportation industry collects data and develop plans, making them more accurate and detailed. While some construction firms and companies are utilizing these technologies

for as-built development, according to published manuals, several STAs are not. Thirty-three STAs provide information on the method used to record as-built information. According to publicly available STA guidelines, 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 to electronic files such as PDF or CAD. Eight STAs allow as-built to be developed manually or electronically and only four STAs require as-builts to be developed electronically from the beginning. Results are displayed in Figure 2.2. Table 2.1 lists the processes used to record as-built information for all 33 STAs in which this information was provided in their publicly available manuals.

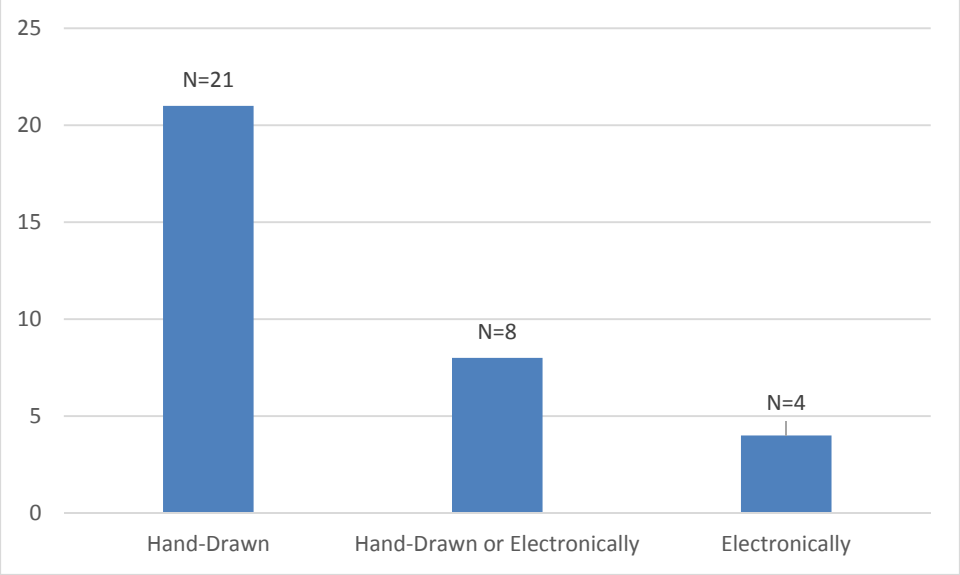

Figure 2.2: Method Used to Record As-Built Information for STAs

The format in which as-builts are stored for various STAs was also examined. Thirty-seven states documented how their department stores completed as-builts. The formats were categorized in one of the following: microfilm, hard copy prints, or electronically stored plans. The categorical breakdown was as follows: 5 STAs store as-

builts as microfilms, 7 store as-builts as hard copies, 15 store as-builts electronically, 5 require more than one form of as-builts to be stored, and 5 provide options for as-built storage. A visual representation of the results can be found in Figure 2.3.

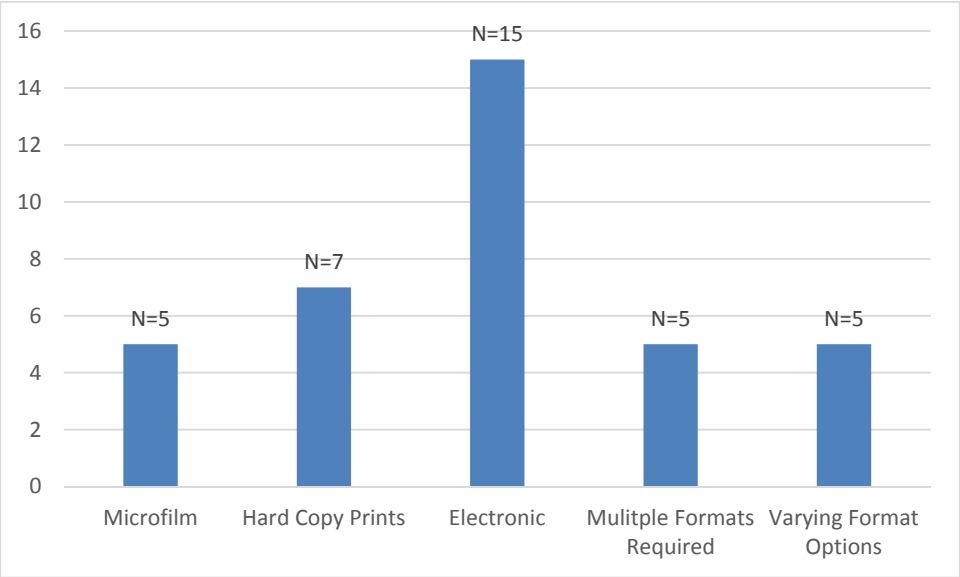

Figure 2.3: Format of Stored As-Builts for STAs

Ten STAs that store as-built plans electronically require they be stored in PDF format. In addition to their PDF as-built plans, Arizona Department of Transportation captures a five to ten minute video recording of the project site weekly. These recordings result in video as-builts of the project. These unofficial video as-builts establish a project time frame by displaying equipment, personnel, material, and construction progress (Arizona Department of Transportation 2015).

The location in which as-built plans are stored relates to the format in which they are stored. Majority of the STAs that are storing as-built plans electronically are storing them in Electronic Document Management Systems (EDMS), while storage locations for the other formats vary by STA. As-Built storage formatting and location for STAs can be found in Table 2.1.

In order for as-builts to be useful beyond their creation, it is imperative to identify what information about the project operators, maintenance crews, and others will need in the future. To accomplish this, it is ideal that individuals or entities who will maintain the facility or infrastructure have a say in what will be included in the as-built plans (Whyte et al. 2016). Several STAs mention in their manuals and specifications what information should be recorded on their as-built drawings. Common required revisions to be recorded on as-built plans throughout 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

The information provided in STA construction manuals, design manuals, and specifications gave insight into how as-builts should be developed and how and where they should be stored. However, there is little to no mention of the handover of the as-built plans from their developers to their potential users or how they are used after

completion. The process of developing and storing as-builts according to guidelines, and accessing them several years down the road when needed may not be an issue with hand-drawn as-builts developed according to agency standards. However, with changing technologies and a lack of attention to detail often noticed in as-built development, there is a need for proper communication and handover techniques between as-built developers and end users. A review of private industry as-built practices offered insight on the importance of communication between as-built developers and end users during the as-built development process. It also provided information on the potential for 3D technologies, such as BIM and LiDAR, in the as-built development process (Randall, 2011). No STA listed 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 also be more detailed. 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, and any others who will need the as-built information in the future to better manage and maintain the infrastructure. This can require meetings 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). Utah is an example of a STA who practices this handover method. Contractors and engineers engage in a preconstruction conference in which the engineer clearly defines what he or she expects on the as-builts for the particular project (Utah

Department of Transportation 2016). Without proper and planned transfer, information is likely to lost or misinterpreted.

The timing of the handover is arguably the most important aspect of the handover procedure. If the handover process is not given adequate time, mistakes are more likely to be made. The physical act of handing over as-built data can only occur once the project is complete and all information has been updated. However, the build-up for handover should begin during the design phase. This involves continuously updating plans and digital data to the as-built condition throughout the project. If changes to the project are not recorded until the end, as-builts are often rushed and mistakes are likely to be made (Whyte at el. 2016). Fourteen STAs require as-built plans to be maintained throughout the project duration. Information on which states require continuous updating 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. In the past, as-built plan development has been a manual process that is error prone (Abdel-Monem and Hegazy, 2013). As-builts often consist of hundreds of plan drawings with unknown accuracy (Randall, 2011). However, it is essential that as-built data be accurate and of high quality for it to be trusted and used in decision making. Because of the potential for inaccuracies, data and as-builts information are often not used even when available (Whyte et al. 2010). For example, an Olympic Delivery Authority grounds work and services manager is quoted, "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, completely falls away," when asked about trust of data for built infrastructure (Whyte et al. 2016). Few STAs mentioned required accuracy of as-built plans, and most had vague descriptions (e.g.

"The as-built plans should be carefully and accurately prepared"). Connecticut Department of Transportation requires field personal to receive training from engineers before they can develop electronic as-builts to ensure accuracy, high quality, and consistency (Connecticut Department of Transportation 2017).

Technology advancements will assist with the improvement of quality and accuracy of as-builts in the future. Building Information Modeling (BIM) is a 3-dimensional representation of physical and functional features of a facility. As of 2011, nearly half of the architecture, engineering, and construction sector was using BIM. It has been noted to have several benefits to traditional 2-D designs, such as an improving lifecycle management of buildings. Laser scanning technologies perform thousands of measurements per second of the 3-D coordinates of a designated area. The 3-D surface model created by these scans are much more accurate than traditional surveys. By combining BIM with laser scanning technologies, as-built conditions can be accurately captured and fully represented in the 3-D model, and updated as the project progresses. At project completion, the project site should be scanned and transferred to the as-built BIM file to assist with facility management (Randall 2011).

Another potential technology to be used for as-built development is Interactive Voice Response (IVR). A case study was performed to analyze the technology and suggest next steps to be taken in order to implement the technology in a larger dimension. The IVR system collected data about the project from supervisors on a daily basis or more frequently if initiated by the supervisor. The system calls the supervisors at the end of the work day and asks if any work has been completed. Based on the response of the supervisor, the system asks follow up questions, such has what percentage of the

expected daily work was completed, and allows the supervisor to leave comments. The system will then send an e-mail to the project e-mail account with the information recorded during the phone call. Finally, a reporting tool will log all communication and update 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 who participated in the case study stated the system was easy to use, had high sound quality, and was practical. However, they also mentioned the potential issues of construction noise on sound quality and 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, however, next steps of the project included adding as-built information such as changes to materials and dimensions to the IVR system (Abdel-Monem and Hegazy 2013).

3. Kentucky Transportation Cabinet End User Interviews

Structured interviews were conducted with engineers and technicians from six end user groups at KYTC including 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. The interview questions were identical for all six groups and are listed below.

- 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 haven't asked?

As interviews progressed end users were asked more specific questions related to their as-built needs.

3.1 Current Uses

The first interview question asked to all end users was "How are you currently using as-builts?" The consensus throughout all end users is that as-builts are rarely being used. The reasons stated as to why as-builts are not being used included:

- as-builts are not being completed,
- as-builts are unreliable,
- new technology is better than hand drawn as-builts,

- as-builts are not required to be made in regards to permitting, and
- some end users, such as utilities, are involved later in the project and do not have time to look through as-builts.

End users that are attempting to use as-builts stated that accurate and available as-builts would save them time and money. Bridge Maintenance uses as-builts for scour assessments. Of the last 500 scour assessments completed by Bridge Maintenance, they were able to find as-builts for three. When they do not have as-builts they have to be more conservative by either increasing inspection frequencies or posting bridges as load limited bridges which has negative economic impacts. Pavement Design stated that after using unreliable as-builts they no longer trust the few as-builts they receive. Because of this, they are performing more forensics than necessary. Last year they spent $217,000 on 10 projects for forensics. They believe if they were able to trust the as-builts they would have spent approximately 50% of that amount.

3.2 As-Built Delivery

According to the Bridge Maintenance and Structural Design/Geotechnical groups, the limited as-built plans they are receiving are delivered to them by e-mail. Pavement Design stated that any as-builts they find they do so by time-consuming searches through project data base systems. The typical format in which as-builts are delivered is PDF.

Most end users believe that as-builts should be stored in a central storage location in which everyone has access. ProjectWise was a common storage location mentioned by end users. One engineer suggested that only a few individuals have write access to as-builts in a central storage location, while most have read only access. PDF is the

preferred storage format by most end users. Bridge Maintenance, Pavement Design, and Structural Design/Geotechnical all preferred red-lined plans, while Highway Design preferred the use of LiDAR for as-built plans

3.3 “Perfect World” As-Builts

Table 3.1 lists the accumulated information wanted from as-built plans obtained from interviews with end users. For example, Bridge Maintenance indicated their perfect world as-builts would include pile tip elevations, concrete cylinder breaks, beam seat information, x-dimensions, culvert fill heights, and foundation layouts. Similar information for all six end user groups can be found in Table 3.1. Table 3.1 also describes the current method used to collect the identified as-built information as well as potential new methods (when known or applicable) that might be used to collect this information. However, methods listed as current may not be practiced or the information recorded using these methods may be lost in transition from developers to end users. Shaded cells in the new method column of Table 3.1 represent areas in which future research is necessary to establish a new method for as-built collection practices or where current methods will suffice. Information noted as being measured indicates it was measured to tolerances specified within the project specifications. Information noted as being surveyed indicates it was measured to universal accuracy tolerances using a Total Station or other surveying equipment. Surveys are location dependent, while measurements are not.

Table 3.1: 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

Table 3.1 (continued)

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

Throughout the interviews it became clear that traditional definition of as-builts needs to evolve. Highway Design, 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 refer to as a "post construction survey" is very important to the design process. While each group had a different view 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 upon their accuracy. If as-builts are accurate they are invaluable, however, if they are not accurate, or if the level of accuracy is unknown, they become worthless since the information cannot be trusted.

3.5 As-Built Process Improvement

Several ideas were provided by the end users on how to improve the as-built process. All groups agreed in order to improve the process it is essential that end users are specific in what information they need and the accuracy they require. This will save time and money and encourage construction to collect as-built information. A liaison between construction and end users was also suggested. The Structural

Design/Geotechnical group plans to hire a technician who will help construction complete and organize as-builts according to their needs. Other suggestions include hiring a licensed surveyor to survey completed projects and creating confidence levels for as-builts. Confidence levels would provide end users with a rating that informs them of how confident they can be in as-built accuracy. The confidence level would depend on the accuracy level construction was able to achieve while completing the as-builts.

4.0 Kentucky Transportation Cabinet As-Built Developer Interviews

After concluding interviews with end users, and summarizing their requested as-built information, the research team conducted an interview with four section engineers responsible for developing as-built drawings. These engineers work for different districts within KYTC, and are located in different geographic regions of the state. All information recorded and written in this section was obtained from a structured interview with these engineers. The interview questions asked during the interview are listed below.

- 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 faces 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

All section engineers are developing as-built plans for major projects, specifically bridge projects. Items often recorded on bridge as-built plan 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 drain and grade projects, such as changes in typical sections. Two section engineers stated their districts

were treating construction revisions on projects as the grade and drain as-built plans, and were not developing as-builts separately.

4.2 Utilization of As-Built Plans by Project Managers

All four section engineers do not believe that project managers are using as-builts. This belief stems from the fact that the section engineers are not confident on where to store as-builts. They are submitting as-builts to different locations because there is insufficient guidance on where as-builts should be sent and stored. 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 agreed that this lack of use of as-builts by project managers is a reason why the emphasis on creating as-builts has waned of the past years. They agreed that if they were certain project engineers were using as-builts, they would be more diligent about collecting and recording as-built information.

4.3 Biggest Obstacles When Developing As-Builts

Engineers were asked, "What are the biggest obstacles your office faces when developing as-built plans?" Answers were similar across all four section engineers and are listed below.

- Insufficient guidance on where to store as-builts once they are completed.
- Insufficient guidance on what to capture on as-built plans.
- Limited inspector capabilities.
- Limited time to complete as-builts.
- Lack of resources needed to develop as-builts.

- Difficulty transferring as-built notes into a format that can be used by end users.

After interviews, it was discovered that a document titled, "Guidance for the Use of ProjectWise in Section Offices for Construction Administration" states that as-builts should be stored in ProjectWise after completion and provides the naming convention to be used when stored (Commonwealth of Kentucky Transportation Cabinet 2017). However, since section engineers were unsure of storage location, it is suggested that this information be replicated into other manuals and guidance documents to provide consistency in all documents on where to store as-built plans. This 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. As-built procedures mentioned at the meeting differed from as-built procedures found in publicly available manuals for four STAs (2018, June10-14).

Current inspector capabilities limit the technology that can be used to create as-builts. Many section engineers have found that inspectors lack the skills required 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, the current KYTC workload is a time resource issue when developing as-builts. As-builts use to be developed in the construction off season, however, today there is no downtime for engineers to develop as-builts for the previous year's projects. Without this designated timeframe, section engineers have trouble making time for as-built development. Also, resources that would help with as-built development are not always available to Section Offices. A GPS rover would be greatly beneficial to

as-built development, however, it is difficult for every office to have access to a rover when needed. Finally, section engineers informed the team that recording as-built notes was fairly easy and reasonable, however, putting this information into a format that can be used by the end users is rather time consuming and often difficult.

4.4 Format and Storage Location of As-Built Plans

The format in which as-builts are created depends on the specific inspector and his/her abilities. If the inspector is capable of using Blue Beam, Adobe, or Microstation, as-builts are developed using these software packages. The section engineers found developing as-builts this way was more efficient. However, some of their inspectors lack the skills to use these programs. When this is the case, half-set plans are marked with red pencil and then scanned to develop the as-built plans.

Storage location of as-builts was also mentioned when discussing this question. Different answers were given for 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 also keep a set of as-builts in their section office either electronically or as paper copies stored in filing. This lack of uniform storage is a major issue and concern with the as-built process at KYTC.

4.5 As-Built Process Improvement

The section engineers had several ideas and suggestions of how to improve the current as-built development process. First and foremost, they want better guidelines on what information to collect, and what to do with the as-built plans after they are completed. Guidelines would eliminate the ambiguity of as-built development and

provide all section engineers with the same checklist when developing as-builts. They also suggested uploading the as-built plans to the GIS referenced project archives. They noted that often in ProjectWise, plans are difficult to find because of their competing project identifiers. When each project has different numbers representing the same 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 geographical location of the project.

While storage location of as-built plans was a major issue with KYTC's as-built development process, the act of developing as-builts also needs improvement. Time was one the obstacles listed by section engineers in the as-built development process. To combat this obstacle, section engineers suggested developing as-builts as the project progresses. Fourteen of the other 41 STAs studied require as-builts to be developed throughout the project duration. While developing as-builts as the project progresses, section engineers could submit partial as-builts as an activity is complete such as submitting storm sewer as-builts as soon as the storm sewer construction is completed. This procedure of developing as-builts as the project progresses will require in field editing capabilities. The section engineers suggested a PDF editor available on their portable iPads to complete as-builts in the field. Training for inspectors on how to create digital as-builts on the iPads may be necessary in order to implement this change. Connecticut DOT does not allow field personnel to maintain digital as-builts unless properly trained. This has ensured consistency and accuracy in as-built drawings for their department (Connecticut Department of Transportation 2017).

Finally, the section engineers proposed the idea of design consultants or contactors assisting 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 collecting, or consultants or contractors developing all as-built plans. Twelve STAs have the contractor or a design consultant developing as-built plans for their projects according to a web review of STA published manuals.

5.0 Interim Recommendations

After the completion of interviews with KYTC employees, interim recommendations were made. Recommendations were constrained to the bulleted list found below.

- Establish a central storage location for as-builts that is known by all Section Offices and end users.
- Develop a naming convention for as-built plans that makes locating as-builts in the storage location straight-forward.
- Develop clear and specific lists of requested as-built information for each end-user and specify the accuracy they require.
- Ensure as-builts are being developed during the project, and not after it is finished.
- Deliver as-builts in PDF format.
- Establish a liaison between construction and end users who ensures as-builts are being completed and stored properly.
- Form a task force to help accomplish the above tasks.

These recommendations were formed based on input from both as-built developers and end users. The goal of the recommendations was to provide procedures to capture and store requested as-built information, while understanding and maximizing the resources available to as-built developers.

6. Task Force Development and Workshop

After the conclusion of the interviews with as-built end users and developers and interim recommendations were made by the project team, a task force was created to review the recommendations. The developed task force consists of five as-built end users representing Bridge Maintenance, Highway Design, Structural Design, and Project Development, and five as-built developers representing two district offices, Highway Design, and the Central Office Construction Section.

After reviewing the recommendations, a workshop was scheduled with the project team and the task force to begin to implement the recommendations. The workshop would help establish what information is required on as-built plans according to the project work type, the level of detail required of as-built information, the preferred method of collecting the as-built information, and the format and storage location of finished as-builts. The complete as-built process from beginning of development to storage would be discussed in great detail as-well.

6.1 Task Force Workshop

The purpose of the workshop was to gather the information listed above through discussion between as-built developers and end users. Throughout this project it was clear that there must be balance between obtaining the as-built information requested by end users while understanding that as-built developers have limited time and resources to spend on as-built development. By gathering both parties, it was intended to reach a compromise and create an official procedure for how as-built information would be recorded and stored.

Table 6.1 below was developed from the workshop. At the beginning of the meeting, each attendee was given a blank table with the only the bolded requested as-built information by end user group. The workshop process was as follows: the project team introduced a new topic under the requested as-built information; the end users explained why they wanted that information and how they preferred it to be collected and stored; the developers discussed their abilities to gather such information; and a compromise was made between end users and developers on a specific item and additional comments were recorded. The final product is below as Table 6.1.

Table 6.1: 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 6.1 (continued)

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 6.1 (continued)

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 6.1 (continued)

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	

In addition to the information gathered in Table 6.1, comments about general as-built procedures were recorded and are listed below.

- End users want separate structure plans apart 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.
- Structural Design is working on developing a group focused on as-builts.
- Construction has used rent-a-techs for as-built development in busy periods.
- Shop drawing changes need to tracked. This may be the responsibility of the shop inspectors and more research is needed in this area.
- Every change to a structure must be recorded even if there is no drawing number.
- Pavement Design has no faith in as-builts and is doing forensics on everything.
- Construction does not have plans on pavement rehabilitation projects, so they are unsure of where to record as-built information.
- Proposal plans need to be linked to the original plans in ArchGIS.
- It is not reasonable or practical for Construction to go back and gather information on facilities that are already there.
- If design consultants are used for as-built development, their contract should be kept open until as-builts are complete (e.g. Consultant would receive 90% of contract amount at the end of construction and the remaining 10% would be awarded after as-built development is complete.)

- Current contractors know that KYTC is not inspecting projects, so they have less of an incentive to build to design.
- 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 for mass use.
- A next step is to establish a liaison between Construction and end users to ensure as-builts are being store uniformly.
- Current contractors are often inexperienced and have a high reliance of technology.

The information gathered through the workshop was used to develop a recommended procedure for as-built development at KYTC. Chapter 7 of this report narratively and graphically describes the recommended procedure. The recommendations are written for current resources available at KYTC. As resources and staffing evolve, revisions to the procedure can be made. These future opportunities at KYTC for as-built development are mentioned, but have not be fully researched. Therefore their presence in the report is limited.

7.0 Recommended As-Built Procedure

At the conclusion of the project, the research team developed a recommended procedure to be implemented immediately at the Kentucky Transportation Cabinet. The team also developed recommended procedures that require additional time and resources by KYTC. Figure 7. 1 below is a graphical representation of the proposed process.

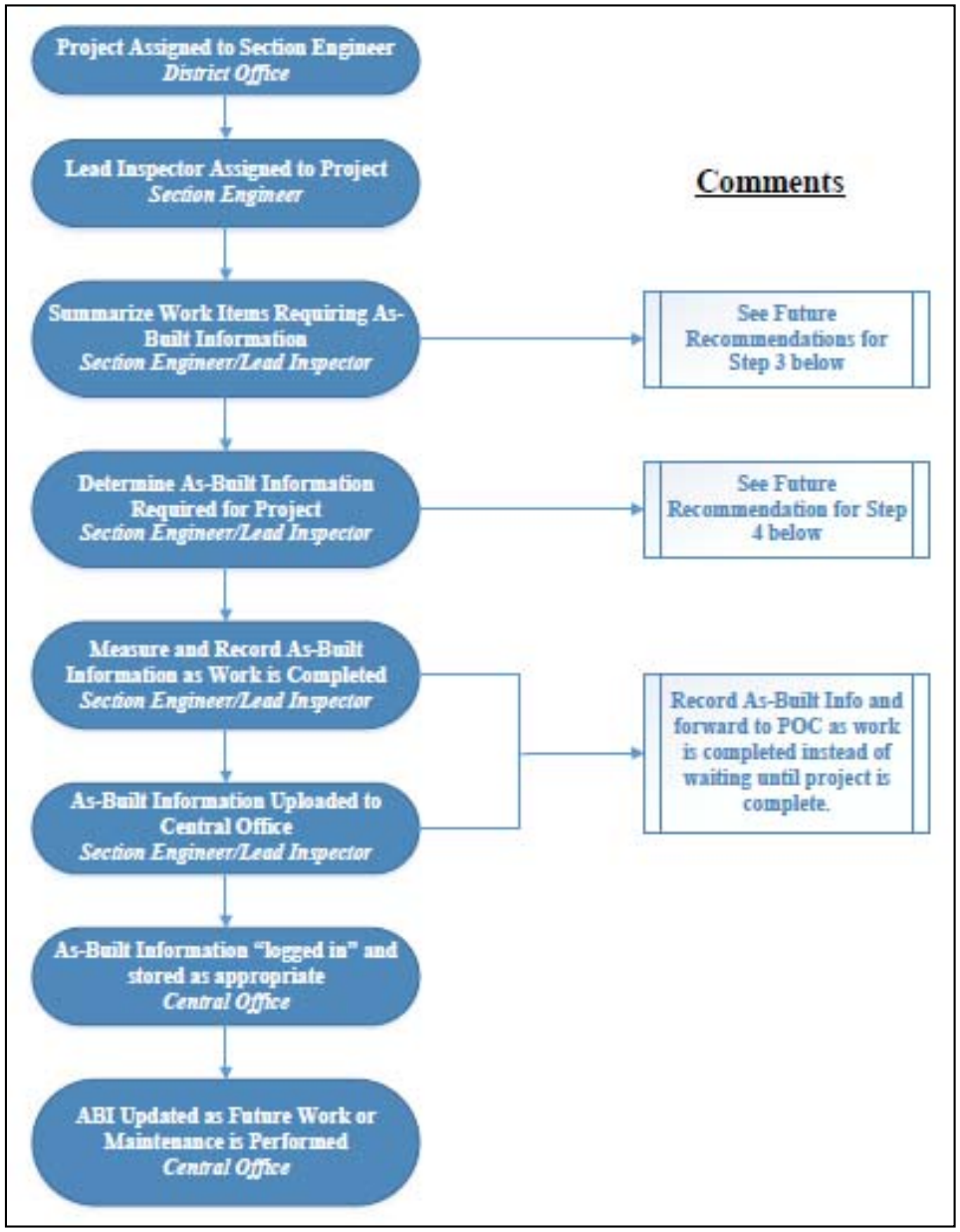

Figure 7.1: Proposed Process for Development of As-Built Construction Information

The process will start as any project at KYTC does, with the project assigned to a Section Engineer and a Lead Inspector. The Section Engineer and/or the Lead Inspector will summarize the work items requiring as-built information and determine the required as-built information for the project. To date, an As-Built Information Checklist has been developed to perform these steps. The checklist shown below as Table 7.1, lists the as-built information. If a project has these work items, as-built information is required. The checklist is organized by end user and also describes the minimum acceptable recording method for all required as-built information. If the as-built developer has access and the skill to record as-built information to a higher accuracy than that listed in the table, it is acceptable. All as-built information should be converted to PDF format before submittal.

Table 7.1: As-Built Information Checklist

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
	X-Dimensions	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

Ideally, requested as-built information would be linked to pay items in SiteManager rather than the As-Built Information Checklist provided. For example, if a project has pay

item 08046 Piles-Steel HP 12x53, the following information would populate in SiteManager as the required as-built information to be collected regarding this pay item:

- Pile tip elevations
- X-Dimensions
- Foundation layouts
- Pile lengths
- Bearing details
- Rock cut slopes
- Cut and fill slopes
- Subsurface utility information
- Utility conflict information

KYTC should consider adding a note to the General Notes sheet of the plans, or a Special Note for proposal only projects, indicating the items that required as-built information. This process will help Construction know what information needs to be collected and what doesn't. For example, if the project requires pay item 06510 Pave striping-temp paint-4 in, SiteManager would not generate required as-built information and Construction would know not to collect information regarding temporary pavement striping.

After the required as-built information to be collected is determined and the project begins, the Section Engineer and/or Lead Inspector will record as-built information and forward it to a designated point of contact as the work progresses, rather than at the end of the project. The designated point of contact should be the as-built point

of contact throughout KYTC and located in the Central Office. His or her job will be to receive as-built information from Section Engineers and upload it to ProjectWise or another electronic document management system if appropriate. It is essential that the as-built information is uploaded and stored uniformly throughout KYTC. As-Built information should be updated continuously as maintenance and future work is performed.

8.0 Conclusions

Through this investigation of current as-built operations, recommendations have been made to redefine construction as-built plans to the Kentucky Transportation Cabinet's needs. A literature review of the State Transportation Agencies and the private industry and interviews with as-built users and developers at KYTC, presented a better understanding of the current issues and potential solutions to as-built procedures at KYTC were developed.

Currently 23 STAs have in-house employees creating as-built plans, while seven allow consultants to create as-builts, and three have the contractors creating as-builts. Fifteen STAs are storing their as-built plans as electronic plans rather than the traditional hard copy plans. End users prefer PDF as-builts in a central storage location accessible to all as-built developers and end users. Finally, guidelines listing what information to include on as-builts and the level of accuracy they require are used by several STAs and private companies.

The private industry offered insights into new technology and handover of data. While many companies in the private industry are utilizing BIM and LiDAR, the State Transportation Agencies are not as advanced. However, STAs have used GPS to gather as-built information, such as the GPS Rover mentioned by KYTC engineers. Information on the handover of the as-built data was limited in the STA web review, however, journal articles on as-built development in the private industry emphasized the importance of as-built data handover. While the physical handover of data can only happen once after the project is complete, the preparation for handover should be a continuous process throughout the project. Both as-built developers and end users should be continuously discussing the information being recorded on as-builts throughout the entire project.

In order to make recommendations for future as-built operations, the team determined the main obstacles faced by engineers today when developing as-builts. Current obstacles include: lack of guidance on what to include on as-builts and where to store them, limited inspector capabilities, limited time to work on as-builts, lack of resources, changing technology, and trouble formatting as-builts into useful plans.

The recommendations established by the project team were created to address the obstacles faced by as-built developers and to take advantage of the evolving technology in the transportation industry. Two recommended procedures were suggested. The first recommended procedure can be implemented without additional research or resources. The main components of the procedure are a checklist of requested as-built information for as-built developers to use, a point of contact for all as-builts to be sent, a common storage location, and PDF format of as-builts. The second recommended procedure will need additional resources and time to be implemented. This procedure recommends that as-built information required for a specific project populates in SiteManager corresponding to pay items rather than a generic checklist applicable to all projects.

This project was based on a web review of published guidelines on STA websites and a case study conducted at the Kentucky Transportation Cabinet, and several limitations were present. Several published manuals and guidelines seemed to be outdated in some aspects and no personal communication was conducted with any other STA members besides KYTC, information gathered for the private industry was based on a limited number of articles and may not be representative of the entire private industry, and interviews with engineers from KYTC included a limited number of engineers and may not represent how all engineers at KYTC perform as-built operations. While there

are other limitations to the study, the limitations listed above are most prevalent and should be stated.

Finally, recommendations for future studies include interviews or surveys with all 50 STAs to discuss their as-built procedures, obstacles, etc., implementation and study of recommendations listed in this report, and further studies on advancing technology's role in as-built operations.

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	https://www.ksdot.org/Assets/wwwksdotorg/bureaus/burConsMain/Connection

	Manual	s/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 Specifications for Road and Bridge Construction	http://www.udot.utah.gov/main/uconowner.gf?n=31730316757114651
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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3. Professional positions held:

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    (b) Tutor Manager- University of Kentucky (August 2017-May 2018)

    (c) Summer Intern- United States Army Corps of Engineers (Summer 2015, Summer 2016, and Summer 2017)

4. Scholastic and professional honors:

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    (b) Provost Scholarship Recipient

    (c) Joseph P. Kennedy Scholarship Recipient

    (d) Downey Scholarship Recipient

    (e) Blythe Scholarship Recipient

    (f) Two time Society of American Military Engineers Scholarship Recipient

    (g) Durr Fellowship Recipient

    (h) Chi Epsilon-Editor (August 2018-May 2019) and Secretary (August 2017-May 2018)

    (i) Tau Beta Pi- Tutor Czar (August 2017-May 2018)

(5) Victoria Lynn Lasley