



Optimizing Available Surveying Technology to Streamline Project Delivery

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in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

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Research Report
KTC-18-11/SPR17-544-1F

Optimizing Available Surveying Technology to Streamline Project Delivery

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16. Abstract Kentucky Transportation Cabinet (KYTC) Project Managers bear responsibility for preparing all phases of highway projects, from initial concept to letting, while Section Engineers manage all phases of highway construction projects, from letting to completion. To perform the activities for which they are responsible, these stakeholders require knowledge of best practices for leveraging current surveying methodologies and equipment. With survey technologies having advanced significantly over the past 15-20 years, staff attrition at the Cabinet depleting its in-house surveying expertise, and contractors frequently undertaking their own surveying, acquiring this knowledge has become increasingly difficult. Drawing on a series of interviews with KYTC district and Central Office personnel, this report discusses current surveying practices at the Cabinet and the challenges many district personnel face in their efforts to procure survey data. Common difficulties encountered at the district level include equipment shortages, lack of trained survey technicians, misalignments between KYTC- and contractor-generated digital terrain models, and a dearth of Cabinet-specific training opportunities focused on surveying. Based on this review of the state of surveying practice at KYTC, this report offers numerous recommendations the Cabinet should consider for strengthening its approach to surveying. Recommendations include developing design-specific guidance, improving the in-house production of digital terrain models, creating survey training tailored to the Cabinet's needs, acquiring additional surveying equipment, and working to improve software compatibility between KYTC and its contractors. Additionally, the report outlines current training needs and includes high-level training course outlines to address them, provides guidance Project Managers can use when determining what survey services are needed on a project, and summarizes — by district — KYTC's current survey equipment inventory.			
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Table of Contents

Executive Summary	3
1. Introduction and Background	5
2. Overview of Current Surveying Practice at KYTC	6
3. Summary of KYTC District Interviews	8
3.1 General Issues	8
3.2 Equipment Issues.....	8
3.3 Digital Terrain Models (DTMs).....	9
3.4 Training and Support.....	9
3.5 Surveying Procedure – Construction Crew	10
3.6 District Interviews	10
3.7 STA Synthesis	15
4. Recommendations for Improved Surveying Services.....	17
4.1 Survey Equipment Inventory	22
5. Immediate Training Needs.....	27
5.1 Basic Surveying for Highway Technicians	27
5.2 Surveying for Construction Inspection (CEI) – Level I.....	28
6. Requesting Surveying Services.....	29
6.1 Process for Requesting Surveying Services	29

List of Figures

Figure 1 Current Survey Coordinator Responsibilities.....	20
Figure 2 Recommended Survey Coordinator Responsibilities	21
Figure 3 All Survey Equipment by KYTC District	23
Figure 4 GPS and Total Station Equipment by KYTC District.....	23
Figure 5 MEL for Primary Survey Equipment by District	25
Figure 6 MEL for Automatic Levels by District	26
Figure 7 Process for Requesting Survey Services	30

List of Tables

Table 1 Labor and Cost Comparisons of Surveying Methods	15
Table 2 Recommendations from District Interviews	17
Table 3 Basic Surveying for Highway Technicians	28
Table 4 Surveying for Construction Inspection – Level 1	28
Table 5 Summary of Survey Methods	32
Table 6 Preferred Survey Methods by Project Type.....	33

Executive Summary

The Kentucky Transportation Cabinet (KYTC) is responsible for managing the eighth largest road system and seventh largest inventory of bridges in the United States. KYTC personnel such as Project Managers and Section Engineers occupy a critical role in planning, developing, and overseeing highway and bridge projects. To perform their jobs effectively, Project Managers and Section Engineers need to be well-versed in the most current methods used to complete surveys as well as the most technologically advanced surveying equipment. Over the past 15-20 years, surveying technologies have undergone rapid advancements — during that same period, loss of staff at the Cabinet has reduced in-house surveying expertise considerably. Wanting to more thoroughly understand the challenges it presently faces related to surveying, KYTC asked researchers at the Kentucky Transportation Center (KTC) to appraise its current approach to surveying and recommend ways to bolster in-house surveying expertise. Through a series of interviews with KYTC district and Central Office personnel, researchers found that staff must routinely cope with problems such as equipment shortages, lack of trained survey technicians, misalignments between Cabinet- and contractor-generated digital terrain models, and a dearth of Cabinet-specific training opportunities focused on surveying. Many field technicians and engineers who participate in surveying activities receive little formal training, other than what is provided standard by equipment vendors when equipment is delivered. These brief trainings are helpful but do not address needs specific to the Cabinet. Often, personnel learn how to use advanced surveying equipment on the fly, when they are already deployed in the field. Based on conversations with KYTC stakeholders and a review of practices in other states, researchers devised a list of recommendations the Cabinet should consider pursuing in order to strengthen its surveying operations. Key recommendations include:

1. Preparing design-specific guidance that describes available surveying technologies, offers advice on choosing appropriate surveying methods, and facilitates development of design bulletins.
2. Improving the usability and quality of digital terrain models produced in-house to increase the efficiency of construction inspection and support independent field checks of contractor work items.
3. Developing and delivering survey training courses tailored to KYTC's needs. Particular focus should be placed on developing trainings geared toward construction inspection and combined design and construction inspection.
4. Establishing two survey coordinator positions within the Cabinet, one with a focus on construction inspection, the other with a concentration on project design.
5. Preparing a surveying services decision matrix that project managers can use when determining what survey services should be requested in design bulletins.
6. Developing a pocket field guide for construction inspection that walks construction inspectors through the process of setting up construction projects, operating equipment, and using GPS surveying equipment on inspections.
7. Acquiring sufficient equipment to staff each field crew with an independent survey crew outfitted with GPS surveying equipment.

8. Refining the degree of accuracy and level of detail of KYTC-generated digital terrain models so they are adequate for industry use.
9. Establishing a process to ensure that software used by the Cabinet and contractors is compatible.
10. Improving the internet connectivity at section offices. Slow internet connections hamper attempts to download/upload data and impede data processing tasks.

Along with these recommendations, this report includes an inventory of the Cabinet's surveying equipment (itemized on a district-by-district basis); a summary of immediate training needs, including proposed curricula for training courses; and guidance documents KYTC Project Managers can use to determine what survey services are necessary on a specific project. Included among this guidance is a flow chart that maps out a process to follow when requesting survey services, a table that provides an overview of different survey methods (e.g., benefits and drawbacks, level of accuracy, applications), and a matrix that can help Project Managers match project type to survey service.

1. Introduction and Background

The Kentucky Transportation Cabinet (KYTC) is responsible for constructing new roads, upgrading existing corridors, and maintaining the eighth largest state road system and the seventh largest inventory of state-maintained bridges in the United States. As part of providing these vital services, KYTC Project Managers are responsible for all phases of preparing a highway project — from initial concept to letting — while KYTC Section Engineers oversee all phases of highway construction projects — from letting to project completion. It is imperative that professionals placed in either role know of and understand how best to utilize the most current surveying technologies available in order to deliver projects promptly and efficiently. Unfortunately, KYTC currently lacks the in-house expertise, experience, and documentation necessary for Project Managers and Section Engineers to quickly acquire knowledge of surveying. To continue efficiently delivering the highway program, KYTC must continually develop up-to-date guidance documents and provide appropriate training to Project Managers and Section Engineers on surveying methods. Surveying is one of several technologies and services KYTC uses to develop project plans and deliver highway projects. The quality and ease of surveying have improved dramatically over the past 15 years through the widespread use of mobile and aerial LiDAR, digital terrain models (DTMs), drones, and GPS-based equipment. Because these advances have occurred so quickly, project development and delivery processes have not yet been adjusted to take advantage of new methodologies and equipment, nor have much-needed resources and training opportunities been developed. KYTC needs to assess its current level of surveying expertise, determine immediate training needs, and develop Cabinet-specific guidance for Project Managers and Section Engineers. A reference document summarizing available surveying technologies and best practices for implementation will be of great value to both the Project Development and Project Delivery & Preservation Branches.

To understand how to develop resources and determine best practices for using the latest survey technologies, KYTC asked Kentucky Transportation Center (KTC) researchers to study the issue. This report summarizes KTC's key findings and recommendations. Chapter 2 briefly reviews past and current surveying practices at KYTC. Chapter 3 looks at the current level of surveying expertise at KYTC as well as equipment issues, training opportunities, and construction surveying procedures. Researchers obtained this information through a series of interviews with KYTC district construction and design personnel. Along with findings from interviews, this chapter also contains a brief synthesis of surveying practices used at other state transportation agencies (STAs). Chapter 4 provides a summary of KTC's recommendations, and Chapter 5 presents immediate training needs as determined by the interviews. Chapter 6 includes a process flow chart that outlines the steps Project Managers should follow when requesting surveying services for design projects, including key decision points. This resource was developed based on interviews with Project Managers and Professional Services.

2. Overview of Current Surveying Practice at KYTC

KYTC requires accurate and timely surveying information in order to efficiently develop and deliver projects. Over the past several years, the proliferation of advanced surveying technologies combined with KYTC's shrinking technical workforce have made it extremely difficult to maintain the needed in-house surveying expertise. In the past when traditional surveying methods were commonly used, the Cabinet employed an adequate number of surveying crews and could provide a majority of surveying services in-house, thereby ensuring an acceptable level of surveying competency was maintained. However, KYTC currently lacks the resources to provide KYTC-specific training. The majority of the training provided is delivered by equipment vendors and outside consultants. While this training is helpful, it lacks the practicality of training developed strictly for KYTC personnel based on the Cabinet's procedures and specifications. Due to this lack of adequate survey personnel and expertise, most surveying services are now contracted out for Project Development and performed by the contractors for Project Delivery & Preservation. KYTC needs to develop procedures and practices to ensure the availability of surveying expertise in both Project Development and Project Delivery & Preservation. While the surveying technologies and methods used for both disciplines are very similar, the information needed, the means of obtaining the information, and the format of the information are all very different. What follows is a brief summary of the survey information required for staff in each of these branches.

2.1 Survey Information for Project Development

Project Development normally contracts for surveying services through the use of a statewide contract or by advertising via a design bulletin. The advantages and disadvantages of each contracting method are detailed later in this report. Each KYTC district has some level of surveying capabilities and in-house crews are still responsible for gathering project information. However, for more complex highway projects, Project Managers more commonly retain consultants for surveying services, mainly due to time constraints and level of expertise required. Outsourcing surveying services lets Project Managers focus less on the technical details of using the various survey methods/equipment and more on the benefits and drawbacks of each method/equipment type and the level of accuracy of the needed information.

2.2 Survey Information for Project Delivery

While the responsibility for construction surveying on highway projects is now delegated to contractors, Section Engineers still need to be able to perform fairly detailed surveying for Construction Engineering Inspection (CEI). The format and level of details required for this survey information greatly differs from what is required in Project Development. The types of information and level of detail of information needed for designing projects differ from what is needed to construct and inspect a project.

Section Engineers and their staff must have different survey skills for construction stakeout and quantity estimates than their counterparts in Project Delivery, whose focus is more on developing topographic, planimetric and right of way features. KYTC relies upon construction inspectors to provide quality assurance and verify that projects are being constructed according to the plans and

specifications and that work items are properly measured for payment. Therefore, depending entirely on contractors to provide the surveying and equipment usage expertise carries an untenable level of risk.

3. Summary of KYTC District Interviews

To understand KYTC's current surveying practices, KTC researchers interviewed personnel from three district offices in December 2016. These interviews sought to document the equipment and methodologies district personnel use to survey project sites and identify challenges personnel face related to surveying (e.g., equipment shortages, training and staffing needs). The interviews KTC conducted were expansive and touched on many topics, but the discussion here is restricted to five major areas: 1) General Issues; 2) Equipment Issues; 3) Training and Support; 4) Surveying Procedures; and 5) Digital Terrain Models. Based on researchers' conversations with district personnel, eight recommendations KYTC should consider implementing to improve surveying practices are outlined here.

3.1 General Issues

All districts highlighted the challenge of maintaining adequate staff with the requisite surveying experience needed to fully leverage the potential of advanced surveying technologies. Most personnel build experience with survey equipment and data collection through on-the-job training rather than formal courses or workshops. Often, only one or two people in each district office possess enough familiarity with surveying equipment to execute data collection in the field. This is problematic because it results in a situation where those one or two people are shared among various field crews on an as-needed basis. While staffing issues have made this arrangement unavoidable, when individuals with surveying experience retire or relocate to other jobs it results in a profound loss of knowledge, leaving district staff scrambling to learn the basics of surveying. It is thus difficult to ensure continuity with respect to surveying operations; many crew members feel they lack the expertise needed to begin surveying quickly if called upon to do so.

District personnel cited the importance of training more field technicians to use surveying equipment. To master the use of equipment, technicians must use it consistently in the field. When staff do not use it for extended periods, their skills deteriorate and they must relearn its operation on the fly, often in the field. This makes for challenging circumstances given that field crews have many responsibilities to attend to, typically with a limited number of field technicians. In most cases, one person per field crew has the skills needed to operate equipment but few opportunities to acquire training, and they will not routinely deploy it in the field.

3.2 Equipment Issues

All districts have seen an increase in their inventory of technologically sophisticated survey equipment. Each district has several Trimble R8 and R10 GNSS units, TSC 2 or TSC3 controllers, and usually one robotic total station. Nevertheless, personnel stated they would greatly benefit if additional equipment was made available for all crews. Currently, equipment is shared across multiple crews, which leads to scheduling conflicts and production issues. If only one person has experience operating a piece of equipment, that person must be loaned out with it to ensure proper data collection and/or inspections. After collecting data in the field, most crews are proficient enough to download and process them in MicroStation. Some section offices have poor internet

connectivity, which results in very slow upload and download speeds. Data processing and submission to the central office can thus be tedious, sometimes taking hours.

3.3 Digital Terrain Models (DTMs)

Current construction techniques are moving toward integrated machine-controlled equipment and stakeless construction sites. These construction techniques require the development and use of DTMs which house all necessary data, points and linework, and layers within a digital file that can be interpreted by machine control or a surveyor controller. While the DTM is the basis for most roadway construction, the official construction documents provided by KYTC are the plan, profile, and cross-section sheets. The relative absence of stakes on today's job sites make it inherently difficult for construction inspectors to verify proper placement and elevations of the roadway without primary survey equipment. While the Cabinet makes DTMs available for most jobs, their quality varies significantly. Often they include layers and/or data points unneeded for the design process and are not optimized for construction stakeout/inspection. Points with "0" elevations frequently exist, which disrupt the surface model and can provide erroneous elevations when used to check construction items. Additionally, KYTC DTM file sizes are extremely large, slowing down survey controllers. Most contractors do not use Cabinet-provided DTMs, opting instead to develop proprietary DTMs based on plan sheets that are optimized for construction. Construction Engineering Inspectors (CEIs) noted that issues arose when discrepancies were identified in the field. When discrepancies are identified, it must be determined if they are the product of improper construction, a faulty contractor DTM, or an error within KYTC's DTM. Sorting through these issues is extremely time consuming. As a result, some CEIs opt to use contractor DTMs for field inspection (and in some cases perform them with survey equipment owned by contractors). Software compatibility issues between KYTC and contractors can lead to major difficulties. District personnel cited the following challenges associated with KYTC-generated DTMs:

- Data often closely agrees at control points but diverges for grade measurements.
- There are often issues where new pavement ties into existing pavement.
- Models do not have the level of detail required by contractors.
- Vertical accuracy can often be an issue caused by extraneous points in the DTM.
- No separate layer exists for utilities, boxes, pipes, and culverts.
- There is overreliance on GPS equipment to check structural elevations given the range of accuracy.
- Crews are hesitant to rely on only KYTC's DTM model, so they usually work with the contractor.

3.4 Training and Support

All district personnel complimented the Cabinet's Survey Coordinator and the assistance they provide. However, they also point out that the Survey Coordinator is overburdened, with their duties being too much for one position. Interviewees commented that the Survey Coordinator located in Project Development often understood workflow activities in terms of topographic or boundary surveying and did not optimize operations for inspection surveying needs. All interviewees agreed that this responsibility demands a minimum of two positions across the state,

and preferably three. Researchers discussed the potential distribution of responsibilities among these positions. Districts agreed the optimal solution would entail having a Survey Coordinator tasked with oversight of all aspects of the surveying program, along with a Construction Survey Coordinator and Design Survey Coordinator. The training and support needs for each position are unique and it would be beneficial to have two separate positions filled by someone with expertise in their respective area.

Specifically, the Construction Survey Coordinator would provide hands-on support in using survey equipment and software on construction projects, offering guidance and assistance on tasks such as using DTMs for initial layout and for checking subgrade, slopes, and elevations. This coordinator would also keep field crews updated on the latest equipment and technologies, assist with their implementation, and assist CEIs with the development and deployment of DTMs to improve efficiency of field checks on the job site. The Design Survey Coordinator would help project development teams understand the level of accuracy attained by different surveying technologies and methods and their strengths and weaknesses. They would assist project teams when they prepare the design bulletin. Currently, project teams are unsure what specific services to ask of consultants when preparing bulletins, and they can be uncertain whether they are requesting services correctly. The Design Survey Coordinator would assist in reviewing, negotiating, and justifying consultant labor hours when advanced survey methods are proposed.

As noted, most experience using advanced surveying methods and equipment is gained on the job. Current training is normally by contract, but its quality is inconsistent and utility unclear. The districts recommended developing in-house training focused on KYTC needs and construction inspection. They endorsed a similar kind of training on the use of MicroStation.

3.5 Surveying Procedure – Construction Crew

While surveying practices vary slightly from district to district, overall, they follow the same general procedure:

- Receive KYTC-generated DTM from ProjectWise
- Load data into the controller and calibrate (checked) with control points
- Locate control points
- Perform initial project layout
- Check subgrade, slopes, and elevations
- Lay out locations for material testing

3.6 District Interviews

KTC researchers interviewed representatives from Districts 3, 6, and 8 about different aspects of construction surveying. In each district researchers spoke with between two and five staff members. Questions focused on the districts' levels of surveying expertise, hardware and software availability, common problems, strengths and weaknesses of the current approach to surveying, field verification procedures, and strategies to improve surveying accuracy and precision. To maintain the anonymity of the interviewees, we refer to them throughout as *representatives*, *staff*,

or *interviewee*. Preserving their anonymity ensures readers focus on the issues at hand and the concerns raised. And while representatives sometimes worked in different section offices in their respective districts, findings are presented at a high-level, referencing particular concerns of smaller offices only where they are germane to the broader discussion. The following sections briefly summarize the interviews. Although each district had unique concerns, several common themes emerged throughout, including the need for more surveying equipment, expanded training opportunities, and a commitment to integrating survey data on utilities and critical structures into geospatial databases.

District 8

District 8 representatives stated that crews generally have at least one person capable of using GPS units for stakeouts. Typically, professional engineers or engineers in training are responsible for operating the equipment. Despite being proficient in the use of GPS units, the representatives noted they had received little formal training. Upon receiving new equipment, manufacturers typically provide limited training, but this does not include working with devices in the field. Accordingly, most learning occurs through experimentation or on the job. Representatives cited the loss of experienced inspectors over the past several years due to attrition or retirement as a critical problem. While staff have sufficient knowledge to collect necessary data with the GPS units, the district lacks people who are well-grounded in surveying theory. The district owns several Trimble R8 and R10 GNSS systems, use Trimble Tsc2 surveying control units, and have one robotic total station. It has recently acquired new units for upcoming projects (e.g., I-75 widening). Despite the recent influx of equipment, the representatives felt additional GPS units are necessary to streamline and improve the efficiency of surveying. Occasionally, personnel have used contractors' equipment to check work (e.g., grade) onsite due to a lack of equipment in the district's offices. Staff use MicroStation to work with surveying data, however, because office computers and internet connectivity are so slow, data processing can be sluggish. When asked about strategies to build the staff's expertise on GPS-based surveying, representatives noted that while the Cabinet offers many classes (which are generally subcontracted to outside vendors), their quality and utility are uneven, and generally an attendee does not know what to expect until they arrive for a course. This is problematic because of the significant time investment required to attend classes. Interviewees endorsed an in-house training program to alleviate these problems. Representatives also commented the Survey Coordinator has been extremely helpful, however, because of their numerous obligations around the state they are often pressed for time. Staff also rely on contractors for assistance with GPS units, because in many cases they have dealt with similar problems and have ideas on how to resolve them.

When asked to describe the process of surveying a typical Grade & Drain project, representatives said the first step is to retrieve a DTM from ProjectWise, load information into a controller, and perform a site calibration. This generally entails determining whether control points specified in the model remain available. If they are no longer available, staff will seek assistance from the district location engineer. Contractors use control points KYTC provides. Representatives observed that the district often relies on contractor DTMs despite receiving Cabinet-generated

DTMs from Highway Design. That being said, staff typically check plans and DTMs, especially if there is a discrepancy between KYTC's observations and a contractor's.

One problem district staff often confront is a mismatch between its elevation data and contractor elevation data. When this occurs, the difference is approximately 0.3" to 0.4". Determining whether KYTC's data or the contractor's data is correct has proven challenging and is a source of frustration, especially when data are in close agreement at control points but diverge for grade measurements. Discrepancies are particularly troublesome on projects where new pavement must be tied into existing surfaces — if this occurs, it requires significant money to resolve the issue. Despite these challenges, representatives felt it is important for the Cabinet to check vertical and horizontal alignments against the plans to preserve a system of checks and balances (which contractors prefer to keep in place as well). Staff would like to use the same DTM throughout the project development and implementation process to ensure consistency, although they did not hold strong opinions on whether it should be generated by the Cabinet or the contractor. One staff member expressed skepticism over whether GPS data, because of the difficulty in obtaining accurate and precise vertical measures, is the best option for measuring vertical differences on structures and grades. Another challenge representatives identified was software incompatibilities between the Cabinet and its contractors. While the district and contractors both use Trimble software, contractors often rely on more sophisticated and advanced versions (e.g., Trimble Access versus SCS900, which is more expensive). Ensuring that district staff and contractors can seamlessly exchange files and data is critical for streamlining KYTC–contractor interactions. A final point of concern raised by the representatives is the failure to develop GIS layers from GPS data that show where utilities (e.g., pipes) and critical structures are located. Having a geospatial inventory of these items would be useful when completing future maintenance or construction activities.

District 3

Representatives from District 3 observed that attrition and retirements have negatively impacted the provision of surveying services. While the district's inventory of advanced surveying equipment has increased over the past few years, surveying expertise is in short supply. Tech III's in the district have become familiar with GPS units, however, they require a broader knowledge base to use the equipment effectively, and a dearth of labor power has made it difficult to accomplish work. While rent-a-techs have been used occasionally within the past four to five years, they have not been surveying experts. Interviewees said personnel generally experiment with new GPS units and learn on the job. Currently the district holds several Trimble R8 and R10 GNSS systems as well as Trimble Tsc3 survey controllers. One robotic total station is available and is often used on bridge replacement jobs. Currently, the district uses GPS units for as many activities as possible, especially horizontal checks (including, for example, checks on striping). Similar to Districts 6 and 8, staff noted that software incompatibilities between contractors and KYTC have been a hurdle. The district offices use Trimble Access whereas the district's primary contractor relies on SCS900 site controller software. Ideally, staff would like to use the same software as contractors, however, the cost of upgrading as well as the staff's existing knowledge of Access has prevented this from happening. Staff also reported having difficulties connecting to contractors'

base stations onsite because their frequencies do not match up, requiring district staff to set up their own base station or hook into the CORS network. One innovative strategy the personnel have used is developing KMZ files from project documents (exported from MicroStation), which are uploaded to Google Earth. In the field, engineers and technicians use this information to locate points to an accuracy of 10-20 feet. Because the files are loaded in plan view, they assist with general issues of location and alignment.

Despite their ability to improvise and learn on the fly, representatives emphasized that the lack of formal training on advanced GPS equipment has been a major stumbling block, noting that manufacturer-provided training is inadequate. Interviewees stressed on a number of occasions the importance of establishing an in-house training program focused on training field technicians, because they are primarily responsible for using the equipment on a day-to-day basis. They also recommended construction-specific training. Like Districts 6 and 8, staff complimented the Survey Coordinator's efforts to provide technical assistance. But they also observed they are stretched very thin because of their expansive job responsibilities. To remedy this situation, representatives suggested that KYTC establish a position for a construction survey coordinator, who could hold more in-depth training sessions and assist with equipment troubleshooting. Because GPS technologies are updated so rapidly, it is imperative that staff remain knowledgeable about the latest equipment and technical standards. Staff also cited another benefit of extensive training — it helps engineers and field technicians spot any problems with contractors' surveying procedures and results.

Reflecting on the process of surveying a typical Grade & Drain project, representatives said they begin with KYTC-generated DTM for initial layouts and vertical measurements. They cautioned that DTMs the Cabinet provides contractors frequently lack sufficient detail, and contractors build in-house models (although contractors rarely provide district personnel with their DTMs). Staff use GPS units to check pipes and curb locations, however, they use levels to check subgrades, slopes, and pipe elevations. The accuracy of vertical measurements is often wanting, is the primary justification for using different equipment. Although staff expressed a great deal of confidence in the district's primary contractor, they felt it would be unwise to rely entirely on a single DTM. Contractors prefer to have a system of checks and balances in place to verify the quality of work is satisfactory. And if KYTC relies entirely on a contractor-generated model, the system of checks and balances dissolves. Staff remarked that having KYTC provide contractors more accurate and precise models benefits all stakeholders, and contractors would likely use them given that they sometimes invest thousands of hours generating their own models. Another advantage of creating a higher quality model from the outset is that it could potentially accelerate project development and improve the bidding process; it would also prevent the Cabinet from effectively paying for models twice.

District 6

District 6 representatives spoke about the importance of getting all field technicians experience on GPS surveying equipment. While many technicians have been excited to learn about its operation, there have been some who have been less enthusiastic. One challenge is that when field technicians

do not use the equipment on a daily basis, they tend to forget the minutiae of data collection procedures. To avoid this situation, one of the district's engineers has developed written step-by-step instructions that walk GPS users through data collection. Having received little formal training on GPS units, personnel have typically learned how to operate equipment on the fly. GPS units and survey controllers are used every day to perform such tasks as measuring quantities, ensuring the correct thickness of fill, working with horizontal and vertical alignments, and making adjustments to plan sheets as needed. They are also used to pinpoint and lock down locations where materials testing occurs. Currently the district owns several Trimble R8 and R10 GNSS systems, Trimble Tsc3 survey controllers, and radio equipment to improve coverage if work takes place beyond areas with cell service. Although most of the district's surveying needs are taken care of, the rural section could benefit from additional equipment (as well as personnel to run it). Like District 3, representatives noted that staff generate KMZ files to determine approximate locations on project sites. Although the staff feel relatively comfortable using equipment in the field, they commented that additional, more formal training would be beneficial. Staff receive basic training on surveying with MicroStation, however, building additional knowledge in this area would facilitate data processing. Aside from training, representatives stated a critical need is air cards, which let engineers and technicians access the internet in the field, check email, and compose reports while they are onsite. Offices have work stations with MicroStation, however, older and slower machines hinder staff efforts to execute complex tasks swiftly. Internet connectivity is also problematic, even in the district's newer offices, with download speeds of approximately 3 Mbps. Representatives complimented the Survey Coordinator's efforts to assist with surveying, but like staff from Districts 3 and 8, they observed that additional personnel to assist with surveying would be helpful given the current workload.

Commenting on surveying procedures used for a typical Grade & Drain project, representatives said the first step is to retrieve all information from ProjectWise and obtain generic design and DTM files for the surface. Information is then loaded into the controller, after which staff hit all benchmarks before any modifications are made to the project site. Benchmarks are critical for calibrating projects — at least five points are necessary to achieve good calibration. Most staff use GPS units to perform spot checks, however, some of the veteran inspectors supplement this with traditional surveying techniques (which, mixing potentially incommensurable datasets could be problematic). One weakness in the Cabinet's surveying procedures the representatives identified is the failure to send contractors a usable DTM file. DTM files generated by KYTC are bogged down with supernumerary layers, which slows down survey controllers as they attempt to load them. Reducing unneeded information would be helpful given that contractors immediately remove excess data upon receiving the files. When they perform checks, staff use contractor-generated DTM files because they load much more quickly into the controllers. Another point raised by staff is the Cabinet-mandated staking requirements that are in effect when contractors use electronic equipment. As per the Standard Specifications, stakes may be placed up to 500 feet apart if GPS units are being used. However, a small number of stakes can prove challenging for an inspector, especially if they lack access to a rover. The standard is not problematic as long as rovers are available, but districts may require a dedicated rover for each of its major projects to ensure the quality of inspections. Echoing the concerns of District 8, representatives commented

on the utility of a GIS database that contains plans and inventories features such as boxes, pipelines, and structures. Although marked-up plan sheets are useful, a more sophisticated (and quicker) means of storing and accessing this information would be extremely valuable.

3.7 STA Synthesis

After speaking with district personnel about their current surveying practices and the application of different equipment types to various surveying activities, KTC briefly reviewed the surveying methods and technologies used by other state transportation agencies to better understand what methods/technologies they regard as most appropriate for different surveying tasks. Other state transportation agencies have compared new and emerging survey technologies with traditional methods to determine their respective application ranges. These comparisons have focused on issues such as accuracy, safety, data collection, processing time, and total cost. Missouri DOT conducted one of the most extensive investigations. The agency evaluated three discrete Lidar systems — static, mobile and aerial Lidar, — traditional survey control, and conventional aerial mapping on a seven-mile corridor. Table 1 summarizes the performance of each surveying method, including the number of hours needed to complete the survey, labor costs, personnel days, and cost per mile. Aerial and mobile Lidar have the least onerous labor demands, however, the impact of their use on scheduling is not dissimilar to traditional survey methods due to the high processing time associated with the large number of data points. Mobile Lidar proved the most accurate, with precision estimated at +/- 0.002 feet compared to +/- 0.019 feet for aerial mapping and traditional survey. With respect to expense, aerial and mobile Lidar were on par with conventional aerial mapping, costing about half that of traditional survey methods. Static Lidar fared poorly in this comparison, due to the long length of the project. However, the agency noted that some projects warrant use of static Lidar, such as tunnels or underpasses, where a greater level of detail and higher data quality are imperative. For example, Pennsylvania DOT demonstrated the value of static Lidar on the Schuylkill River Bridge in Hamburg, Pennsylvania. By using static Lidar, the agency finished the survey in 270 hours, a much lower figure than the 720 hours the project was estimated to take using traditional surveying techniques.

Table 1 Labor and Cost Comparisons of Surveying Methods

Survey Method	Hours	Labor Cost	Person Days	Cost Per Mile
Traditional Survey Design				\$18,798
Aerial Lidar	444	\$58,250	55.5	\$8,321
Mobile Lidar	726	\$81,688	90.8	\$9,933
Static Lidar	1,700	\$204,805	212.5	\$29,258
Conventional Aerial Mapping	548	\$55,234	68.5	\$7,891

Source: Missouri DOT

Pennsylvania DOT evaluated survey technologies to identify the most appropriate applications of different methods. The agency's evaluations were driven by a focus on safety, as it wanted to reduce the exposure of survey crews within the travel way and cut down on the length of roadway closures. Pennsylvania DOT, like Missouri DOT, found mobile Lidar to be very accurate to a distance of approximately 30 feet from the shoulders, while aerial Lidar and photogrammetry are less accurate but nonetheless may be used to supplement mobile Lidar. On a recent project, a ground survey was still required in areas too obscured for the use of Lidar or photogrammetry, and surveyors staked off inaccessible areas such as slopes, bridges, and roadways. Pennsylvania DOT also found that mobile Lidar has poor accuracy on vertical faces, such as slopes and ditches, with returns being significantly influenced by vegetation. As with the Schuylkill River Bridge project, static Lidar was preferable for smaller/inaccessible sites (e.g., dangerous slopes and cuts, bridge girders and decks, high-traffic intersections, tunnels, and underpasses). Aerial Lidar excelled in wide-area topographic data collection, especially on long corridors and new alignments.

4. Recommendations for Improved Surveying Services

Based on KTC’s interviews with district personnel, researchers have developed recommendations for improving the Cabinet’s surveying program. These are summarized in Table 2.

Table 2 Recommendations from District Interviews

Recommendation	Justification and Description
1. Design-Specific Guidance	<p>Guidance for Project Development should achieve the following results:</p> <ul style="list-style-type: none"> • Assist project managers and team members on understanding available surveying technologies and matching surveying methods to specific design needs • Assist project managers in requesting the most appropriate surveying services when preparing design bulletins <ul style="list-style-type: none"> ○ This training should instruct on <i>what</i> to request of consultants and <i>how</i> to correctly and clearly request these services. • Assist project managers with the negotiation of consultant labor hours for surveying services <ul style="list-style-type: none"> ○ Current guidance is based on traditional surveying methods.
2. Improved Digital Terrain Models	<p>If KYTC design worked with the intention of producing a useable DTM, and production is informed by what is needed to construct and inspect a project in the field, this will increase the efficiency of construction inspection and ensure a completely independent field check of contractor work items.</p>
3. Develop KYTC-Specific Training	<p>Basic training provided by equipment manufacturers is adequate for completing initial setup, but not for using equipment to execute complex design- and construction-related activities. A training program should focus on KYTC practices and procedures. As KYTC may lack the resources to develop training internally, outside assistance may be necessary. The Cabinet will need to offer direct guidance on any trainings that are developed. Training needs must be addressed in three areas.</p> <p>Construction Inspection-Specific Trainings focused on:</p> <ul style="list-style-type: none"> • Retrieving KYTC-generated DTMs from ProjectWise and loading them into GPS equipment and software • Evaluating the accuracy of KYTC-generated DTMs and resolving discrepancies with contractor-generated DTMs • Hands-on training on the correct use of GPS equipment for construction inspection duties, such as: <ul style="list-style-type: none"> ○ Initial project layout ○ Structure layout

	<ul style="list-style-type: none"> ○ Utility location and layout ○ Checking subgrade, slopes, elevations, and horizontal and vertical alignments ○ Pipe layout and placement <p>Design and Construction Inspection Trainings focused on:</p> <ul style="list-style-type: none"> ● MicroStation training for KYTC processes ● Understanding the degree of accuracy provided by KYTC DTMs and when DTMs may be used or plan sets referenced ● Manipulating and/or refining KYTC-generated DTMs ● Understanding and resolving compatibility issues between Trimble software and other software used in the industry
1. Establish Two Survey Coordinator Positions	Although districts recommended hiring three survey coordinators, given KYTC’s financial constraints and the difficulty of hiring quality surveyors, this is not a realistic expectation. KTC recommends dividing surveying coordinator duties between two positions: <ul style="list-style-type: none"> ● Survey Coordinator — Construction Inspection ● Survey Coordinator — Project Design
2. Develop a Surveying Services Decision Matrix for Project Development	Project Managers need reliable guidance on requesting surveying services in design bulletins. A decision matrix will help project managers choose an appropriate surveying method and provide instruction for requesting services in the bulletin.
3. Develop a Pocket Field Guide for Construction Inspection	Construction inspectors will benefit from a field guide that walks them through the process of setting up construction projects, operating equipment, and using GPS technology for construction inspection.
4. Acquire More Surveying Equipment	Sufficient equipment should be purchased to staff each field crew with an independent GPS survey crew. While equipment is expensive and funding is limited, a starting point is to develop a long-term plan to affordably outfit all crews.
5. Refine KYTC-Generated DTMs for Industry Use	The districts agreed that creating one KYTC-generated DTM for contractors is a goal worth pursuing. While the contractors do not fully concur, they have said that one DTM is a more practical option if it offers the degree of accuracy and level of detail they require.
6. Ensure Software and Equipment Compatibility	KYTC uses Trimble equipment and software for GPS surveying. Because some contractors use products from other vendors, software and equipment compatibility issues have arisen. KYTC should establish a process to ensure compatibility between the software and equipment it uses and those used by its contractors.
7. Improve Internet Connectivity at Section Offices	Slow internet connections hamper the ability of personnel to finish data processing quickly. Improving connectivity to ensure faster upload and download speeds will help increase productivity.

All interviewees emphasized the need for KYTC-Specific survey training. Table 2 highlights the most important areas mentioned during the interviews, which require the development of training courses or modules. The most immediate training needs are in Project Delivery. As part of this research, KTC prepared draft outlines for the most immediate training needs, which are presented in Chapter 4.

All interviewees, including those in Project Development and Professional Services, discussed the different types of surveying technical support needed for design and construction activities. Although all were complimentary of the support provided by Survey Coordinator, they believe the responsibilities are too much for one position. Although interviewees preferred three Survey Coordinator positions, given KYTC's current financial constraints and the difficulty hiring quality surveyors, this is unrealistic. Therefore, it is recommended that KYTC consider having two Survey Coordinator positions and divide the support responsibilities by project design and construction inspection. Figure 1 illustrates responsibilities currently assigned to the Surveyor Coordinator, and Figure 2 shows the recommended responsibilities utilizing two Survey Coordinator positions.

Current Survey Coordinator Responsibilities

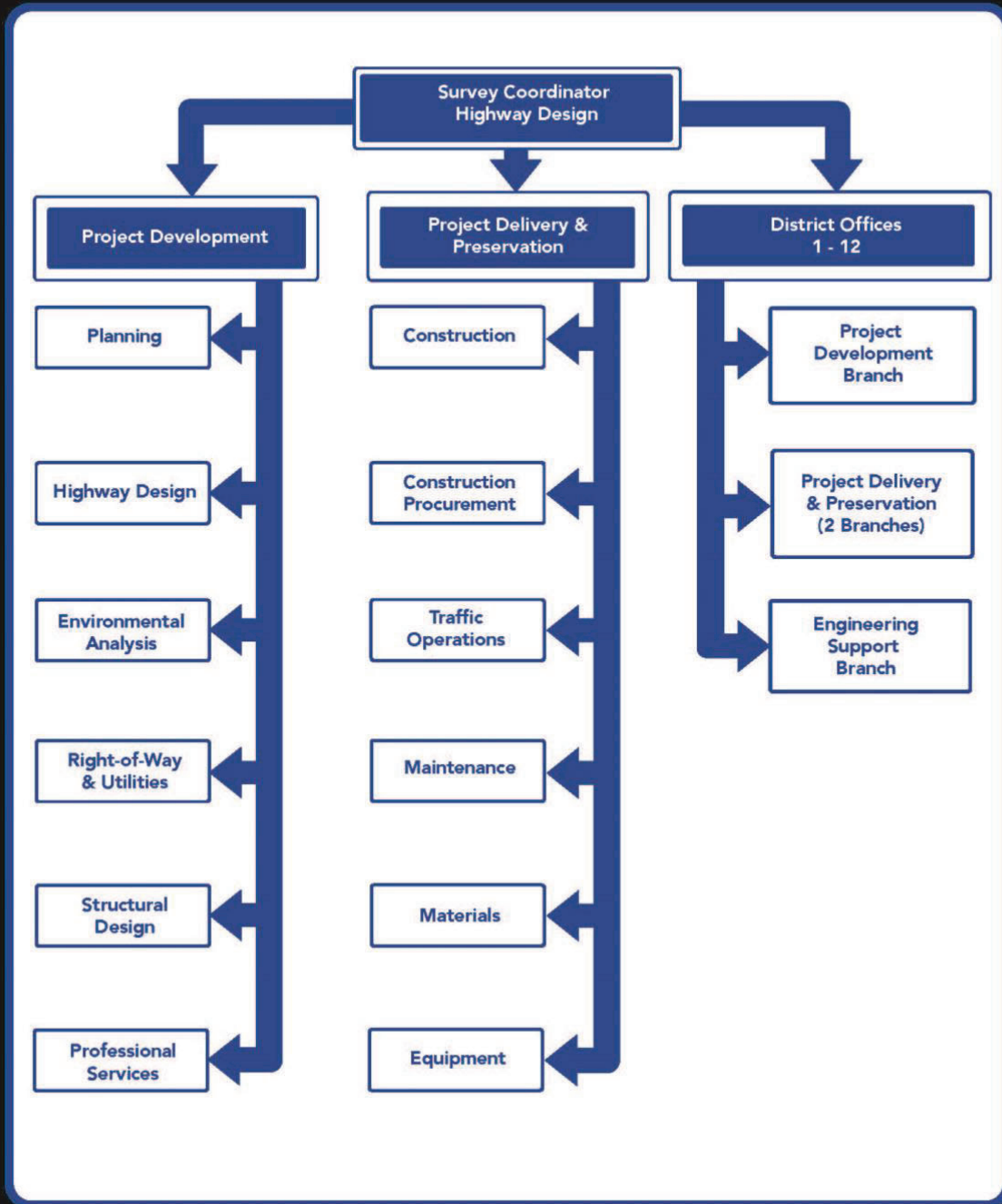


Figure 1 Current Survey Coordinator Responsibilities

Proposed Coordinator Responsibilities

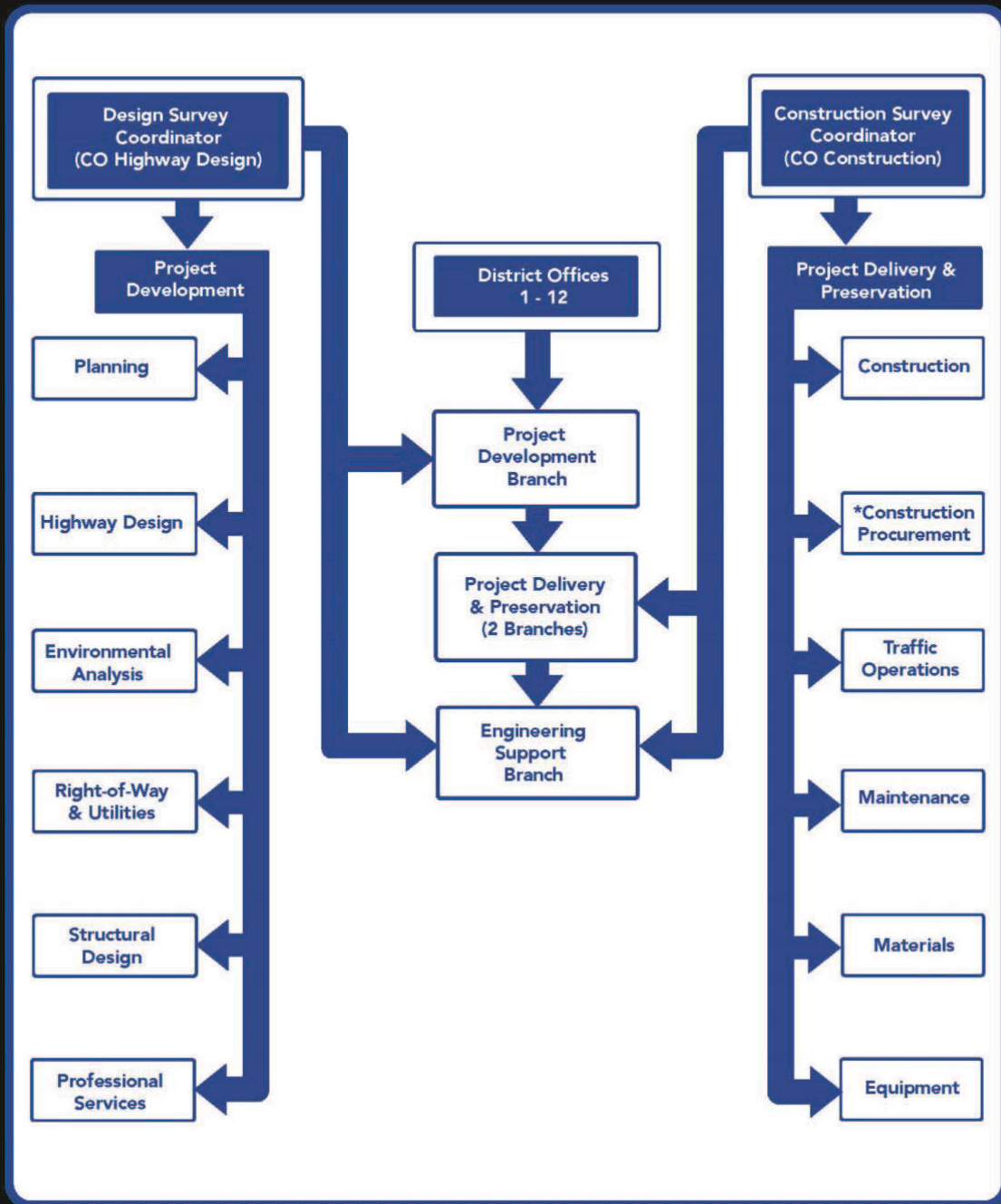


Figure 2 Recommended Survey Coordinator Responsibilities

Interviews with Project Delivery and Professional Services also highlighted the lack of guidance and resulting difficulty for Project Managers when requesting Surveying Services from consultants. All interviewees agreed that a simple decision matrix outlining the procedure and decision steps involved to effectively prepare a request for consultant surveying services would be extremely helpful. This has been developed and is presented in Chapter 5.

4.1 Survey Equipment Inventory

Interviewees raised a number of concerns related to the use and availability of survey equipment. Several interviewees also brought up the need to be able to quickly borrow needed survey equipment from nearby crews. Based on interviews, it is apparent that the amount and type of survey equipment varies greatly among the 12 districts. While all district stakeholders expressed the desire for every section office to have an acceptable level of surveying equipment, the Cabinet lacked a comprehensive survey equipment inventory sorted by district and an organized plan for distributing equipment. KTC researchers obtained a statewide inventory of survey equipment from the Division of Facilities Support, current as of September 1, 2017. Researchers used these data and added specific section locations to assist KYTC with preparation of an exhaustive inventory. To provide KYTC with an intuitive resource summarizing the availability of survey equipment across the state, survey inventory data are presented in graphical form and sorted by district and Central Office. Figure 3 captures all inventoried survey equipment, and Figure 4 shows only the GPS-based and total station survey equipment. Providing information in this format will help Cabinet staff know what offices to contact to borrow particular surveying equipment, identify equipment operators, and pinpoint districts requiring additional investments in survey equipment. The survey equipment inventory is maintained in a master spreadsheet, and it is recommended that this file be updated regularly to provide potential users up-to-date information.

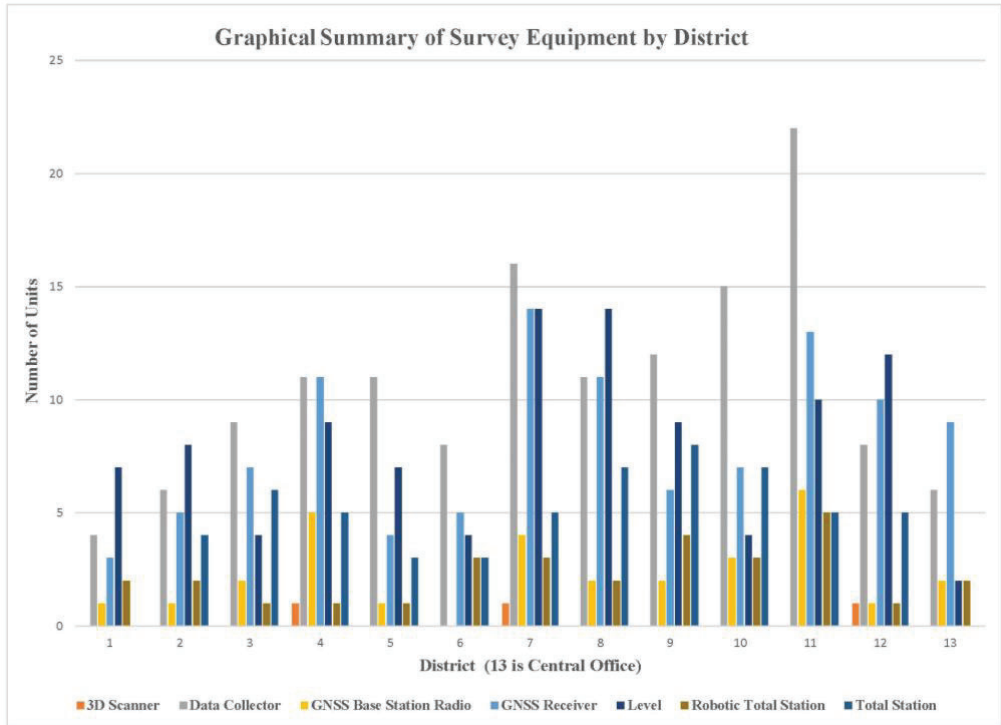


Figure 3 All Survey Equipment by KYTC District

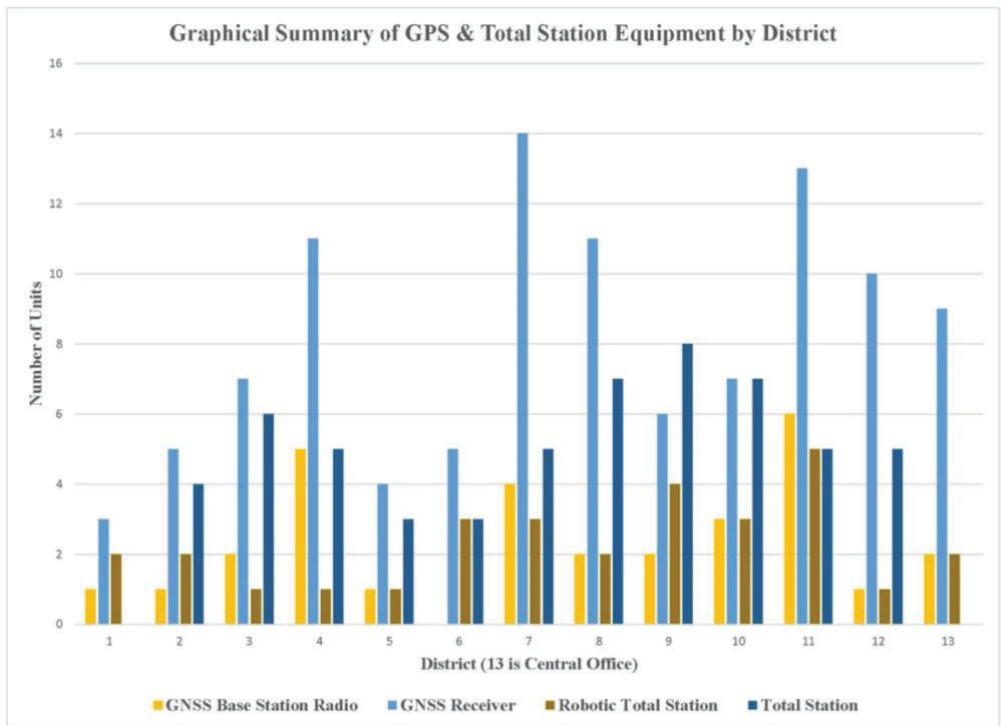


Figure 4 GPS and Total Station Equipment by KYTC District

When evaluating the distribution of survey equipment among construction inspectors, an additional consideration is determining a minimum equipment list for each crew, section office,

and district. The equipment list for each district should be matched to the frequency of use and number of active crews. As a starting point for this project a minimum equipment list (MEL) is suggested, which should be refined by district and section engineer. After establishing the MEL, it is possible to determine if the current equipment disbursements are sufficient. The following is suggested for the MEL.

- Two sets of primary survey equipment capable of determining x,y,z coordinates within each section office, including the following:
 - 1 GPS receiver with access to the KYCORS network
 - 1 robotic total station
 - Ideally, providing a minimum of one set of equipment to each section office will allow for easy accessibility to meet ongoing demands on during construction and allow for selection of the optimum choice of equipment for each job.
 - Primary survey instruments may be supplemented with electronic total stations requiring at minimum a two-man crew when primary instruments are in use.
- For GPS rovers, 2 GPS base stations per district with associated radios may be required to facilitate survey during outages of the KYCORS network.
 - Section offices having large areas of poor cell phone reception due to topography may consider additional base stations and radios to permit RTK surveying without KYCORS data access.
- Each inspection crew should be outfitted with a survey grade level and rod for checking elevations on a job site, due to the instrument's low-cost and versatility.

Figures 5 and 6 evaluate each district's current equipment inventory against the recommended MEL. Representing the available survey equipment in this manner, KYTC managers can quickly identify which districts have less than what is recommended by the MEL and based on this knowledge rectify the equipment budget accordingly. The MEL — and investments over this minimum list — will improve the efficiency of construction inspection operations.

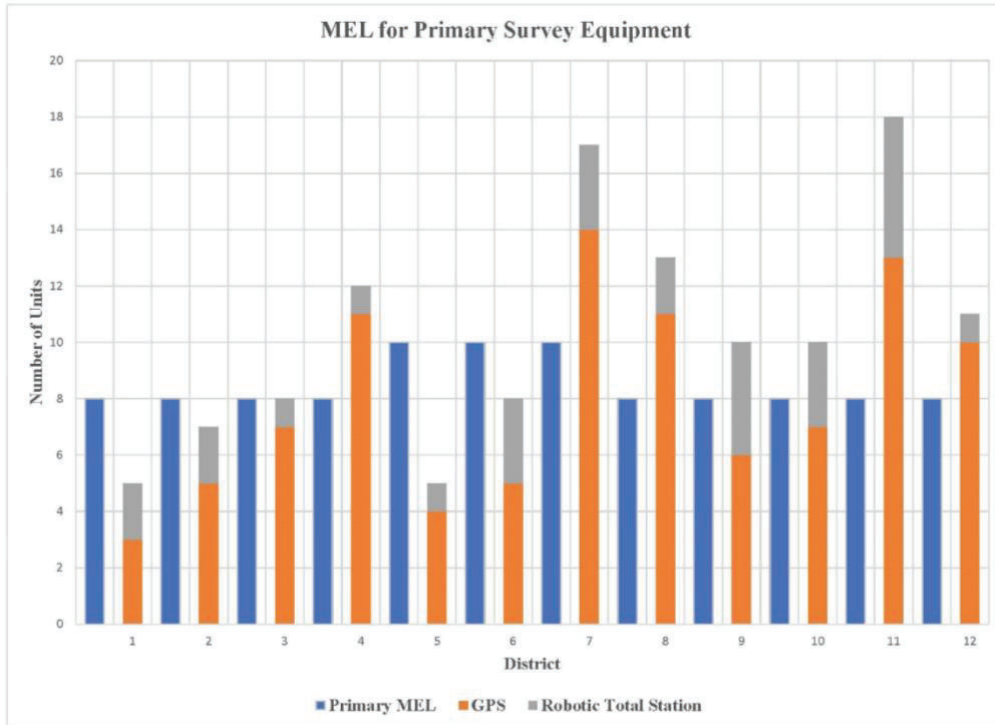


Figure 5 MEL for Primary Survey Equipment by District

With the exception of Districts 1, 2, 5, and 6, all districts meet or exceed the suggested MEL of two primary survey instruments per section office. However, it is also evident that there is a high reliance on GPS equipment for primary survey instruments. While GPS provides efficient data collection, the vertical accuracy of GPS is less than that of a total station and level. Relying entirely upon GPS should be avoided.

Figure 6 shows the number of automatic levels identified within each district and the suggested MEL. Estimates for the MEL are based on the assumption of four inspectors per section office, each of whom should maintain an auto level to check grades and elevations. Very few districts meet the suggested MEL in this area. While the MEL may need to be assessed by each section office based on its current staffing and project needs, comparing the number of automatic levels to the number of GPS units also indicates an overreliance on GPS technology. Districts 3 and 6 have four auto levels but seven and five GPS units, respectively. While GPS units may be more efficient, their inconsistent vertical elevations and the low number of available levels should be addressed.

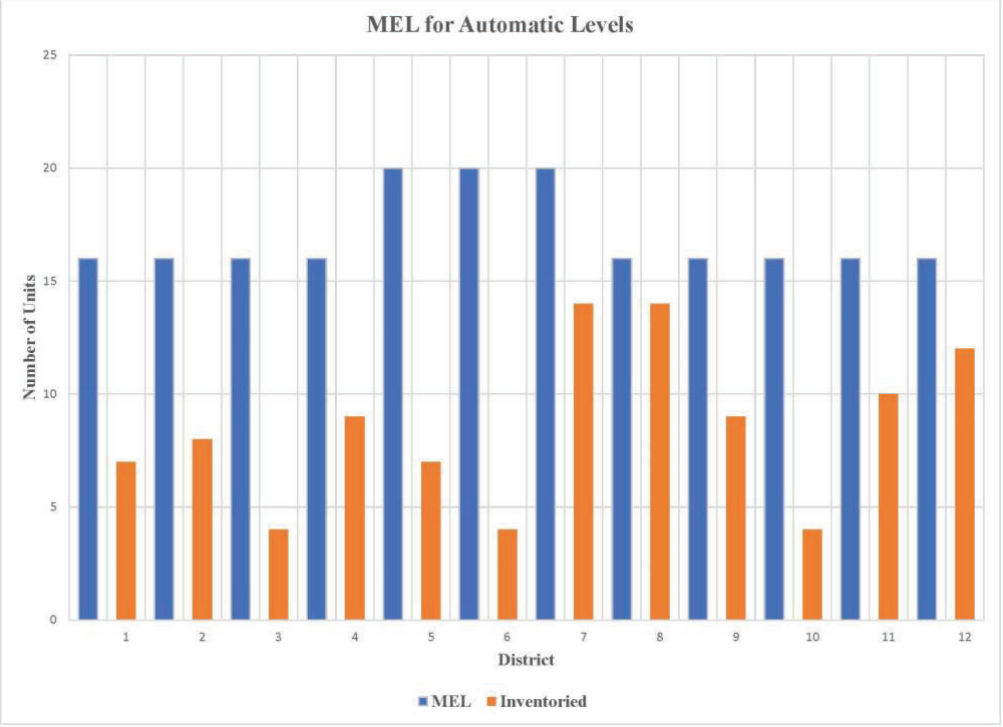


Figure 6 MEL for Automatic Levels by District

5. Immediate Training Needs

As researchers moved deeper into the project, it became apparent that while survey training is necessary throughout both Project Development and Project Delivery and Preservation, the most pressing need is in Project Delivery and Preservation. Immediate needs exist for both basic survey training and introductory Construction Engineering Inspection (CEI) survey training. KYTC is currently working to consolidate the Highway Equipment Operators (HEO) series, Engineering Assistant (EA) series, and Transportation Engineer Technicians (TET) series into one Highway Technician series. As part of the eligibility requirements for becoming a Highway Technician, personnel will be required to take a basic survey course. Recognizing this, Cabinet leadership asked KTC researchers to determine the basic survey skills which should be imparted by this training and prepare a draft course outline. Interviews with Project Delivery and Preservation staff also revealed the need for an introductory level survey training for construction inspectors. KYTC leadership requested that KTC researchers devise content for this training and assemble a draft course outline as well. As a result of this research, KYTC has initiated projects to develop two training classes for appropriate Cabinet personnel — Basic Survey Skills for Highway Technicians and CEI Surveying Level I. The following sections summarize the purpose and content of both training courses and contain initial draft outlines.

5.1 Basic Surveying for Highway Technicians

When Cabinet leadership asked researchers to prepare a curriculum for introductory survey training, they stipulated that the training should provide basic guidance and instruction to personnel involved in highway construction and maintenance surveying. The training's intended audience is technicians and inspectors, especially those without previous construction or maintenance surveying experience. Taking account of KYTC's request and information gathered during interviews with field personnel, researchers propose dividing the recommended training into three main areas:

- I. Basic Surveying Concepts
- II. Measurement and Construction Surveying
- III. Surveying Mathematics

After completing the course, participants should be able to:

- Describe basic surveying concepts
- Understand measurements and construction surveying
- List the instruments and techniques used in measurement
- Perform stationing and staking operations
- Perform basic survey mathematics

With these desired training outcomes in mind, and drawing from the recommendations described above, researchers prepared the following draft outline. It is currently being elaborated upon and refined for the Cabinet as part of a separate project. Table 3 shows the preliminary outline for the course being developed.

Table 3 Basic Surveying for Highway Technicians

Delivery Method	Duration	Topics Covered
1. Classroom Instruction		<ul style="list-style-type: none"> • Basic Surveying Terms and Equipment • Basic Measurements – Units and Calculations • Basic Survey Mathematics
2. Field Instructions	0.5 Day	<ul style="list-style-type: none"> • Basic Slope and Grade Measurements – Hand • Basic Leveling Operations <ul style="list-style-type: none"> ○ Recording Grades ○ Elevations

5.2 Surveying for Construction Inspection (CEI) – Level I

During interviews, Cabinet field personnel indicated there is a pronounced need for KYTC-specific survey training for construction inspectors. Trainings provided by equipment suppliers and outside vendors are acceptable for using and maintaining equipment, however, they are insufficient because they do not offer instruction on the basic field duties which must be carried out to independently inspect and verify contractor activities. The course outlined below will introduce inspectors to survey responsibilities as well as equipment and its proper operation. The emphasis is on field applications — identifying items to be surveyed, acceptable tolerances based on survey equipment and construction techniques, and proper survey documentation. The preliminary outline is shown in Table 4.

Table 4 Surveying for Construction Inspection – Level 1

Delivery Method	Duration	Topics Covered
1. Classroom Instruction		<ul style="list-style-type: none"> • Basics of Equipment Operations (Level, Total Station, GPS) • Data Collector File Management • Survey Field Book Basics
2. Field Instruction	1.5 Days	<ul style="list-style-type: none"> • Level Operations (Level Loop) • Robotic Total Station <ul style="list-style-type: none"> ○ Topo ○ Stakeout • GPS <ul style="list-style-type: none"> ○ Calibration ○ Setting Control Points ○ Topo ○ Stakeout

6. Requesting Surveying Services

With Project Development and Project Delivery struggling to keep pace with the rapid advancements in surveying technology, staff need assistance deciding what surveying services are needed for a project. One of the main recommendations presented in Chapter 3 was the development of a decision matrix or process flow chart to assist Project Managers with the task of requesting surveying services as part of a design project. Information obtained from surveying services is critical for the successful design of a highway project. However, project designers do not currently receive adequate guidance in understanding the technical details of surveying, nor do they have a step-by-step overview that walks them through the process of requesting surveying services. The result is that often project designers issue a generic request for surveying services, either through use of a statewide contract or inclusion in a design bulletin. This practice transfers away from KYTC staff and to design consultants the decision-making authority for determining what survey information is needed, the method of survey to be used, and the level of detail required. In many cases this leads to scope creep of the surveying portion of the design project and KYTC ultimately ends up paying for much more detailed surveying information than is needed, which brings with it a corresponding increase in project delivery time. A simple, high-level, guidance document outlining the steps involved in requesting survey services and the necessary decisions required of KYTC Project Managers would be of great benefit.

6.1 Process for Requesting Surveying Services

KTC researchers conducted formal and informal interviews with Project Managers, Central Office Location Engineers, and Division of Professional Services staff. From these interviews, researchers found that knowledge of the process for requesting surveying services varies greatly among Project Development staff. Given that surveying information is just one of many pieces needed to design a highway project, this finding is not unexpected. Even though information gleaned from surveys is critical to project success, the process of requesting the surveying services is rarely given significant thought when initiating a project. As noted, transferring the decision-making authority regarding surveying to consultants places the KYTC Project Manager at a conspicuous disadvantage when negotiating scope and cost. The flow chart depicted in Figure 7 contains decision points and essential information that Project Managers should reference when preparing design bulletins.

Process for Requesting Surveying Services

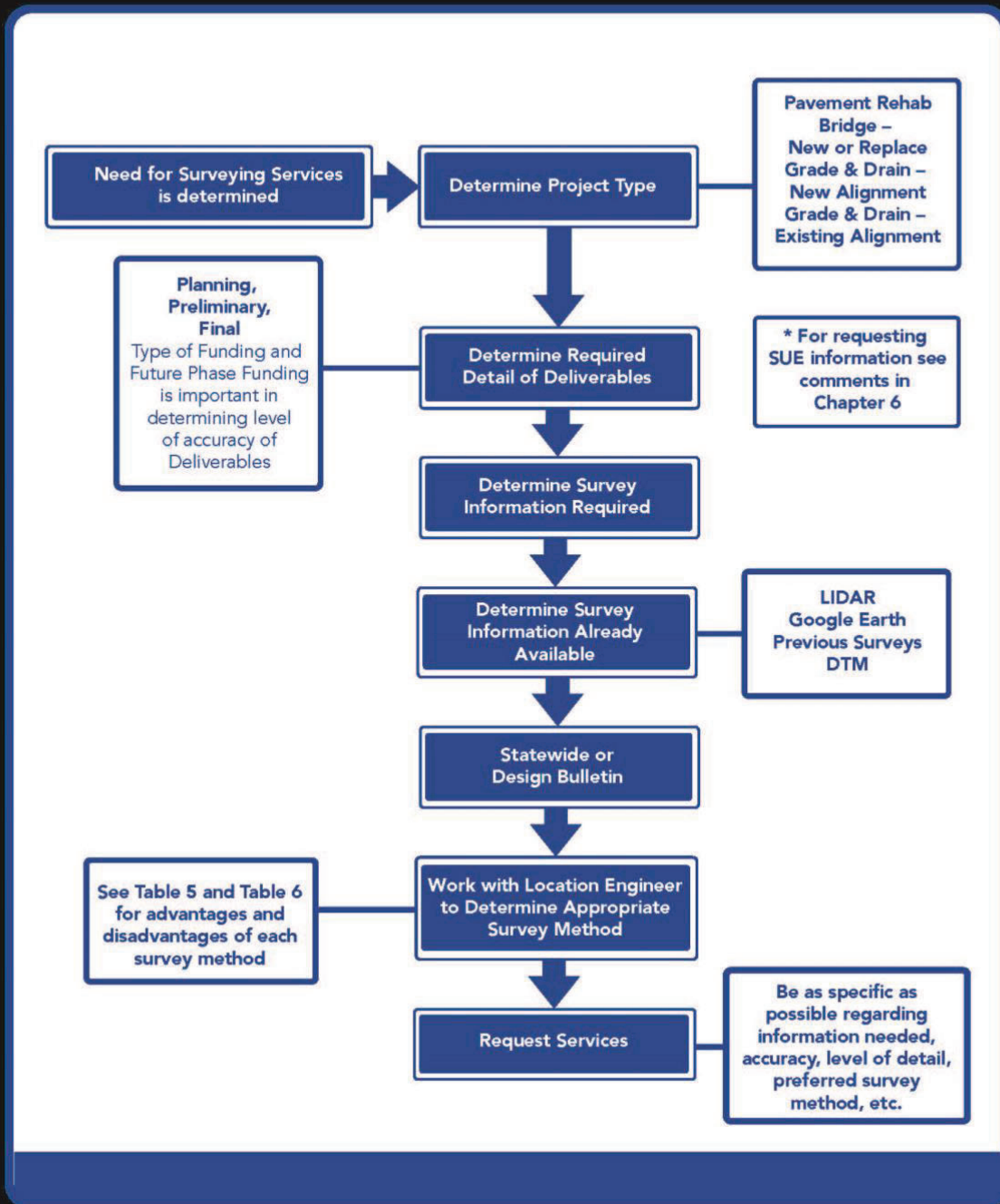


Figure 7 Process for Requesting Survey Services

After the Project Manager decides that surveying services are necessary — typically when project design funds are approved — they must first understand the type of project being designed. This may sound simple, but it is important to apprehend the differences in information type, delivery, and level of detail needed for various project types. Four broad project categories were used to develop the flow chart: 1) Pavement Rehab, 2) Bridge Construction — New and Replacement, 3) Grade & Drain — New Alignment, and 4) Grade & Drain — Existing Alignment. Many other project types exist, but most fit onto one of these categories. For example, if a project is a culvert construction, it should be assumed that the required survey information will be similar to what is needed for bridge construction. Subsurface Utility Engineering (SUE) information is often required irrespective of project type and should be considered when initially requesting surveying services. ASCE Standard 38-02 provides useful information and recommended levels of detail for utility location based on the complexity of utility conflicts within the project.

Next, the Project Manager should determine the level detail required of survey deliverables and information needed. For this task the Project Manager should analyze three main categories: planning, preliminary design, and final design — the level of detail required for each differs greatly. For example, the Project Manager may be able to obtain the necessary information from Google Earth for a planning study, while corridor evaluations during preliminary design may require the use of statewide Lidar and imagery. Final design may require a traditional survey with very detailed information. Understanding the scope of the project is invaluable for ensuring that KYTC does not contract and pay for more services than are needed.

There are instances in which the Cabinet may benefit from requesting more information than is necessary for the current project phase. For this reason, it is important for Project Managers to know the funding status of future project phases. If the current funding is for a planning study while funding is imminent for preliminary design or final design, it may be prudent for the Project Manager to request more information at a finer level of detail. It is also important to spend time researching whether survey information is already available for the project location. Information may be available from statewide aerial Lidar, aerial surveys from adjacent projects, and Google Earth, which project designers could use to fine-tune the request for survey services.

At this point the Project Manager should begin thinking about the best method for requesting surveying services. A request can be included in the design bulletin for the entire project or, or surveying services may be obtained by using an existing Statewide Contract for Surveying Services. Each method has advantages and disadvantages for each method, and these vary based on project context. Including the surveying services in the project design bulletin lets the prime consultant designer control the scheduling and details of the survey, which may lead to a more efficient and innovative design. Larger or more complex projects may benefit from this approach. The use of the statewide contract can often result in significant time savings due to the elimination of the advertising and selection process involved with placing a request in the design bulletin. Therefore, if a project has an aggressive schedule or complicated access issues, a statewide could be used so that surveying begins while the other project design elements are being contracted. This may also be critical when there is a need to collect aerial data during leaf-off conditions. Statewide

contracts can also be used to help determine project scope and identify potential issues before advertising for design services. For help in selecting the best method for a particular project, the Project Manager should work with the Survey Coordinator to explore the pros and cons of each.

The final step before requesting services is deciding which survey method is the best suited for a project. The most appropriate methods vary according to the survey information need for different project types. The Project Manager should work very closely with the Central Office Location Engineer to select an appropriate survey method. Table 5 provides a brief summary of the various types of available survey methods.

Table 5 Summary of Survey Methods

Survey Application	Applications	Advantages	Disadvantages	Accuracy
Traditional Survey	Manually intensive, but provides high accuracy especially in dense vegetation that may affect remote sensing technologies such as LIDAR and Aerial	Very Accurate High Availability easy Mobilization Low office Time	Sparse Data Safety Concerns (high volume areas) High Cost May require multiple trips	+/- 0.02
Aerial Photography	Large Area Topos	Very Dense data Complete Topo Competitive Cost	Lower Accuract Scheduling High Processing Time	+/- 0.15
Mobile Lidar	Preferred for corridors of high conflicts within an isolated corridor for improvement, due to limited width of data retrieval	Very Accurate Very Dense Data Low Field Time Provides overhead of structures etc. Reduced maintenance of traffic needs	Limited to view from pavement. Improved view of vertical faces, signs, buildings, etc. (100s pints /m2) Requires field pick ups for slopes/ditches Shoulder to Shoulder applications Requires high processing time and data storage requirements	+/-0.035
Stationary Lidar	Slides Small area topo Structures	Very Accurate Very Dense Data Low Field Time Provides overhead structures	Small Areas Only High Processing Time	+/- 0.02
Aerial Lidar	Efficient data collection for deveolping DTMs for wide areas such as off alignment corridors or evaluating alternative corridors Best for preliminary design studies	Large area topo Low Field Time Dense Data	Can be extremely useful in developing bare ground DTM. Point density greatly affected by flight level. Traditional survey and/or photogrammetry may be required to identify breaklines, ditches shoulders and to define appropriate planimetric features. Narrow vertical features such as guardrail, poles, signs utilities may also require traditional survey techniques. Poor resolution of vertical faces. (1-60 points per m2)	varies by flight level

When selecting a survey method, it is important to know whether there is a survey method that, historically, has proven effective for the project type under consideration. Table 6 summarizes preferred survey methods for each project type. The information in this table should be viewed as a starting point to begin deliberations on the selection of a survey method. No survey method should be implemented without using sound engineering judgement to evaluate the decision. Project-specific details and schedules also must be considered when selecting a survey method. Relevant details to consider are access to the project site, traffic control, project phasing, project budget, and project complexity.

Table 6 Preferred Survey Methods by Project Type

Survey Method	Project Type			
	Pavement Rehab	Bridge Replacement	Grade and Drain (New Alignment)	Grade and Drain (Existing Alignment)
Discussion:	A typical pavement rehab with smaller areas of reconstruction or recrowning, may be easily addressed by traditional survey methods. Dependent upon the ADT of the roadway and access for survey crews, MOT needs may interfere with traditional roadway surveys making mobile LIDAR an option to be considered. Additionally, longer corridors with significant areas of improvement may also benefit from the rapid collection of data provided by Mobile LIDAR.	The small area of bridge replacement projects and required high accuracy lend themselves to traditional survey methods or stationary LIDAR data collection. Aerial surveys do not provide the accuracy necessary for bridge replacement. Stationary and/or Mobile LIDAR has the ability to reduce data collection and increase safety for obtaining data on poorly accessible areas of the bridge structure.	New alignments benefit most from the wide area data collection provided by Aerial Lidar and Photo. For preliminary design of grade and drain projects, current statewide datasets should be sufficient to provide accurate corridor level analysis of alternatives. However, small areas of special concern may require traditional survey pickups to increase understanding of the area. Final design of projects will require increased resolution of data points through lower level LIDAR flights and/or supplementation with Aerial Photography. Supplemental data beyond the statewide lidar dataset should be collected once a preferred corridor and/or alignment is chosen to support final design and limit data collection expenses.	Grade and Drain projects on existing alignments may utilize Mobile LIDAR when proposed improvements are intended to remain within the shoulder of the existing roadway. Mobile LIDAR does not provide the accuracy or coverage outside of the shoulder area and is poor at collecting data on vertical slopes of fill sections and/or ditches. This will require additional pickups with traditional survey methods. For grade and drain projects extending beyond existing shoulder low level LIDAR data, such as those collected by helicopter, may be the most cost effective data collection method, due to the wider coverage and high point density provide by the low flight level.
Preferred Method	Traditional Survey Mobile LIDAR	Stational LIDAR Traditional Survey	Aerial Photogrammetry and LIDAR	Mobile LIDAR Aerial LIDAR (Low Flight Level) Traditional Survey

Once the Project Manager selects a survey method they are ready to submit a request for surveying services by either statewide contract or include it in the design bulletin. Regardless of contracting method, Professional Services strongly recommends providing as much detail in the request as possible. The more details provided concerning the specific information needed, desired format, accuracy of deliverables, and preferred survey method, the easier it is to make a final determination of scope of services and negotiate a reasonable fee.