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16. Abstract

The lack of adequate information about the location and characteristics of utility facilities can result in a number of problems, including damages to utilities, disruptions to utility services and traffic, "lost" utility facilities as construction alters the landscape and pre-existing benchmarks are removed, and delays to highway projects. To address this issue, the research team reviewed the state of the practice in utility investigations and developed best practices for timing and use of utility investigation services in the TxDOT project development process. Major activities of the research included a review of current utility investigation techniques and technologies, a review of best practices and use of utility investigation practices in other states, and a review of TxDOT project data to examine effects of utility investigation services. The research team surveyed TxDOT organizational units on current utility investigation practices, developed draft best practices for utility investigations, and conducted workshops to allow feedback from practitioners. Based on the feedback, the research team reviewed and revised the draft best practices for utility investigations, developed draft content for inclusion in the *ROW Utility Manual*, and developed and tested training materials.

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UTILITY INVESTIGATION BEST PRACTICES AND EFFECTS ON TXDOT HIGHWAY IMPROVEMENT PROJECTS

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LIST OF ACRONYMS, ABBREVIATIONS, AND TERMS

AASHTO	American Association of State Highway and Transportation Officials
AC	Alternating current
ADT	Average daily traffic
ANSI	American National Standards Institute
AFA	Advance funding agreement
ASCE	American Society of Civil Engineers
CAD	Computer-aided design
Caltrans	California Department of Transportation
CFR	Code of Federal Regulations
CI	Construction Institute
CIS	Contract Information System
CSJ	Control section job
DCIS	Design and Construction Information System
DOT	Department of transportation
EM	Electromagnetic
EMI	Electromagnetic induction
ENV	Environmental Division at TxDOT
ESRI	Economic and Social Research Institute
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FUCC	Florida Utilities Coordinating Committee
GDOT	Georgia Department of Transportation
GIS	Geographic information system
GPR	Ground penetrating radar
GSSI	Geophysical Survey Systems
IRWA	International Right of Way Association
IT	Information technology
ITS	Intelligent transportation systems
kHz	kilo Hertz
LPA	Local public agency
MDOT	Maryland Department of Transportation
m-ohms/m	Milli-ohms/meter
MOU	Memorandum of understanding
MPO	Metropolitan planning organization
mS/m	Milli-Siemens/meter
NHS	National Highway System
NCDOT	North Carolina Department of Transportation
ODOT	Ohio Department of Transportation
OSHA	Occupational Safety and Health Administration
PDF	Portable document format
PennDOT	Pennsylvania Department of Transportation
PS&E	Plans, specifications, and estimate
QLA	Quality level A

QLB	Quality level B
QLC	Quality level C
QLD	Quality level D
RFID	Radio frequency ID
ROW	Right of way
ROWIS	Right of Way Information System
RTI	Research and Technology Implementation Division at TxDOT
RTK	Real-time kinematics
SHRP	Strategic Highway Research Program
SUE	Subsurface utility engineering
TAC	Texas Administrative Code
TC	Terrain conductivity
TTI	Texas A&M Transportation Institute
TPP	Transportation Planning and Programming Division
TxDOT	Texas Department of Transportation
UAR	Utility accommodation rules
UCM	Utility conflict matrix
UIR	Utility Installation Review
UIT	Underground Imaging Technologies
USC	U.S. Code
VDOT	Virginia Department of Transportation

CHAPTER 1: INTRODUCTION

SUBSURFACE UTILITY ENGINEERING

The lack of adequate information about the location and characteristics of utility facilities can result in a number of problems, including damages to utilities, disruptions to utility services and traffic, "lost" utility facilities as construction alters the landscape and pre-existing benchmarks are removed, and delays to highway projects. In addition, detecting utility conflicts as early as possible during the project development process can help to substantially improve the timely relocation of utilities and/or allow time to develop alternatives to avoid utility relocations (*1*, *2*, *3*).

Collecting accurate underground utility location information from utilities can be challenging. This is one of the reasons Subsurface Utility Engineering (SUE) has become a critical tool to help identify and locate utility installations within the right-of-way. The national Construction Institute/American Society of Civil Engineers standard CI/ASCE 38-02 outlines typical SUE activities in connection with the collection and depiction of utility data (*4*). A critical component of SUE is a quality level (QL) attribute, which can be one of the following:

- QLD, which involves collecting data from existing records or oral recollections.
- QLC, which involves surveying and plotting of utility appurtenances that are visible at ground level.
- QLB, which involves the use of surface geophysical methods to determine the approximate *horizontal* position of subsurface utilities.
- QLA, which involves the precise *horizontal* and *vertical* location through exposure of utilities at certain locations.

With the exception of QLA data, the SUE process normally produces horizontal positions (i.e., 2-D data). However, technologies such as ground penetrating radar (GPR) and electromagnetic inductive (EMI) arrays are increasingly making it possible to obtain 3-D imagery and depictions of utility installations from which it is possible to infer not just horizontal but also vertical positions of underground installations. When referring to elevation data obtained using GPR or EMI, vendors and practitioners often use unofficial terms such as "QLB-Plus" or "QLA-Minus."

Collecting information about utilities through existing records, oral recollections, and surveys of visible utility appurtenances is a routine practice in the project development process. In fact, it is common to collect QLD and QLC data as early as the preliminary design phase of a transportation project. By comparison, collecting QLB and QLA data tends to take place during the detailed design or Plans, Specifications, and Estimate (PS&E) phase (Figure 1). The decision to collect these data is typically a responsibility of the project manager and depends on project parameters such as project complexity and project type. Data collection at QLB and more so at QLA is costly and must therefore be limited to the extent needed and to the extent that it is justified. However, not all project managers have experience with the SUE process and standards, or may lack an understanding of potential benefits. In some cases, project managers know (or suspect) that most, if not all, utility facilities need to be adjusted anyway and decide that investing resources in QLB or QLA investigations is unnecessary.

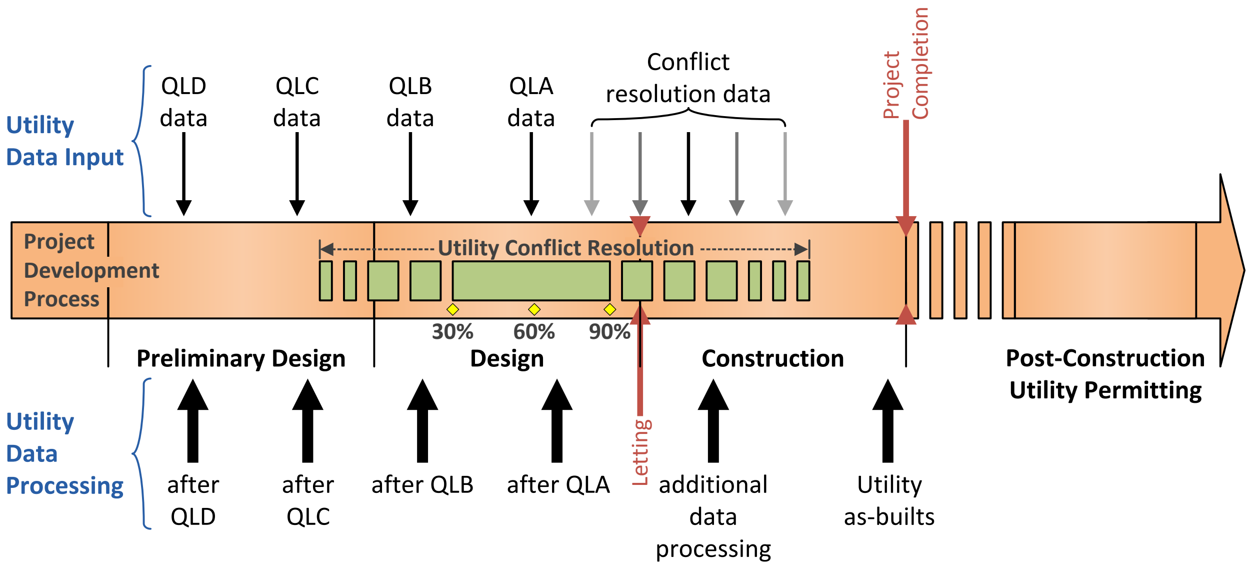


Figure 1. Potential Utility Data Exchange Points.

QLD and QLC data collection requires equipment that is typically available at TxDOT, so project managers frequently perform these types of data collections using in-house staff. QLB and QLA data collections require specialized equipment that may not be readily available at TxDOT, so project managers typically hire a SUE contractor to collect this kind of data. This fact may also contribute to a common confusion that SUE data collection only refers to activities that produce QLB and QLA data.

Although TxDOT has successfully collected QLB and QLA data on several projects, most TxDOT projects currently do not collect this type of data or use it to its full potential. The primary objective of this project is to review the state of the practice in utility investigations and develop best practices for timing and use of utility investigation services in the TxDOT project development process. Major activities of the research included:

- Review current utility investigation techniques and technologies.
- Review best practices and use of utility investigation practices in other states.
- Review TxDOT project data to examine effects of utility investigation services.
- Survey TxDOT organizational units on current utility investigation practices.
- Develop draft best practices for utility investigations.
- Plan and conduct workshops with practitioners.
- Review and revise draft best practices for utility investigations.
- Develop and test training materials.
- Develop draft content for inclusion in the *ROW Utility Manual*.

This report describes the procedures and findings associated with the project. The remaining sections of the report are organized as follows:

- Chapter 2 provides an overview of the geophysical survey techniques or methods that have been or could potentially be used for underground utility detection. The chapter also summarizes underground utility investigation practices based on several interviews to SUE providers who have presence in Texas.

- Chapter 3 describes in detail the current utility investigation practices and perception of SUE cost/benefits based on a survey conducted with a large number of TxDOT officials in different districts, regional support centers, and divisions.

- Chapter 4 reviews utility investigation practices in a sample of states across the nation and introduces a number of best practices in those states that may potentially benefit TxDOT if implemented in Texas.

- Chapter 5 examines effects of SUE on project costs, project efficiencies, and project delivery time based on an in-depth analysis of project performance data of a large number of sample projects at TxDOT.

- Chapter 6 describes a number of best practices developed for implementation at TxDOT. The chapter also describes the effort the research team took to gather feedback from stakeholders through workshops and incorporate it during the refining and revising of the best practices.

- Chapter 7 describes the training materials developed during this project and the process of testing the materials through a round of workshops across Texas. The training materials are included in research product 0-6631-P1 that is submitted separately from this report.

- Chapter 8 concludes with a summary of the research findings, recommendations based on the research, and issues associated with the potential implementation of the research findings.

CHAPTER 2: UTILITY INVESTIGATION TECHNIQUES AND PRACTICES

UNDERGROUND UTILITY INVESTIGATION TECHNOLOGIES

There is a wide range of geophysical survey techniques that have been or could potentially be used for underground utility detection. This section provides an overview of available utility detection methods along with a detailed discussion of these methods. Depending on a survey method's underlying technology, methods can be categorized into one of the following groups:

- **Methods Based on Electromagnetic (EM) Waves.** Electromagnetic radiation is a form of energy exhibiting wave-like behavior. In the order of increasing frequency and decreasing wavelength, the electromagnetic spectrum covers radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays. Examples of utility detection methods using radio waves are Ground Penetrating Radar, pipe and cable locators, electromagnetic induction, and electromagnetic terrain conductivity (TC). Infrared thermography is a method that uses shorter electromagnetic waves in the infrared spectrum.

- **Methods Based on Mechanical Waves.** Examples of mechanical waves are acoustic waves, water waves, and seismic waves. Methods based on mechanical waves require the presence of a medium in which the wave can propagate. Acoustic location is an example of a method utilizing mechanical waves.

- **Other Methods.** These methods can be used for utility location and do not fall in the above groups, including electricity resistivity methods, magnetic methods, micro-gravitational methods, and chemical methods.

Table 1 provides a summary of underground utility detection methods that are commonly used, and Table 2 provides a summary of underground utility detection methods that are less frequently used. Following the tables, this chapter provides for each method a description of basic underlying theories, design and implementation of products using the method, and a description of typical applications for these products. Readers should take note that during a complex utility investigation, it is a common practice to employ a combination of methods for more accurate and reliable detection results.

Table 1. Summary of Commonly Used Underground Utility Detection Methods.

Method	Application	Major Advantages	Major Limitations
Ground penetrating radar	• Utility detection and tracing	• Ability to detect both metallic and non-metallic utilities. • Can be used for initial searches of larger areas.	• Relatively short detection range. • Reliability largely depends on utility dimensions, utility materials, buried depth, and soil conditions. • Cannot detect utility type. • Data are difficult to interpret.
Pipe and cable locators	• Utility detection and tracing	• Especially suitable for tracing metallic utilities or nonmetallic utilities with tracing wires that are accessible. • Can be used in both a passive mode and an active mode (see following section). • A large variety of instruments available.	• Results affected by factors such as utility diameter, ground conductivity, existence of other conductors. • Extremely prone to environmental interferences when used in passive mode. • Accurate detection and tracing require access to utilities. • Depth estimation is not reliable.
Ground penetrating radar and/or electromagnetic induction arrays	• Utility detection and tracing	• More reliable and accurate results than traditional GPR and pipe and cable locators. • Capable of 3D utility mapping.	• Less portable than traditional GPR equipment and pipe and cable locators. • Requires sophisticated software for data processing.
Terrain conductivity	• Utility detection	• Detection distance is relatively high. • Suitable for search of isolated utilities. • Can detect nonmetallic utilities.	• Prone to interferences by nearby electromagnetic noises. • Not suitable for tracing utilities. • Incapable of depth estimation. • Reliability largely affected by soil type.

Table 2. Summary of Infrequently Used Underground Utility Detection Methods.

Method	Application	Major Advantages	Major Limitations
Resistivity measurements and capacitive resistivity method	• Utility detection	• Suitable for general utility searching.	• Data collection and interpretation is difficult compared to other methods, and requires experienced personnel. • Method is intrusive and not suitable for hard surfaces.
Magnetic methods	• Utility detection	• Suitable for searching over a large area. • Suitable for utilities marked with magnets.	• Shallow detection range. • Not capable of depth estimation. • Prone to interference from nearby magnetic sources.
Infrared thermography	• Utility detection	n/a	• Shallow detection range. • Requires very sensitive equipment. • Not capable of depth estimation.
Acoustic location	• Utility tracing	n/a	• Prone to interference from background noises. • Requires access to or prior knowledge about utilities. • Not capable of depth estimation.
Micro-gravitational techniques	• Detection of very large underground objects	n/a	• Requires very precise measurements and experienced personnel.

Pipe and Cable Locators

Basic Theories

Pipe and cable locators are by far the most commonly used utility detection method. These locators utilize electromagnetic induction technology using antennas with coils to detect magnetic fields generated by buried utility facilities. Pipe and cable locators can be used to locate a large variety of underground conductors.

The fundamental principle of electromagnetic induction is that changes of magnetic flux through a surface bounded by a closed circuit will induce a voltage in it. Pipe and cable locators utilize electromagnetic induction in two ways (*5*):

- Imposing a signal onto a buried utility facility by subjecting it to a magnetic field generated by an alternating current (AC) source.

- Detecting a magnetic signal generated by a buried conductor with a current flow using an aerial receiver.

An insulated underground conductor (i.e., the metallic utility facility to be detected) needs to have a current flow to generate a magnetic field that aerial antennas can detect. Although the buried conductor is not necessarily part of a complete electric circuit, it works as a string of small capacitors with the conductor itself and the ground surrounding it as two conductors separated by the insulation protecting the conductor. Upon receiving an AC current, the conductor charges up relative to ground, and current flows out both ways from the point where the AC current is applied, creating a magnetic field around the conductor. There are several factors affecting this electromagnetic process (*5*):

- **Utility Diameter.** Capacitance (i.e., the ability of body to hold an electrical charge) increases with conductor area, and therefore the size of a utility facility affects the distance the current travels along the conductor. From a larger pipe, the same current strength will leak away over a shorter distance than from a smaller pipe. On the other hand, the capacitance of a small diameter cable may be so low that little or no current will flow and result in a magnetic field too weak to be detectable.

- **Ground Conductivity.** Ground conductivity varies locally (e.g., wet soil is a better conductor than dry sand). Better ground conductivity makes it easier to induce a current flow, yet causes the current to be lost along a shorter distance. Lower ground conductivity requires more energy to induce current, but it will be detectable over a greater distance.

- **AC Frequency.** The higher the frequency, the greater AC voltage and capacitance current flow can be induced in the conductor, yet the shorter the distance over which the current will travel.

Product Design and Implementation

There are two basic means that pipe and cable locators identify buried conductors: passive location and active location (*5*). Passive location methods take advantage of the fact that many buried utilities naturally carry a detectable current, such as electric cables. In addition, buried conductors may also have a current triggered by other existing sources such as an existing current in the earth and/or long-wave radio transmissions.

Only a receiving instrument is required for passive location, which implies that the operation is theoretically simple and does not require digging first for access to the buried facilities. However, passive signals are not reliable and subject to change anytime. The fact that all buried conductors tend to have this type of signal complicates the detection, especially in locations where multiple utility facilities are buried. It is also difficult to identify a conductor located through passive signals. Currently, there are pipe locator products that detect signals around 50 to 60 Hz, the frequency range that underground power lines typically generate. There are also instruments capable of detecting buried conductors emitting very low frequency signals triggered by remote long-wave radio transmissions.

The design voltage of the buried utility line is not directly related to the strength of detectable signals. Obviously, high-voltage power cables do not emit strong detectable signals when they are unloaded. Further, many power cables contain twisted cores or carry three-phase power, which largely cancel out a detectable signal. Therefore, passive detectors may easily miss a major high-voltage power cable while locating a street light cable in the near vicinity.

Active location methods require a user to deliberately induce a known AC from a transmitter onto a utility line. This method enables users to locate and identify a line even from a congested web of underground utilities. Because the user controls the signal source, it is possible to vary frequencies and therefore select a suitable frequency to locate the facility more precisely. However, the requirement of an AC source applied to the utility line entails having access to the line and the use of a signal transmitter, whereas the passive method does not. There are several methods to induce AC to a buried utility line:

- **Direct Connection.** A grounded AC source is directly connected to the pipe or cable to be detected through an access point such as a valve, meter, or an end of the line. This method may also trigger signals on any lines in the vicinity that share a common ground point.

- **Clamping.** The output from a transmitter is coupled to a buried utility line by clamping around it with a split toroidal (i.e., ring-shaped) magnetic core. Clamping has the advantage of direct connection and ensures the clamped utility line to have the strongest signal.

- **Induction.** This method uses a rectangular coil that is part of an AC circuit. The coil generates a magnetic field that then triggers AC on the buried utility lines underneath it. Coils positioned vertically will generate a localized magnetic field and are therefore suitable for detecting single lines. Coils positioned horizontally generate a more expansive magnetic field that is useful for signal application on multiple parallel lines simultaneously. In general, a frequency of 8 kHz or higher is suitable for induction, but a higher frequency may cause other adjacent lines to be induced. Induction is not as effective as direct connection or clamping, but depending on the situation, induction may be the only way of applying an active signal.

Many detectors allow both passive and active detection modes, but require a separate transmitter when work in active mode. The combination gives users more choices and flexibility and therefore enables more convenient and efficient location of utility facilities.

Receiving antennas are a key component for pipe and cable locators. A receiving antenna typically contains a coil that converts alternating magnetic flux passing through it into an AC voltage. The voltage is electronically amplified to provide a response on a meter and/or in a speaker. In practice, receiving antennas generally include ferrite rods in their coils to improve the reception. Many modern detectors use antennas containing multiple coils (e.g., twin aerial antennas) to improve detection accuracy and enable depth measurement, especially at situations where multiple conductors exist both underground and overhead. During detection, antennas are typically positioned so that coils are horizontal to the utility lines for better detection of their location and direction. However, it is sometimes necessary to place antennas such that their coils are vertical to the utility lines to cross-check detection results.

While the basic theory behind pipe and cable locators has not changed significantly during the past decade, improvements in software and packaging have led to useful features such a simultaneous monitoring of multiple active and passive frequencies. Likewise, current direction and strength indicators are useful in isolating specific facilities in environments where multiple targets are present. The development of more powerful transmitters enables modern pipe and cable locators to increase the depth in which utilities can be detected.

Applications

Pipe and cable locators are generally used to locate metallic utility lines or non-metallic lines with tracing materials installed along them. In addition, the method can be used to detect non-metallic utility lines without tracing materials, if a metallic conductor or a transmitting sonde can be inserted into the utility line. Currently, a large range of locators are available with various frequencies between 50 to 480 kHz (*4*). Major issues concerning the application of pipe and cable locators in the field include the following (*5, 3,* and *6*):

- **Accuracy.** The accuracy of a locator largely depends on site conditions, the locator's capability to measure accurately, and magnetic field distortions. *Horizontal* accuracy for detected utilities is typically within inches, although it is not rare to have results with a horizontal positional error of more than a foot. When utilities are buried at a depth beyond 15 feet, horizontal positional information can be highly subjective. For homogeneous soil, the positional errors are typically consistent along the same utility lines. In the case of depth measurement, some well-calibrated instruments under ideal conditions can be very accurate. However, depth estimations are in general problematic, especially when site conditions are complicated such as urban intersections with congested utility clusters underneath. In fact, some SUE providers indicated that they use the depth display more as an indication if a detector is following the same utility lines. Detection accuracy can be improved by selecting better designed locators, using multiple aerials, and measuring multiple times with vertical and horizontal antennas.

- **Detection Depth and Distance.** Detection range is affected by several factors including detector sensitivity, utility electromagnetic properties, insulation status, utility dimensional properties, soil conductivity, and existence of other utilities in the close vicinity. Under ideal conditions, typical pipe and cable locators can effectively detect utilities up to a depth of 20 ft. High-power sondes can sometimes increase the detection depth to 50 ft or more. Other mechanisms to improve detection depth and distance include the following:

    - Reduce the rate of signal loss by choosing the most suitable frequencies and using clamping instead of other active detection methods. Several trials are frequently needed to identify an optimum frequency band for a particular line and situation.
    - Increase the signal current by improving ground connections (e.g., wet the soil at ground connections), choosing suitable voltages (due to different line impedance), and/or increasing the transmitter power.
    - Increase receiver sensitivity by improving amplification and noise filtering functions.

- **Locator Selection.** Currently, there are a wide range of locators available, varying in frequency, antenna design, accessory features and functions, grounding method, and remote pipe attachment devices. There are cases where instruments with identical frequencies, similar antennas, and comparable signal outputs under same site conditions do not detect utilities equally well. Therefore, it is important to select the suitable device, which means multiple experiments need to be conducted before attempting to locate utilities. In practice, many SUE providers use different types of locators from different manufacturers to improve detection results.

TxDOT requires all non-metallic pipes to be installed concurrently with a durable metal wire or other approved means of detection, allowing pipe and cable locators to detect them (*7*). Due to this requirement and industry practices, gas lines typically contain tracing wires that make them easier to be detected by pipe and cable locators. However, regardless of the requirement, many water lines are not installed with tracing wires and therefore often cause difficulties during detection. Most fiber optic cables contain a metallic wrap that can be utilized for detection. Field experience shows that pipe and cable locators work best for small diameter copper wires due to their high conductivity, and work less effectively for cast iron or ductile iron pipes.

Many SUE providers interviewed indicated that soil conditions are generally not a major factor for pipe and cable locators. However, soil in some Texas regions can be extremely dry and rocky, which can significantly reduce the detection range.

Ground Penetrating Radar

Basic Theories

GPR is one of the common geophysical techniques for detecting underground objects such as cavities, rocks, buried utility facilities, and underground structures, and increasingly for probing other media such as wood, concrete, and asphalt (*8*). It has been a focus of research and development as it can theoretically detect buried objects of different materials non-intrusively. A complete understanding of GPR theories requires an in-depth discussion of electromagnetic and material permittivity/conductivity theories, which can be very technical and is not part of the scope of this research project.

In general, a GPR unit must have a timing unit, a transmitter, and a receiver. Antennas are connected to the transmitter and receiver to convert an electromagnetic field and electric signal. In a simple GPR system, a timing unit initiates a signal to the transmitter electronics, which then send out a short direct current (DC) pulse to the transmitting antenna. The antenna translates the excitation voltage into a predictable, temporally, and spatially distributed electromagnetic signal. Part of this signal transmits through boundaries under the ground and the rest is reflected back to the receiver. The receiver detects the temporal variation of the returning electromagnetic field and translates it into a recordable signal for analysis and display. Figure 2 shows an example of a 2D GPR image generated for a pavement study.

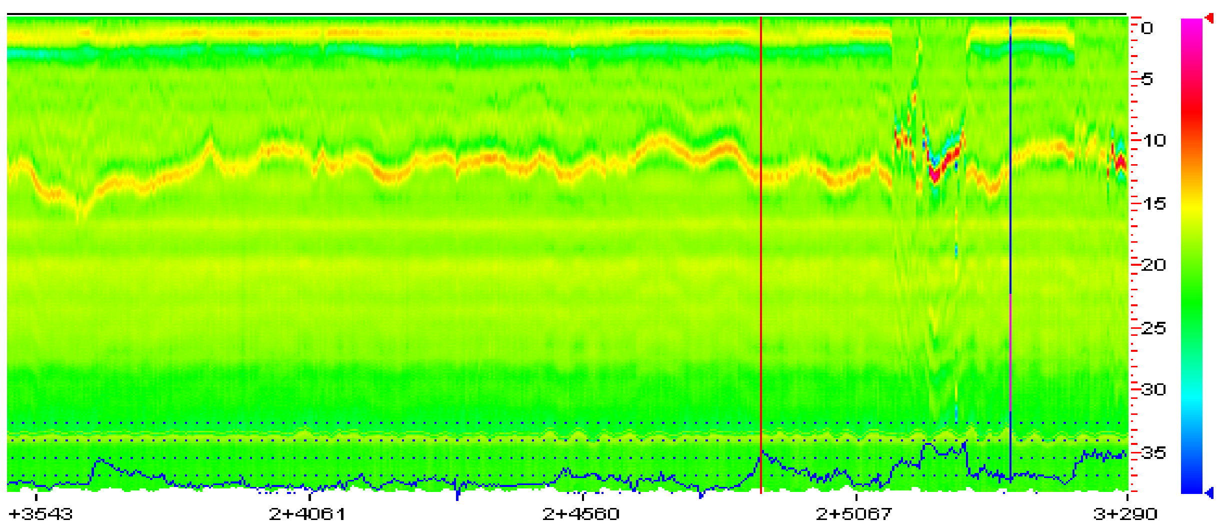


Figure 2. Sample 2D GPR Image for a Pavement Investigation.

Product Design and Implementation

A typical GPR deploys the transmitting and the receiving antennas in a fixed geometry moving over a ground surface. The transmitter sends short, high-frequency electromagnetic pulses into the ground and the receiver receives reflections at the ground surface. GPR can also be used in a transillumination mode where the transmitting antenna is inserted into the study media through a borehole and the receiving antenna is inserted into an adjacent, parallel borehole to receive the transmissions. The two antennas are moved relative to each other at various offsets to probe the different sections between the two boreholes. In both methods, the positional and geometric attributes of buried objects are obtained by analyzing the electromagnetic discontinuities they cause due to their different permittivity or conductivity.

In practice, many factors affect the quality of signal feedback received by the receiving antenna. Transforming raw GPR data into a format ready for application-specific interpretations takes several steps, many of which are automatically performed in modern GPR systems. Listed below are some key steps involved in GPR data processing (*8*):

- Dewow.
- Time-zero correction.
- Filtering.
- Deconvolution.
- Velocity analysis and depth conversion.
- Elevation or topographic corrections.
- Time gain.
- Migration.

GPR technology is relatively new compared with other technologies. During the past decade, there have been limited improvements in the technology itself (e.g., detection depth and result accuracy). Most recent improvements in this area are aspects of data processing, data presentation, and GPS tools.

Applications

GPR has applications in many areas such as earth sciences, engineering, environmental studies, archaeology, and military. In transportation engineering, GPR has been used for purposes such as infrastructure study and utility detection. In the case of utility detection, GPR technology is best suited for buried utility facilities for which preliminary information is not available. GPR systems used for identifying underground utility facilities are typically within the frequency range of 50 MHz and 500 MHz (*3*).

When surveying a large area, a GPR instrument is usually pulled along a grid spaced small enough to sufficiently cover the study area without data gaps. SUE providers sometimes simultaneously deploy several GPR instruments that are connected to a central computer to improve detection speed, especially for projects on undeveloped land when large areas need to be probed. If needed, a GPS unit can be used together with GPR instruments to georeference the data points for later mapping and interpretation of the collected GPR data. Before using GPR, an experienced practitioner must evaluate the project site for GPR suitability. In addition, it is frequently necessary to use multiple bandwidths and to use GPR in conjunction with other techniques.

When used properly, GPR can theoretically detect utilities of a large range of materials, unlike some other electromagnetic methods that can detect metallic facilities only. However, GPR technology several drawbacks (*9*):

- The effectiveness of GPR largely depends on the size and shape of the target, and the degree of discontinuity at the reflecting boundary. In general, GPR is more effective for detecting medium- to large-diameter utilities than small diameter pipes or buried cables. Detection of a small utility facility requires higher frequencies that attenuate, i.e., lose their intensity significantly faster than lower frequencies. As a result, it is extremely difficult to locate small-diameter facilities that are buried deep. Very small pipes are generally difficult to detect, regardless of how deep they are buried. In addition, clay sewer pipes may be hard to detect since their dielectric constant (relative permittivity) is not much different from the surrounding soil.

- GPR has a relatively short detection range. The maximum depth of utility detection is typically about 10 ft in favorable conditions, although instruments with well-designed antennas may find large pipes buried deeper than 15 ft in soils that are dry, sandy, and homogeneous. The pulse strength can attenuate quickly in conductive materials such as clay and saturated soils, reducing the effective detection distance. Studies indicated that, with modern GPR systems, a 12:1 depth-to-diameter ratio provides reliable utility detection down to the first 6 ft in reasonable conditions. Beyond 6 ft, it becomes more difficult to detect pipes of any size.

- GPR reliability is highly sensitive to operation conditions. Modern GPR systems generally produce reasonable results in ideal soil conditions (e.g., dry, sandy soil) combined with favorable utility characteristics. Factors such as the presence of highly conductive soil, very rough surface, tightly spaced pavement reinforcing steel, road deicing salt, and ground moisture can dramatically decrease the detection range and reliability. When used on pavement, GPR generally works well on asphalt pavement due to the layered structures. GPR generally does not work well on reinforced concrete pavements.

- GPR cannot detect utility types. GPR is a technique used to detect subsurface boundaries formed between different materials with significantly varying permittivity and conductivity. It must be used in conjunction with supplemental data or other detection techniques in order to determine the type of underground utility facilities.

- GPR data are difficult to interpret. GPR output data can be extremely fussy and confusing, depending on soil characteristics.

In the past decade, the major improvements in GPR technology have been primarily in the areas of portability and usability of GPR instruments, and sophisticated data processing software. As a result, modern GPR systems have become more user-friendly and require less data interpretation effort. One person can operate most systems, with results displayed to the operator on a real-time basis. With the help of available external software tools, GPR results can be visualized into various formats. In addition, GPR equipment has become much more affordable and is considered standard surface geophysical equipment for SUE providers.

Compared with some other states, Texas has many regions that have soils with high levels of clay, caliche, and/or limestone and therefore are less suitable for GPR (see Figure 3). Among the major urban areas in Texas, SUE providers that the research team interviewed had indicated that the soil conditions in El Paso are more suitable for GPR compared with the Texas Triangle. Nevertheless, GPR is still used in these areas as one of the major tools to detect underground utilities, especially water, sewer, and storm water lines that pipe and cable locators cannot detect. In many cases, GPR is not used to directly detect utilities facilities themselves but rather to detect indications of the existence of underground utilities, such as trenches, conduits, and utility banks. As such, utilities that were installed through trenches are much easier to detect compared with those that were bored in, as the latter do not interrupt soil above the boreholes and are typically installed deeper than trench-installed utility facilities.

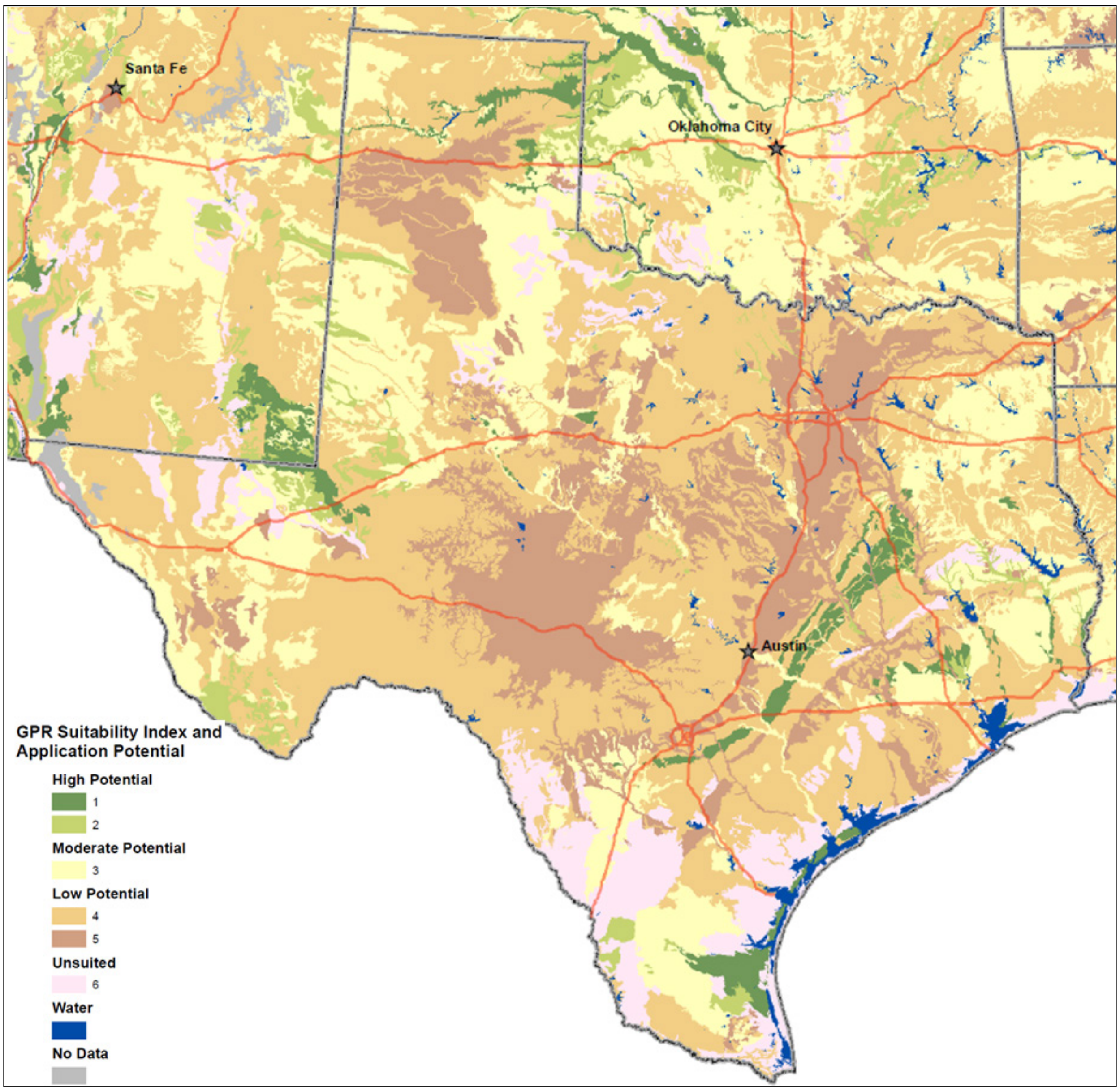


Figure 3. GPR Soil Suitability Map in Texas (modified from [*10*]).

SUE providers interviewed for this project reported that from field experience, GPR in Texas can in general detect large utility facilities buried up to 3 feet. When conditions allow, large utility lines buried up to 4.5 feet can be detected as well. Note that GPR systems may miss fairly large utilities during detection. However, if detected, the indicated locations are reasonably accurate in most cases. Field experience showed that the level of error for most GPR systems is typically within the 10–15 percent range for depth estimations and about 2–3 inches for horizontal locations. In urban areas with densely located utility facilities, GPR can detect only the facilities located closest to the top.

Terrain Conductivity

Basic Theories

TC is a non-intrusive geophysical method for detecting underground objects by measuring the conductivity of a cone-shaped volume of underground soil (*3, 9*). A typical TC system contains two coils separated at a certain distance: a transmitter and a receiver. The transmitter generates and emits a time-varying electromagnetic signal in the ground underneath the coil, which then induces very small circular electrical currents (named eddy currents) in the earth below the coil. These eddy currents in turn generate a secondary magnetic field, which the receiver coil detects together with the primary field.

Theoretically, the secondary magnetic field is a complicated function of the inter-coil spacing, the operating frequency, and the ground conductivity (*11*). Terrain conductivity systems are designed to operate within the low-frequency range such that the skin depth of the electromagnetic wave (defined as the depth below the surface of a conductor at which the current density has fallen to 1/e of that at the surface) is many orders of magnitude higher than the systems' effective depth of penetration. Under this condition (technically known as operation in low induction numbers), the ratio of the secondary to the primary magnetic field becomes directly proportional to the ground conductivity, and the phase of the secondary magnetic field leads the primary magnetic field by 90°. The following equation shows this relationship:

$$\frac{H_s}{H_p} = \frac{i\omega\mu_o\sigma S^2}{4}$$

where:

H_s = secondary magnetic field at the receiver coil.
H_p = Primary magnetic field at the receiver coil.
$\omega = 2\pi f$.
f = frequency.
μ_0 = permeability of free space.
σ = ground conductivity.
s = inter-coil spacing.
$i = \sqrt{-1}$.

Consequently, the ground conductivity can be estimated as:

$$\sigma = \frac{4}{\omega\mu_0 S^2}\left(\frac{H_s}{H_p}\right)$$

Terrain conductivity meters designed based on this theory can therefore detect ground conductivity by simply measuring the ratio of the magnitudes of the primary and secondary magnetic fields. Underground objects are detected by identifying variations in terrain conductivity that these objects caused.

Product Design and Implementation

Typical terrain conductivity systems contain a transmitter coil and a receiver coil installed on a frame with a fixed or sometimes adjustable separation, where the distance of separation is directly related to the effective depth of penetration. An instrument console is also installed with the system to house the control unit as well as the conductivity meter. Operators move the systems along the ground surface and collect conductivity readings at a fixed temporal or spatial interval.

A terrain conductivity meter can be used in two different ways:

- Both transmitter and receiver coils are placed horizontally to ground surface.
- Both transmitter and receiver coils are placed vertically to ground surface.

The horizontal configuration approach enables a larger effective exploration depth than the vertical configuration, but it is insensitive to changes in near-surface conductivity. The two configurations may be used in conjunction with each other to improve detection accuracy.

The most important factors that affect terrain conductivity measurements include porosity of the subsurface material, degree of saturation, and concentration of dissolved electrolytes in the pore fluids (*12*). Soil type is another factor affecting conductivity due to the effects of soil particle size and shape on the geometry of the flow paths that electrical currents follow around the insulating soil particles. Conductivity generally increases with decreasing particle size due to a more direct current path. Therefore, silty soils tend to have a higher conductivity than clean sand or gravel.

Most modern terrain conductivity systems can record conductivity readings automatically; others require a separate data recorder to store the readings. The readings are commonly expressed in the conductivity units of milli-ohms/meter (m-ohms/m) or milli-Siemens/meter (mS/m). In addition to conductivity measurements, modern systems are frequently able to detect an "in-phase" signal component response that can indicate the existence of metal objects. Some systems can transfer the data automatically to external computers. Spatial data are typically collected through a GPS receiver linked to the TC system. In most cases, external software is required to further process and visualize the conductivity data and georeference the information according to the corresponding GPS data. Figure 4 shows an example of an underground conductivity map showing buried utility facilities.

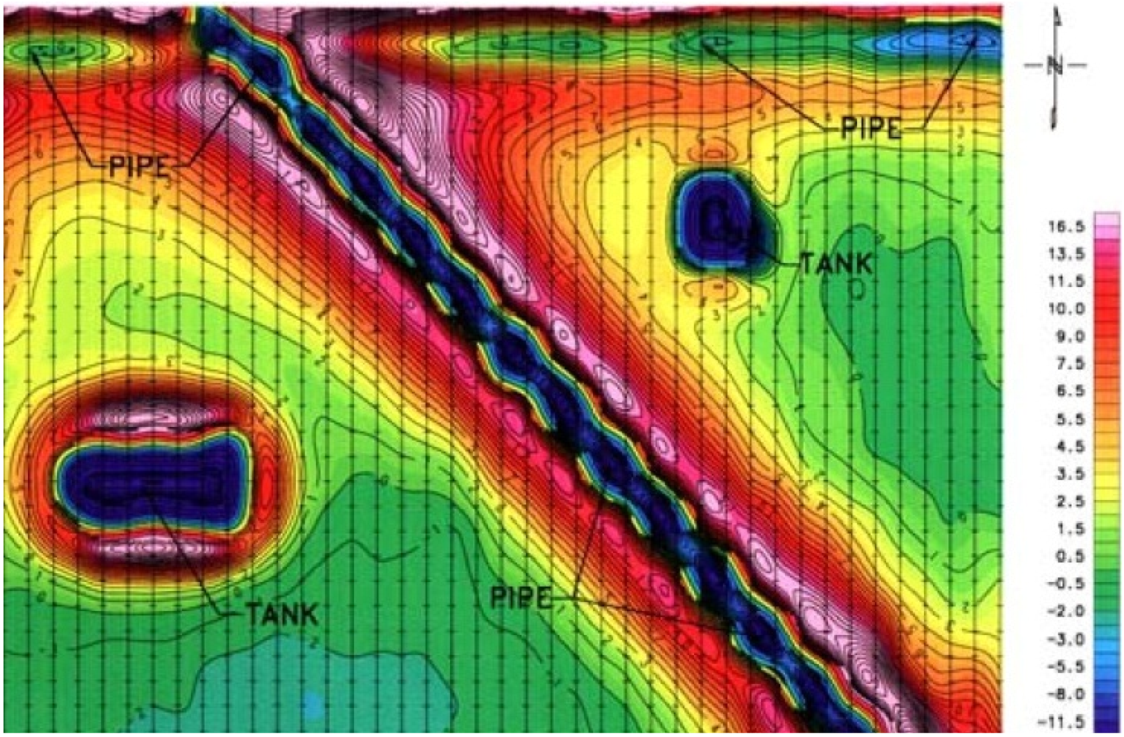


Figure 4. Sample Ground Conductivity Map Showing Underground Utility Facilities (*13*).

Applications

The TC method has been used in various types of environmental and soil studies. The method is useful for underground utility detection especially in non-utility congested areas or in areas of high ambient conductivity (*3, 6*). In general, it can detect isolated metallic utilities, underground storage tanks, wells, and vault covers fairly well. Under certain conditions, large non-metallic water pipes in dry soils or large non-metallic empty and dry pipes in wet soils are also detectable via this method.

Although current terrain conductivity systems tend to detect utilities successfully within the first 10 ft of cover, some systems may effectively penetrate a depth of 15–20 ft and some can even reach as deep as 150 ft when conditions allow. Utilities' resistivity can range from extremely low (e.g., metallic) to very high (e.g., large empty clay pipe) and therefore significantly affect the rate of detection success.

Magnetic fields produced along overhead power lines and aboveground metal objects interfere with terrain conductivity measurements. In addition, higher levels of salt in soil can increase the ground conductivity, which makes it more difficult to detect metallic utilities yet relatively easier to detect non-metallic utilities. In soil saturated with water, the ground conductivity is too high to detect any kind of utility, unless it is watertight, empty, large, and relatively shallow.

The TC method provides another non-intrusive means for underground utility detection. Many instruments are portable and one person can carry any one of them. Therefore, it requires relatively little effort to carry out a survey using TC equipment. However, tracing is more difficult than detection and requires large amounts of data. To provide meaningful results, the terrain conductivity method frequently requires sufficient data collected with different antenna orientations or within a tightly spaced grid search pattern. In addition, terrain conductivity data are generally much more complex to interpret than pipe and cable locator data. Currently, it is not realistic to perform accurate depth estimation using terrain conductivity methods.

Other Geophysical Methods

The following are some other methods that have been or can be used for underground utility location (*3, 6, 9, 14,* and *15*).

GPR and/or EMI Arrays

In recent years, GPR and EMI arrays have generated considerable interest because of their improved ability to locate underground installations not just horizontally but also vertically. GPR and EMI arrays work through the simultaneous use of multiple sensors and/or data channels assembled in a single mobile cart, typically 4–7 feet wide. Modern EMI arrays typically utilize one of the two EMI technologies that have been commonly used for pipe and cable locators and terrain conductivity methods. Carts that have both GPR and EMI sensors onboard are also available. During a survey, a vehicle is typically required to tow the array over a study area.

To provide a geo-reference to the data, it is common for array units to have GPS receivers with or without real-time kinematics (RTK) differential correction capabilities, or laser transmitters that work in conjunction with stationary theodolites, which are useful in situations where limited sky visibility is not adequate for good GPS reception. Special-purpose software is also used to receive, process, and convert the signal data to 3D geo-referenced images. In general, vendors use proprietary image processing software, e.g., RADAN® in the case of Geophysical Survey Systems® (GSSI) and SPADE® in the case of Underground Imaging Technologies® (UIT) (*16, 17*). Some vendors also use commercially available software such as Surfer® by Golden Software® or DPlot® by Hydesoft Computing® to perform additional tasks, e.g., to provide shading and other 3D visualization effects.

GPR/EMI arrays can cover large areas in a relatively short time period. Regardless of their advantages, GPR/EMI arrays are expensive, so most SUE providers rarely use these. Figure 5 provides a sample map that UIT developed, showing underground gas lines (yellow), a manhole (green), shallow targets (orange), and an unknown large target (magenta) (*18*).

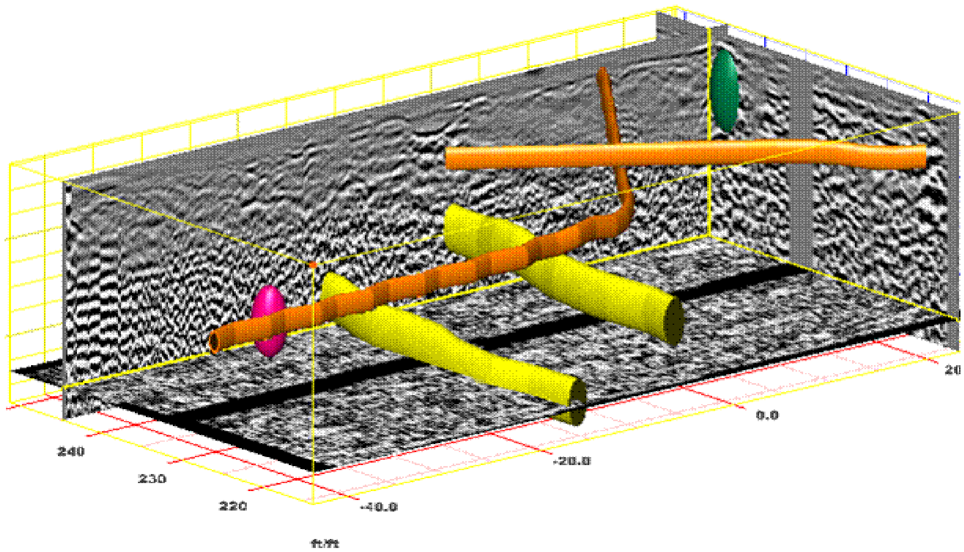


Figure 5. Sample 3D Image of Underground Utility Installations (*18*).

Resistivity Measurements

Electric resistivity of a material is a fundamental physical property related to the ability of a material to conduct electricity. It determines the resistance of a conductor of a given cross-sectional area and length. The purpose of resistivity measurements is to determine the subsurface resistivity distribution of the ground, which can then be related to physical conditions of interest, such as buried objects, porosity, the degree of water saturation, and the existence of voids.

Resistivity measurements are taken by injecting DC into the ground using two or more electrodes and then measuring the resultant voltage difference at receiving electrodes. Resistivity is then calculated based on the current and voltage values of the complete circuits enclosing the tested ground. The measurements are then processed and mapped through external software either in a two-dimensional format or in some cases, a three-dimensional format to identify underground objects that resistivity changes have indicated. Figure 6 shows an example of resistivity measurements mapped as a 2D image.

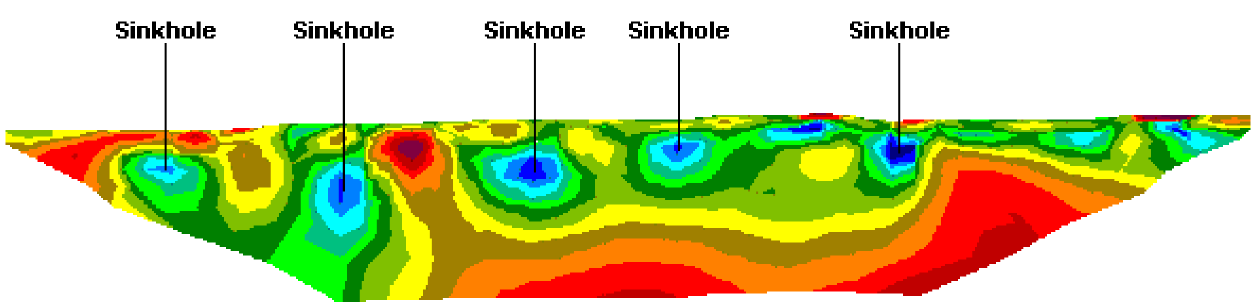


Figure 6. Sample 2D Image Visualizing Resistivity Measurements (*19*).

The detection depth of this technique depends on the penetration depth of the injected current, which is in turn determined by ground resistivity, and the electrode spacing and configuration. The major disadvantages of this method are the complexity of data collection and interpretation and the requirement for galvanic electrodes to be driven into the ground. Thus, this method may be useful as a search technique during utility detection but not as a trace technique.

An alternative method to measure ground resistivity is the so-called capacitive resistivity method. This technique employs non-contact electrodes to couple AC into the ground. It is therefore a non-intrusive method and can be used on hard surfaces with a drastic improvement in the data acquisition speed. Just measuring the amplitude of the received current would yield comparable results as those from DC resistivity measurements, but the phase information associated with the AC further improves the resistivity measurement. Currently, neither of the methods is commonly used for utility location.

Magnetic Methods

Magnetic methods in geophysical surveys identify underground objects by measuring the variations in direction, gradient, or intensity of the earth's magnetic field over the area surveyed. The theory behind these methods is that ferrous objects exhibit an induced magnetic field when they are in a strong field such as the earth's, causing localized disturbances or anomalies in the earth's total magnetic field. There are two general types of magnetic surveys applicable to utility detection: total field and gradient.

Total field survey measures earth's total magnetic field at the ground surface. The field of ferrous objects that magnetic induction caused is analyzed from the measured total magnetic field to identify their existence. The gradient survey method uses an instrument to cancel the effects of internal and external magnetic fields through the placement of two total-field sensors within a known distance of each other. These two sensors are in balance unless a ferrous object is close to the instrument, in which case it results in an imbalance that the instrument captures. Typically, signal patterns for a vertically oriented target exhibit peaks over the top and a horizontally oriented target exhibits peaks at their ends (e.g., pipe joints).

The total method can be useful for a utility search over large areas in the absence of power lines, railroads, or other large ferrous objects that create magnetic interferences (Figure 7). The gradient method is typically effective for detecting valve boxes, steel drums, iron markers, and manhole lids. It can also be used to detect magnetized non-metallic fiber optic cables or cast iron pipes. Large objects buried up to 25 ft from the surface may be detected in ideal conditions. In general, pipes that are more than several feet below the surface can be difficult to detect, unless they have a very high initial magnetic strength that is related to object shape, internal structure, material purity, and the object's manufacturing location.

A large variety of magnetometers are commercially available today, most of which are portable by one person and can measure both the earth's total magnetic field and the magnetic field gradient. However, this method is not commonly used for utility location.

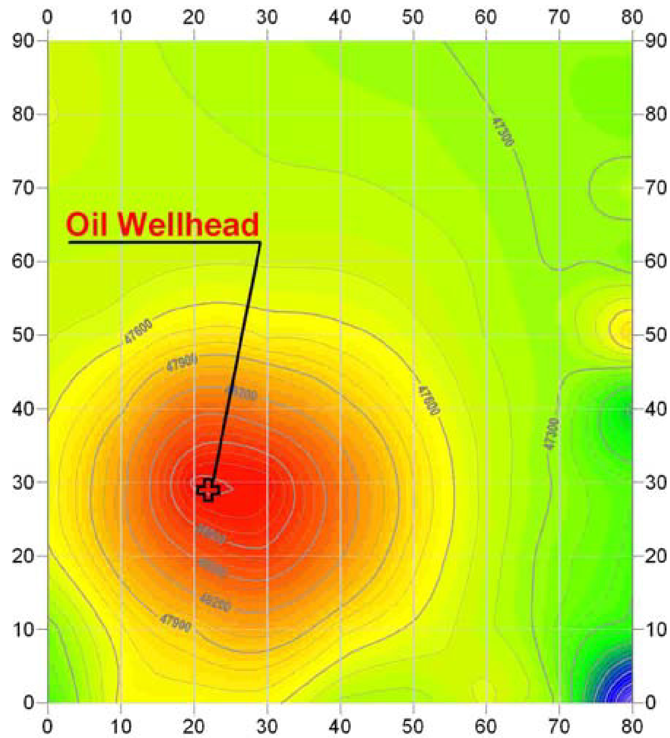


Figure 7. Sample Magnetometer Data Showing Earth's Total Magnetic Field Intensity (*20*).

Infrared Thermography

Infrared thermography is based on basic heat transfer principles including conduction and radiation. The insulating effect of different types of underground materials changes the flow of energy in the ground, which may be detected to indicate the existence of underground objects such as voids, boulders, and utilities. Some utilities, such as steam lines, energized power cables, sanitary sewer lines, and industrial process lines have operating temperatures distinguishable from that of surrounding ground. The sun serves as the heat source by warming the ground to be tested during daytime; in turn, the ground then becomes the heat source during nighttime.

Sensitive infrared thermographic equipment can be used to detect the temperature variations when they are significant enough and produce 2D thermal images. Other than the high cost of sensitive infrared thermographic detectors, several other reasons currently limit the use of infrared thermography for utility detection. Factors such as weather (e.g., temperature and wind), soil properties, and utility conditions largely affect its applicability. In many cases, utility facilities must be buried near the surface to become detectable. In addition, this technique currently cannot provide depth estimation. Experiments that one of the interviewed SUE providers had done showed that the method was able to successfully detect a cable and a water line buried less than 5 ft deep, but missed a major petroleum line. Interestingly, the SUE provider was able to detect the same water line under a pavement structure but not under a grass surface.

Acoustic Location

Acoustic location methods detect acoustic emissions from underground utilities using special sensors such as geophones or accelerometers that convert motion into electric signals. Presumably, the highest vibration amplitude at the ground surface indicates the location of a buried utility. Acoustic sources can be one of the following:

- **Active.** Sound waves are induced onto or into a pipe from active sources such as a transducer connected to the pipe or simply striking the pipe or manhole covers using hard objects.

- **Passive.** The sound is produced when a pipe vibrates because its product escapes at a hydrant, a service valve, or a leak.

- **Resonant.** Sound waves are created by interfacing the surface of the transporting fluid in a pipe (e.g., at a hydrant). The oscillator's frequency may be tuned to one of the resonant frequencies of the pipe to maximize the sound waves for better detection.

In any of these cases, the sound travels along the length of the pipe and attenuates gradually through the pipe wall into the surrounding soil. The detection range and accuracy largely depend on factors such as rigidity of the pipe material, depth of cover, type of surface, soil type, compaction, ground moisture, and presence of rocks and other pipes. Experiences indicate that the method may detect up to 8 ft in depth in the case of gas pipes and 6.5 ft in the case of water pipes. The horizontal range reaches up to 1,000 ft for plastic gas pipes and more than 500 ft for water pipes in favorable conditions.

The acoustic location method is typically used for tracing rather than searching. Disadvantages of this method include being prone to interference from background noises, requiring access to utilities or prior knowledge about their locations, and inability to estimate the depth of buried utilities. Because of these factors, SUE providers use this technique only for large water or sewer pipes that cannot be detected using other major tools. The method is used only on relatively new pipes since aged facilities can easily be damaged when these are struck to create an acoustic wave. In some cases, prior approvals from utility owners need to be obtained in order to use acoustic detection on their facilities. In many cases, this method has to be carried out during nighttime when there is no ground traffic and other background noises are minimal.

In addition to acoustic location, researchers have also been looking into the potentials of using seismic refraction and reflection for underground object location. Seismic methods are typically used in geological surveys to determine site geology, stratigraphy, or rock quality. They currently have very limited applications in underground utility investigation.

Metal Detectors

Strictly speaking, metal detectors are a type of instrument instead of a technology. Metal detectors are based on EMI technology where a transmitter is used to send an AC signal into the ground and a receiver is used to detect a corresponding magnetic field generated by buried metal objects. From this perspective, some pipe and cable locators or smaller terrain conductivity meters can function as metal detectors as well. Based on applications, metal detectors can be classified into three groups:

- Hobby and treasure finding equipment are suitable for detecting very shallow but small metal objects.
- Utility location and military instruments are used for detecting deeper and larger objects, but usually without data recording and post-processing capabilities.
- Specialized metal detectors with large coils are typically mounted on vehicles and have continuous data recording and post-processing capabilities.

Metal detectors are standard tools used by many SUE providers for quick detection of large metallic utility appurtenances such as manhole lids, valves, and meters.

Micro-Gravitational Techniques

These techniques are based on the principle that the gravitational force at any given point on the surface of earth is directly related to the effects of mass. Theoretically, large underground objects with densities different from that of the surrounding soil will create variations in this force that can be detected using sensitive equipment. Gravity methods have applications in geologic studies involving mass variations, such as study of fault problems, ground water inventories, and basins. These techniques require very precise measurements and are very rarely used for utility location purposes.

Chemical Techniques

Liquid chemicals conveyed in pipelines left around pipes due to leaks, or gas leaks from pipes can sometimes be utilized to detect the presence of an underground pipe. For example, natural gas companies detect pipe leaks by finding leaked gas with flame ionization or photoionization detectors. Currently, chemical techniques are typically not being used for general utility detection purposes.

Joint Use of Other Traditional Methods

In addition to the methods outlined above, the following traditional techniques can further improve utility location results (*3*):

- **Utility Markers.** Many types of utility markers can be used to increase the visibility of utility facilities, especially for non-metallic utilities, to aid with the detection by a geophysical method or other specific detector:
  - **Visual Markers.** Utility owners frequently indicate the presence of buried utilities with markings, signs, or other types of markers visible at ground surface above the buried utilities. Visual markers may be installed in the ground flush with the ground surface or directly connected with the buried utilities. These markers provide important preliminary location and attribute information about existing utilities for

geophysical surveys. However, markers are somewhat unreliable in that they can be easily moved or removed, which may cause misinformation.

  - **Utility Tracing Tapes or Wires.** A known practice in the utility industry is to install tracing tapes or wires along with buried non-metallic utilities. A disadvantage for tracing tapes or wires is that they may break overtime due to pipe construction, repair, or maintenance, which may cause difficulties during detection and tracing. In addition, tracing tapes and wires may be moved away from their original locations overtime and thus result in detection errors.

  - **Utility Marking Magnets.** Utility marking magnets are permanent magnets installed with buried utilities to improve their visibility during nonintrusive detection. A magnetometer or other magnet-sensitive detectors can detect some of these magnets up to several feet under the ground surface.

  - **Passive Electric Markers.** Passive electric markers contain a passive antenna that can reflect signals from a locator. These markers typically use different colors and frequencies to indicate different types of utilities. They may be installed at ground surface or buried up to several feet below surface above a utility facility. Passive electric markers require specific locators in order to be detected.

  - **Radio Frequency Identification (RFID) Utility Markers.** RFID technology has been widely used in various industries for product inventory and tracking. Some SUE providers refer to RFID utility markers as one of the most significant technological improvements in relation to underground utility detection and identification. Markers typically contain passive RFID tags that store important utility information and broadcast it via radio waves when an RFID reader has activated these tags. They are installed at strategic locations along utility lines to provide necessary information about the buried utilities. RFID utility markers can be designed to work long-term in various challenging environmental conditions and have the potential to function when buried deep below surface. It is also theoretically feasible to install RFID readers to excavation equipment to provide real-time warning about the existence of underground utilities.

- **Boreholes.** As mentioned earlier, GPR antennas can be applied in transillumination mode where the two antennas are inserted in boreholes for better results. Boreholes may also be used in conjunction with other techniques to bring sensors (e.g., transmitters or receivers) closer to utilities or to reduce surrounding noises. Air or water vacuum devices or micro-directional boring devices are less intrusive and can be used to reduce the probability of damaging existing utilities. In addition to vertical holes, boreholes may be drilled horizontally from right-of-way line to right-of-way line for horizontal imaging.

- **Excavation.** Exposing utilities through excavation is the best way to accurately measure and characterize their location. Excavation is typically necessary when there is knowledge about the existence of a utility facility and other methods cannot provide satisfactory results. Several methods are typically used to excavate utilities, including manual excavation, machine excavation, and vacuum excavation. Among these methods, air/vacuum and water/vacuum excavation have a low potential to damage existing utility facilities during excavation. The air/vacuum method uses a tool that blows pressurized air to loosen the soil in a small excavation hole, and then a powerful vacuum to remove the soil from the excavation hole. The water/vacuum method uses water instead of air to loosen soil that is then removed using a vacuum. The air/vacuum method is more labor-intensive and time-consuming yet less likely to cause utility damage, and the removed soil can typically be re-used as backfill. The water/vacuum method consumes less time and manpower but is not appropriate for all utilities and somewhat more likely to damage utilities and surrounding soil.

SURVEY OF SUBSURFACE UTILITY ENGINEERING PROVIDERS IN TEXAS

Underground Utility Investigation Practices

The research team contacted several SUE providers actively providing SUE services in Texas to discuss utility investigation practices, techniques, and technologies. Following an introduction email, the research team conducted several interviews with seven SUE service providers in Texas. Appendix C provides a copy of the email sent to SUE providers, followed by a list of discussion points that the research team used during the interviews.

Based on the interviews with SUE providers, it is clear that SUE providers have different preferences for utility detection methods and have varying procedures to carry out utility surveys. However, most SUE providers interviewed indicated that they use ASCE/CI 38-02, Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data, as a guideline to determine typical tasks, procedures, and responsibilities for SUE services (*4*).

SUE providers in Texas mostly perform utility investigations at QLB and QLA, surface geophysical methods, and test holes. QLD and QLC activities are typically performed by TxDOT or a local public agency and then forwarded to the SUE provider if QLB or QLA data are needed. This practice appears to contribute to the tendency that some transportation officials and utility owners equate SUE services with QLB and QLA data collection only. Based on the interviews with several SUE providers in Texas, the following sections describe some general activities for QLA and QLB data collection.

Records Research

SUE investigations typically start with records research. Depending on the scope of the work and staffing/expertise availability, SUE providers may perform this task or rely on information provided by their clients. Many SUE providers use one-call services to first identify potential utility owners in the area of interest and then coordinate with individual utility owners to obtain preliminary utility information. Therefore, effective communications with utility owners is critical for SUE providers.

Several SUE providers indicated that insufficient and/or inaccurate utility records are a significant challenge for SUE providers. In addition, utility facilities that are abandoned, or for which owners cannot be found due to historic changes of ownership or owner names, can be significant challenges for SUE service providers.

Utility Designation

Many SUE providers start the utility designation process with confirming and marking utility facilities using existing records or visible appurtenances. Depending on site conditions, some SUE engineers suggested that a good practice is to start the designation process in less congested areas and then move to more congested areas, a process sometimes referred to as "mapping into congestion." Some SUE providers also suggested that detection should not necessarily be limited to project limits or area of interest. Frequently, there is a need to go beyond the project boundary to better understand utility conditions and impacts and to produce meaningful results.

Pipe and cable locators are generally the most common tool that SUE providers use. It has become a good practice among SUE providers to use multiple locators of different configurations and frequencies from different manufacturers to improve detection results. Pipe and cable locators are most frequently used in active mode by clamping or direction connection. For extremely dry soil, operators may pour water on the ground at the connection point to improve detection range and sensitivity. GPR and metal detectors have also become standard tools that most SUE providers use for detecting non-metallic facilities and isolated, shallow, and metallic utility objects.

Several SUE providers mentioned a common procedure referred to as "utility sweep." A utility sweep is used to scan for utility facilities at a new site at the beginning of a comprehensive SUE investigation. Utility sweeps are also used to detect the existence of unknown or abandoned utilities at the conclusion of a utility investigation. SUE providers typically use pipe and cable locators (in passive or induction mode) and/or GPR equipment to perform utility sweeps. During a sweep, SUE providers scan a highway section along both pavement edges and/or right-of-way lines. Some perform the sweep by walking across the area diagonally from both directions. Many indicated that a grid-style scan using GPR equipment or pipe and cable locators is very effective and desirable but not performed for every project as such a scan can be time-consuming and labor-intensive.

Some SUE providers suggested that during QLB investigations, an attempt should be made to open and access all utility appurtenances in an effort to improve detection results. This would require SUE providers to include personnel trained and equipped to perform confined space entries in accordance with relevant Occupational Safety and Health Administration (OSHA) regulations. For utility investigations involving work zones, a trained and/or certified work zone traffic controller would also need to be available.

Some SUE providers interviewed indicated that in some cases, insufficient coordination among TxDOT divisions can pose a challenge for SUE service providers. Examples in the past include uncoordinated maintenance activities and roadside mowing operations during or right after SUE investigations that damage utility markings on pavement or shoulders.

Utility Location Using Test Holes

Critical underground utilities often need to be exposed during QLA utility investigations using test holes. Currently, there are primarily two excavation methods that have been widely used for utility investigations in Texas: air/vacuum and water/vacuum. Air/vacuum uses a high-pressure air flow to dig into the ground while a powerful vacuum removes the loosened soil. Instead of air, water/vacuum uses a high-pressure water flow to fracture the ground and a vacuum to remove the water-soil mixture.

Compared with water/vacuum method, the air/vacuum method is less likely to damage utilities and the vacuumed soil can be used for backfill after testing. The water/vacuum method, on the other hand, is more powerful and efficient. However, it can be dangerous for operators and is more likely to damage utility facilities. In addition, it requires access to water and the mud generated during excavation has to be shipped out for disposal. TxDOT generally does not allow the use of water/vacuum excavation within state right-of-way. However, some areas in Texas contain rocky soil where test holes can only be excavated using the water/vacuum method. When this is the case for a TxDOT project, SUE providers request special permission from both TxDOT and utility owners.

Test holes during QLA utility investigations are typically between 8 and 12 inches in diameter and up to 20 ft in depth. Some powerful equipment can excavate as deep as 45 ft. If a test hole does not reach the probed utility facilities, operators expand the bottom of the hole up to 3 ft until the utilities are found. For QLA level services, the major challenges include pavement, traffic control, and access to job sites. Some bored-in utilities may go through solid rock, which makes them hard to detect and very difficult to locate via test hole. To improve data accuracy, some SUE providers recommended that vertical QLA data should be taken through direct rod readings on exposed utilities instead of deriving the data from surface elevation data.

Preparing SUE Deliverables

An integral activity associated with SUE services is to prepare and submit SUE deliverables such as maps and reports. After utilities are detected and designated on the ground, SUE contractors collect coordinates of the marked utilities and then process the information using a quality control mechanism. The coordinate information can be collected by a licensed surveyor from the contractor's staff, TxDOT, or a subcontractor, using either handheld GPS instruments or traditional survey equipment. Some SUE contractors have the ability to produce georeferenced SUE reports in 2D and/or 3D formats using popular computer-aided design (CAD) software tools (e.g., Bentley® Microstation®) and GIS tools (e.g., ESRI® products). Animated 3D videos showing the visualized utilities can also be produced upon requests. In addition, many clients ask SUE providers to include digital images of utility facilities taken at test holes and other strategic locations in both QLB and QLA SUE reports.

Unlike SUE service providers, utility designation services such as One-Call typically do not provide formal SUE reports. During utility designation services, utilities are marked on the ground as they are detected. Some SUE providers use unique colors (e.g., pink) so that their markings are differentiated from the standard colors used by utility owners and One-Call centers. If required by clients, contractors obtain the coordinates of the marked utilities using handheld

GPS instruments and provide a georeferenced CAD map or map the utilities with tools such as Google Maps.

Subsurface Utility Engineering in the TxDOT Project Development Process

The TxDOT Project Development Process manual suggests the collection of utility location data before the start of the detailed design phase, although there are times when some utility location data are needed while developing preliminary or geometric schematics (*21*). Design engineers need utility data before establishing final alignments of the roadway and related features (e.g., storm drains, other excavation work) so that major utility conflicts may be avoided. Although recommended, SUE services are not a required component in the TxDOT project development process. When SUE services are determined necessary, project managers develop and execute a work order for the SUE investigation in coordination with district utility coordinators and the TxDOT Design Division.

SUE providers suggested that QLB data should be collected as early as possible during the project development process and before the detailed design phase, which would allow design engineers to have sufficient information about utilities and avoid major utility relocations. In cases where QLB services were requested after the 60 percent design meeting, the data were not useful to avoid utility conflicts but rather used to facilitate utility adjustments.

SUE providers noted that in many project scenarios, it is advisable to pursue a combination of QLB and QLA data collection. Many QLB utility investigations include critical utility facilities that cannot be mapped using typical QLB detectors and require QLA investigation. However, QLA data collection is much more expensive as compared to QLB data collections, and therefore unnecessary test holes should be avoided. For example, QLA data collections could be limited to utilities in conflict or suspected conflict with the design.

SUE providers generally recommended the collection of QLA data between the 30 percent and 60 percent stage of the detailed design phase. At this stage, the design has proceeded to the point that designers can identify utility conflicts through the review of QLB data, yet there should be enough time for small design modifications, which may avoid a costly utility relocation.

Some SUE providers had experiences with TxDOT projects that were delayed for months or even years after SUE services were performed due to funding or other issues. In many cases, TxDOT had to request SUE investigations again once the projects resumed, either because SUE data from the initial utility investigation was no longer available, or because too much time had passed and concern that utility conditions might have changed over time. Although there might not be a solution for the latter issue, the former issue could be addressed by good policy regarding the storage of SUE deliverables. SUE providers also recommended that using just one SUE contractor throughout the entire SUE data collection process (i.e., from QLD-QLA) has significant benefits and can improve efficiency and reliability of the data collection.

CHAPTER 3: UTILITY INVESTIGATION PRACTICES AT TXDOT

To understand the current utility investigation practices at TxDOT, the research team conducted an online survey of several organizational units within TxDOT, including districts, regional support centers, and divisions, about the current process of using utility investigation practices. This chapter describes the findings of the survey.

DEVELOP AND CONDUCT ONLINE SURVEY

The contact list for the online survey was assembled using feedback from district offices, regional support offices, and the ROW and DES divisions. Researchers contacted TxDOT districts, regional offices, and right-of-way and design divisions with a short explanation of the project and need for a list of potential contacts. Following the phone call, researchers sent a contact list template to the person contacted by phone with a detailed explanation of the project, deadline, and contact information for any questions regarding the project. Researchers sent a reminder email a week later to contacts that did not respond along with contact information, projects abstract, and an additional copy of the contact list template. Of the 25 TxDOT Districts, four Regional Support Centers, and two Divisions, a total of 22 Districts, two Regional Support Centers, and one Division provided corrections, additional names, or feedback to the contact list. After gathering all of the edited information, the contact list was compiled and sent to the project director for final additions and revisions. The final contact list contained 269 potential survey contacts.

The research team developed a list of relevant questions for the online survey. This questionnaire initially included approximately 30 questions. The questionnaire was then converted using the online interface of SurveyMonkey, a commercial online survey provider. To reduce the overall time needed to complete the survey, the research team added several Yes/No questions that allowed the use of question logic. This provided the ability to skip questions and route survey respondents based on their responses. The final survey consisted of 47 questions on 35 pages and is included in Appendix A.

The online survey was opened for respondents on June 15, 2011, and closed on June 23, 2011. The research team used two survey data collectors, the main data collector, and a secondary collector for corrections and bounced emails. For each collector, the research team created an official survey invitation, and a follow-up email for contacts that had not responded with a week.

ANALYSIS OF SURVEY RESULTS

Survey Participants

Out of 269 recipients of the survey invitation, 129 responded (48 percent), 139 did not respond (52 percent), and one recipient did not respond and opted out from further emails. The majority of respondents provided information about their geographic location (see Figure 8 and Table 3). From the responses, it appears that most respondents were located at TxDOT districts (93 percent), with a few respondents from the ROW and some of the regional offices (7 percent).

Shown in Figure 8 are the locations of TxDOT districts, the four regional centers, and the Right of Way Division. Numbers in Figure 8 are the number of respondents from that location.

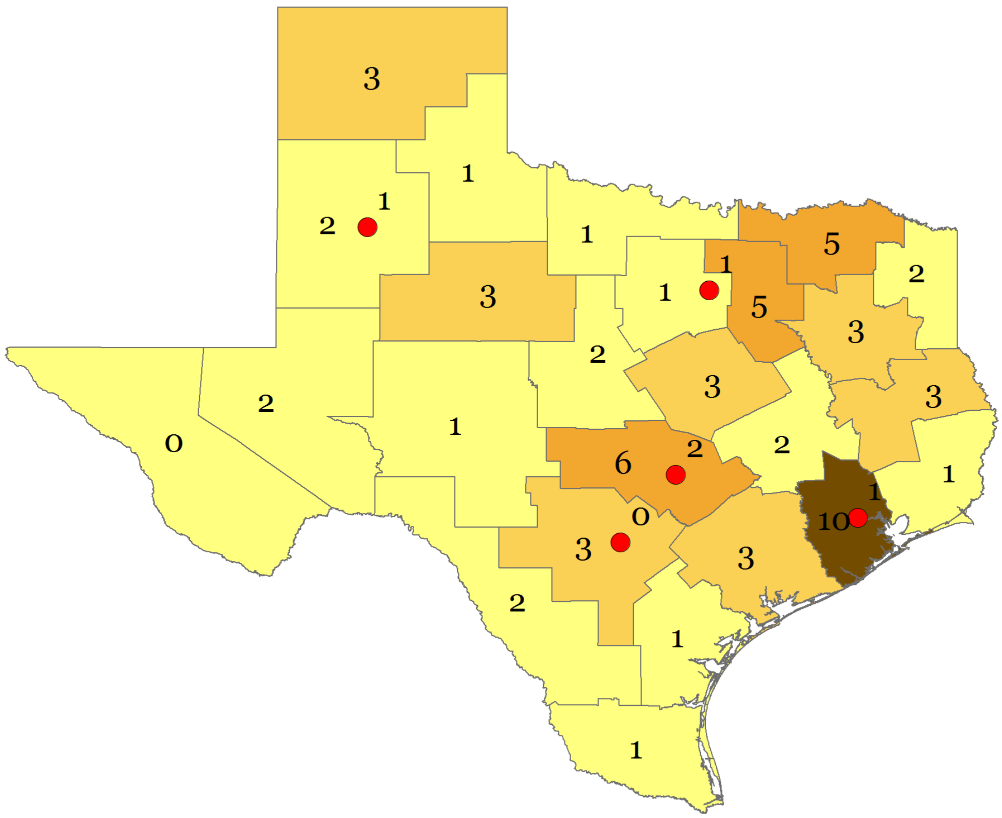


Figure 8. Distribution of Survey Respondents (71 Answered, 58 Skipped).

Table 3. Geographic Location of Survey Respondents (71 Answered, 58 Skipped).

Geographic Location	Count of Responses	Geographic Location	Count of Responses
Right of Way Division	2	Houston	10
North Region	1	Fort Worth	1
West Region	1	Laredo	2
East Region	1	Lubbock	2
Abilene	3	Lufkin	3
Amarillo	3	Odessa	2
Atlanta	2	Paris	5
Austin	6	Pharr	1
Beaumont	1	San Angelo	1
Brownwood	2	San Antonio	3
Bryan	2	Tyler	3
Childress	1	Waco	3
Corpus Christi	1	Wichita Falls	1
Dallas	5	Yoakum	3
		Total	**71**

When asked about the section or field of work, a majority of respondents provided a response (72 of 129). For the majority, respondents replied to work in design, followed by utilities, other, and right-of-way (Figure 8).

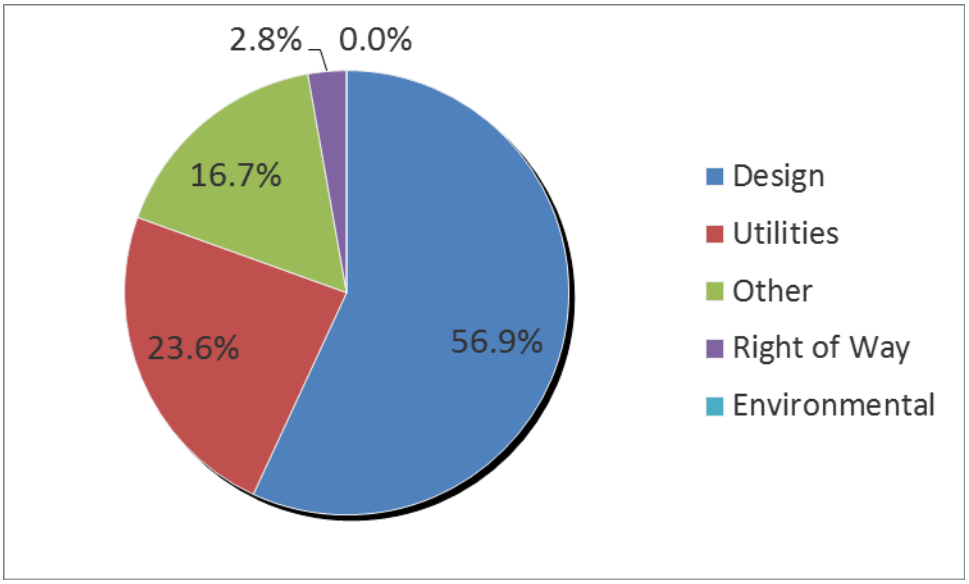


Figure 9. Section or Field of Work of Survey Respondents (72 Answered, 57 Skipped).

Researchers asked about what type of utility investigation services have been used at the district of the respondent. As Figure 10 shows, around 90 percent of respondents answered that districts have used existing records search and surveying of surface utility appurtenances. About three-quarters of respondents replied to have used pipe and cable locators, and about 40 percent have used vacuum excavation. Other methods of utility investigation, including ground penetrating radar (18 percent) and magnetic methods (10 percent), have only occasionally been used. All other methods have only been rarely used.

The research team also compared responses from respondents located in rural versus urban districts. However, there was no difference in the relative ranking of utility investigation techniques used, and only small differences in the responses for each utility investigation technique. The biggest difference was given for vacuum excavation, with 52 percent for respondents from urban districts and 34 percent for respondents from rural districts.

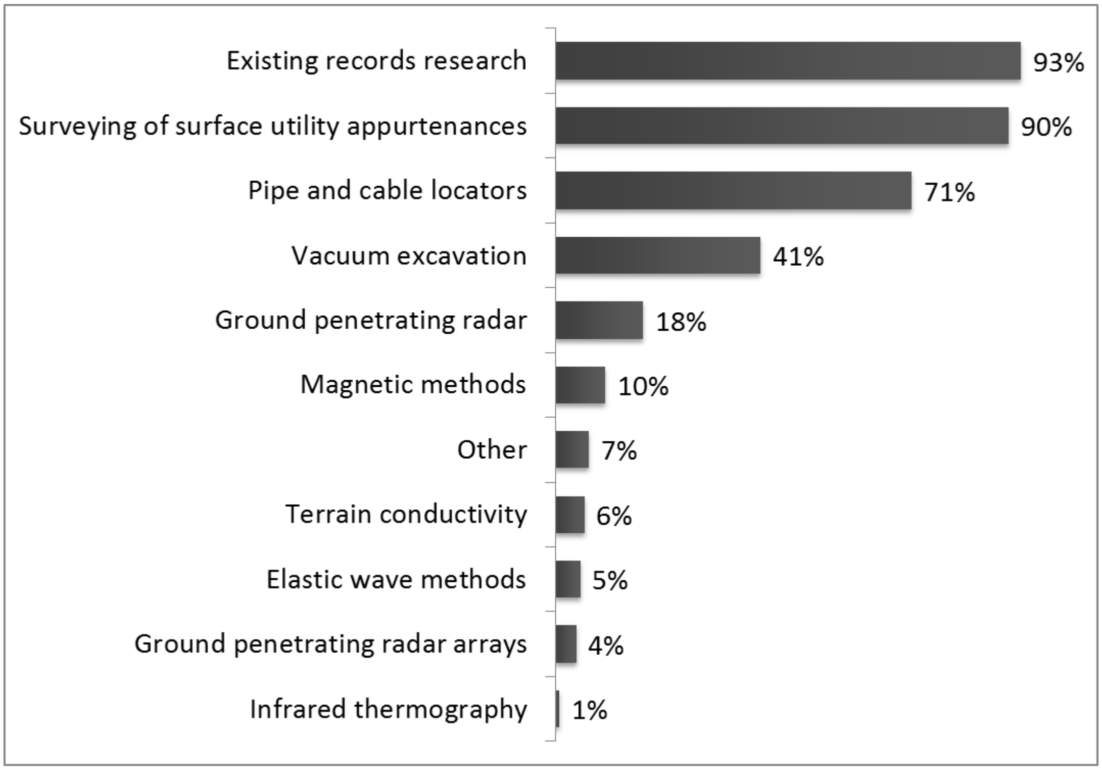


Figure 10. Utility Investigation Techniques Used at TxDOT Districts.

General Utility Investigation Procedures

Several questions were asked to identify characteristics of utility investigation process. This included the timeline for collection of utility data as well as the type of data collected. The utility investigation process for all quality levels of utility data was also determined through the survey. A description of response received is described in the following section. Appendix B includes the responses to essay questions in the survey.

Timeline for Collection of Utility Data

Survey participants were asked which quality level of utility data are typically collected for each of six phases of the project development process, spanning from the preliminary design phase to the construction phase. Figure 11 shows the responses in six columns, where each column represents the responses for a particular phase of the process. Respondents were allowed to select none, one, or more than one type of data collection for each phase. Each column in Figure 11 shows how frequently respondents chose a type of data, indicating that they typically collect that type of data during that phase of the process. Below each column, Figure 11 also shows the number n of respondents for that process phase. For example, the second column shows the responses for the 0-30% design phase: 93 survey participants responded, of which 55 indicated they typically collect QLC data during this phase, and 44 indicated they collect QLD data during this phase.

The responses show that during the preliminary design phase, QLD and QLC data is typically being collected, QLD being more prevalent. During the preliminary design phase, there is rarely data collection at QLB, and only 10 of 97 respondents indicated they do not collect any data during this phase. At the beginning of the design phase, most respondents indicated they typically collect QLD and QLC data, while a smaller number of respondents indicated that they typically collect QLB and QLA data. 30 of 93 respondents provided that QLB is typically collected during this phase, and 16 of 93 respondents indicated the collection of QLA data.

Throughout the design phase and in the construction phase, a significant number of respondents indicated that both QLD and QLC data is typically collected. By the end of the design phase, a smaller number of respondents indicated that they typically collect QLB data, while more respondents indicated that they collect QLA data. QLB data collection was most frequently selected at the 30-60 percent stage while QLA data collection was most frequently selected during the construction phase.

The responses to this question were further clarified with follow-up calls that resulted in an adjustment of the initial results. For instance initially, about 6 percent of responders noted that either QLA or QLB data were collected during the Planning and Programming phase. Follow-up calls to these responders revealed that indeed no such level of data was collected during this phase.

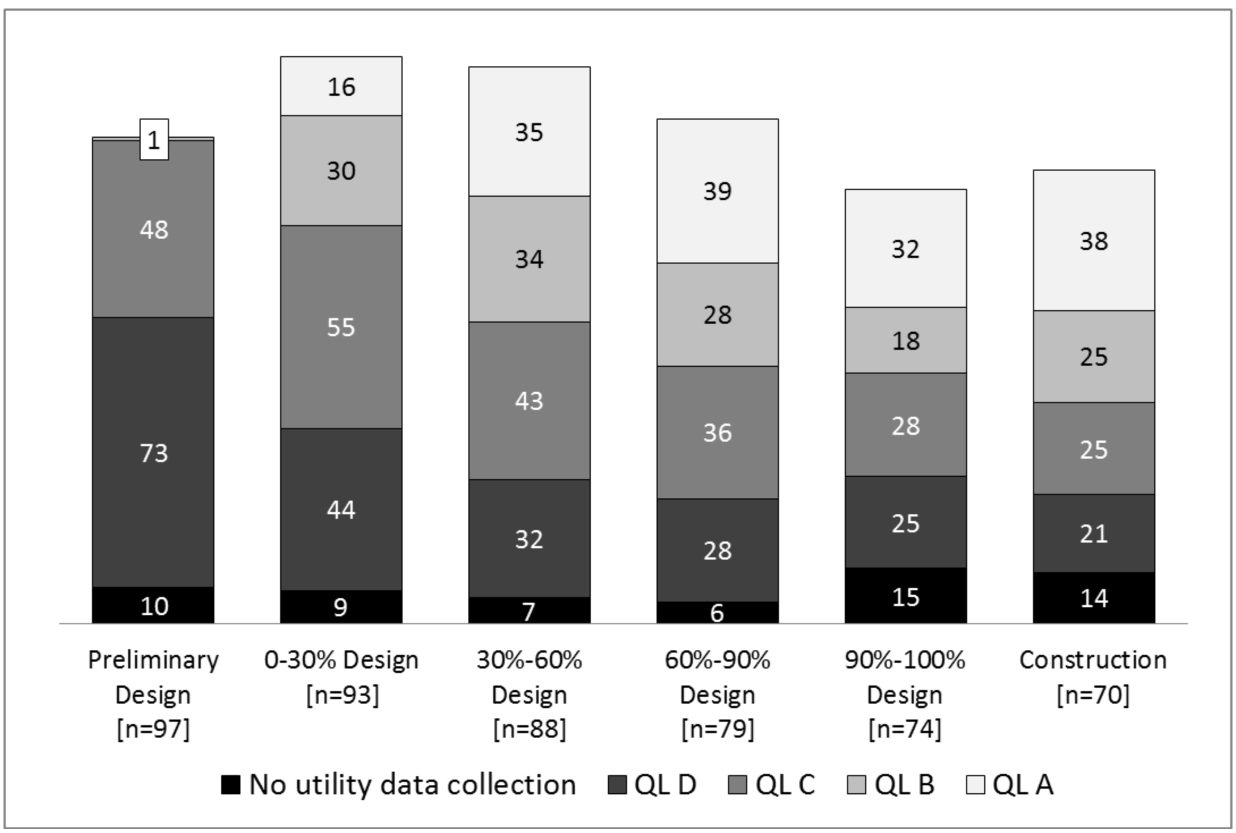


Figure 11. Stated Use of Utility Data Collection at Different Project Development Process Phases (n = Number of Respondents).

Based on additional follow-up conversations with survey responders, it was evident that the type of project being undertaken determined, to a large extent, the sequence and detail of utility data collected. For instance, high-profile projects in dense urban sections with high-volume traffic will typically mandate a detailed QLB and subsequent QLA data collection. For instance, smaller, off-system small bridge repairs will completely bypass these detailed data collection levels.

Researchers also asked who is authorized to request the use of utility investigations at different quality levels. Out of 129 respondents to the survey, only 93 responded to this question, which may indicate there is some uncertainty about this item. Figure 12 provides further evidence of this, showing that less than 60 percent of the respondents indicated that the project manager is authorized to request a QLB data collection for a project. In reality, there is little limitation within TxDOT about who may request the collection of any kind of utility data. Rather, it is a matter of who may authorize the data collection, which researchers asked in the following question.

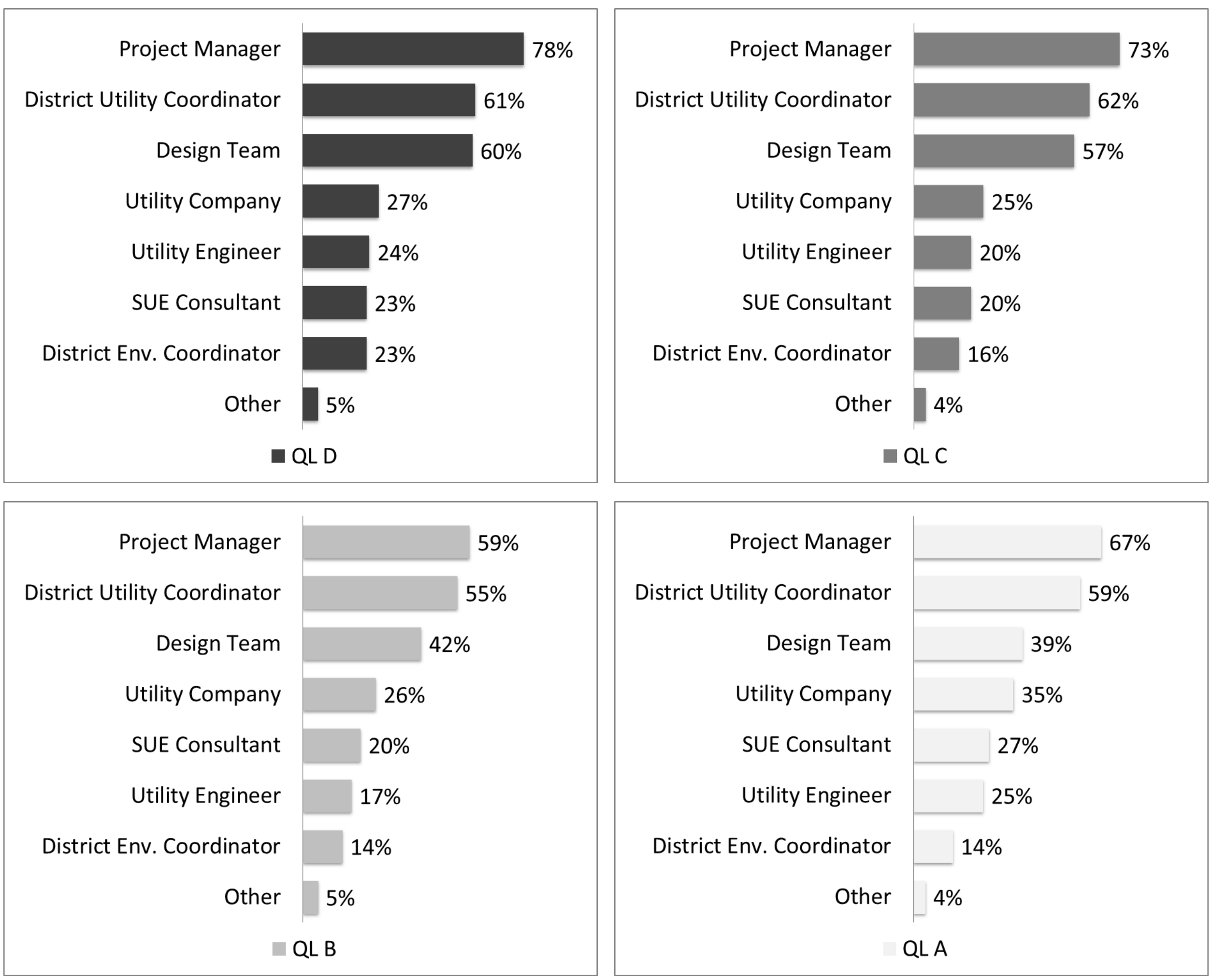


Figure 12. Authority to Request Utility Data Collection at Quality Level (QL) at TxDOT Districts.

Less clear is the question on who makes the final decision on the use of a utility investigation technology. As shown in Figure 13, less than half of respondents answered that the project manager has the final authority to use QLB on a project, and only slightly more than half of respondents believe the project manager has final authority to use QLA. In comments requested to explain the selection of other, most respondents indicated the Director of Transportation Planning and Development as responsible for making the final decision in the use of utility investigation technology.

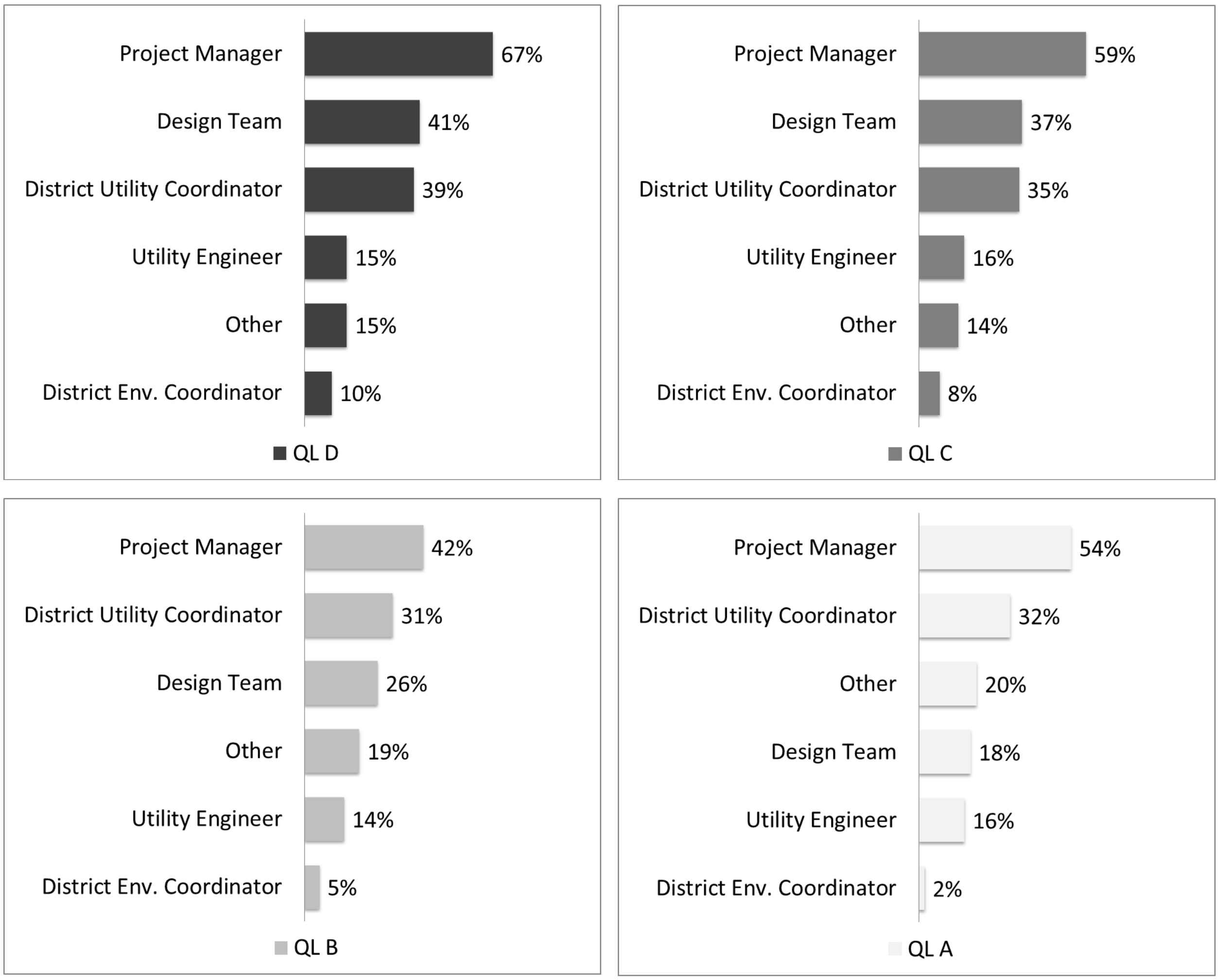


Figure 13. Final Decision to Use Utility Investigation Technology at Quality Level (QL) at TxDOT Districts.

Utility Investigation Procedure for Quality Level D Data Collection

Responses from survey participants provided that depending on the size of the project, QLD data collection typically starts during the preliminary design phase or the detailed design phase. It appears that it is the responsibility of the project manager, or project designer/leader of the design team to determine the need for any utility investigations. The area engineer and maintenance supervisor will provide insight at the project design conference. Some districts have a utility coordinator (also called projects construction utility coordinator) that receives all available data, evaluates the information, and follows up with utility owners as needed. A discussion between the project designer and the utility coordinator determines what type of data needs to be collected for the project.

As needed, the project manager can perform the utility investigation or assigns the task to project staff. On major projects, project managers may get directly involved in the data collection process. Otherwise, the utility coordinator is typically responsible for acquiring sufficient data to determine if a utility facility is either clear or in conflict. Responses indicated that QLD data collection may start anywhere between the preliminary design phase and the 30 percent detailed design meeting. QLD data collection may include the following:

- Conducting a visual site survey and/or contact Texas One Call for a listing of utilities to determine affected utility owners.
- Contact utility owners to obtain existing plans, drawings, and maps of existing facilities. District staff may send utility owners a project layout that utility owners can use to sketch in the approximate location of their facilities.
- Reviewing existing documents available at the district maintenance office and area offices including utility permits, UIR permits, as-built data, right-of-way maps, old construction plans, block maps, and SUE records.
- Research property interests held by utility owners using court house records.

Other activities related to QLD data collection include:

- Coordinating with local government staff, irrigation and drainage district staff, and the TxDOT district utility office during planning phase. An initial meeting during the planning phase with utility owners to obtain information about facilities within proposed construction area.
- Coordinating with local government staff and the district utility office during preliminary design. This activity may include an initial meeting or workshop to help obtain existing utility information from utility owners.
- Comparing existing utility plans to the preliminary construction plans, and identifying potential conflicts.
- Transfer utility information to project plans.
- Send project plans with utility information to utility owners for verification.

Extensive QLD data collection during the early stages of preliminary design must be approved by the project manager and the district review committee, if applicable. If the project requires a survey, the QLD can be included in this activity and delayed until the survey is performed. Survey respondents provided relatively few issues with QLD data collection. However, some respondents noted that for QLD data collection, many cities and other local public agencies provide online access to records. Records research can be complicated by the fact that many TxDOT personnel do not have Internet access.

Utility Investigation Procedure for Quality Level C Data Collection

Typically during the preliminary design phase, the project manager and/or design team leader determines the need for QLC data collection and then makes a request to the district survey engineer for a survey. For other projects, QLC data collection may not start until the beginning of the PS&E phase. The request may also come from the district utility coordinator but does not guarantee that survey staff is available to perform the survey. If the project requires a survey, the project manager may coordinate with the district advance planning engineer to request that utility data collection is included in the survey activities. Some districts require that all topographic surveys include the location of utility facilities; other districts must request the data to be included. If survey staff is not available, a QLC data collection might not occur and instead the utility coordinator will plot QLD data on design plans as the information becomes available.

The QLC data collection might either use data from a QLD investigation, or include the QLD data collection in the QLC data collection activities. For example, the surveyor or designer may mark utilities (QLD) on design plans during an initial site visit or field investigation. If a meeting with utilities has not taken place, it is often included as part of QLC data collection.

The surveyor may call One Call and/or utility owners to mark their facilities on the ground and then survey the paint markings. There appeared to be some confusion on the appropriate quality level of those markings. Although the surveyor can survey the paint marking with great accuracy, these markings provide only an approximate location of the utility underground. As such, the surveyed paint markings should be considered QLD data.

The survey should include all aboveground utility appurtenance and comments from the surveyor about obvious signs of utility facilities. The data collection may also include approximate depths of utility facilities, if the utility owners so provided these. Project managers may use additional site visits to perform a visual survey and apparent potential utility conflicts. Information is forwarded to the utility coordinator for further evaluation and potential follow-up, and to make the final determination if a utility facility is in conflict or not.

Some districts use QLC data collection as a verification of previously collected QLD data. Verified QLC data may be forwarded to the utility owner for further confirmation of the results. If a utility conflict is potentially reimbursable, district utility coordinators are involved in the process.

Some districts combine QLC data collection with QLB investigations by utility companies as part of contracted surveying services. Other districts request a consultant to perform this type of data collection. The project manager may request consultant services, which the director of Transportation Planning and Development (TP&D) and/or the regional office must approve.

Some responses suggested that there are no differences between QLD and QLC data collection, which may indicate unfamiliarity with the difference of the two quality levels. Other responses provided data collection activities that indicate a QLD or QLB, which indicates some confusion about the difference of quality levels among survey participants.

Utility Investigation Procedure for Quality Level B Data Collection

In general, the project manager or design team leader determines during the detailed design phase the need for QLB data collection, which a consultant typically provides. For example, a utility owner may not have accurate records, or the records may appear inaccurate, or may have lines that were abandoned, which would be common reasons to request the use of QLB data collection. Another reason is a potential conflict of a utility facility with proposed design features. The district utility coordinator or survey coordinator requests the SUE work, if the project has funding for a SUE consultant. Work authorizations are drafted and approved either by the director of TP&D or the district engineer, along with a justification to collect these data. The project manager often makes a cursory calculation of estimated cost versus benefit of using a SUE consultant. In many districts, it is ultimately the region that approves the use of a SUE consultant.

Some districts have equipment available to perform QLB in-house, such as a pipe locator, but this response was not very common. Some districts use QLB data to verify previously collected QLD and QLC data then send the information to the utility owner for further confirmation. Other districts include QLD and QLC data collection in the QLB data collection contract.

As part of the design review process for added capacity projects, a district may also call on the utility owner to perform a QLB investigation. This may be in the best interest of the utility owner if the designer can potentially avoid a utility relocation. A contractor may also request this kind of data collection at the beginning of the construction phase, if there is some doubt about the location of some utility facilities. During the construction phase, the contractor may request for QLB data collection to minimize delays caused by a utility conflict.

Some responses indicated that QLB data collections are rarely or never used. This is generally due to the lack of funding to hire a SUE consultant. A large number of responses indicated a confusion of Texas One Call service with QLB data collection.

Utility Investigation Procedure for Quality Level A Data Collection

Generally, TxDOT districts and regions use QLA utility data information on major projects, such as mobility projects in a highly urbanized area. Typically QLA level utility data are considered after a QLB survey identifies a possible conflict. There is some coordination between the districts and the corresponding right-of-way section at the region to allocate the required resources and funds needed to either pursue the work via a SUE consultant or through the utility company. In recent times, QLA data collection is seldom pursued because of the costs associated with pursuing that level of utility data collection. In addition, some district survey crews are capable of collecting pothole data, which according to the ASCE standard is not QLA data collection, but provides useful information to the designer.

QLA data are usually not collected project-wide but only at critical locations, as the design team has determined. QLA is typically collected to verify known conflicts of utility facilities with proposed design features or if there is a potential for conflict that another method cannot verify. Typically, the design section determines and requests the location of test hole survey information and generates utility test hole data sheets, which are forwarded to utility owners for verification.

A utility owner or a TxDOT funded contract with a SUE consultant may provide QLA data. Depending on the district, requests for SUE consultant work might be sent through the district utility coordinator. If funding is available, a work authorization is drafted and approved by the director of TP&D and/or the region. In other districts, the project manager requests SUE consultant services, which the district design engineer must authorize. If the request is approved, the project manager works with the consultant to negotiate a work authorization or contract. The director of the region must then approve the work authorization or contract.

Occasionally, designers or project managers request QLA data from utility companies if there is a potential conflict. For example, the project manager or survey crew may contact the utility owner to schedule a meeting to discuss the need to more accurately locate some of their facilities. At the meeting, the design or survey staff and the utility owner develop a plan of action to address the conflict. The utility owner may decide to relocate or, if there is a potential to avoid the conflict, decide to perform QLA data collection. If the utility owner decides to use his own crew and equipment, the project manager or survey crew meets the utility owner in the field to complete investigations. Otherwise, the utility owner may hire a SUE consultant to collect the data, or perform the data collection using TxDOT staff. After reviewing the information, the design team determines if the utility must relocate or if there is an opportunity to redesign the work to avoid the utility.

Differences in Utility Investigation Process for Different Project Types

Researchers asked survey participants if utility investigations are different based on the following project factors:

- Projects in urban vs. rural locations.
- Projects on new vs. entirely on existing right-of-way.
- Projects with added capacity vs. non-added capacity.

Figure 14 provides an overview of the responses.

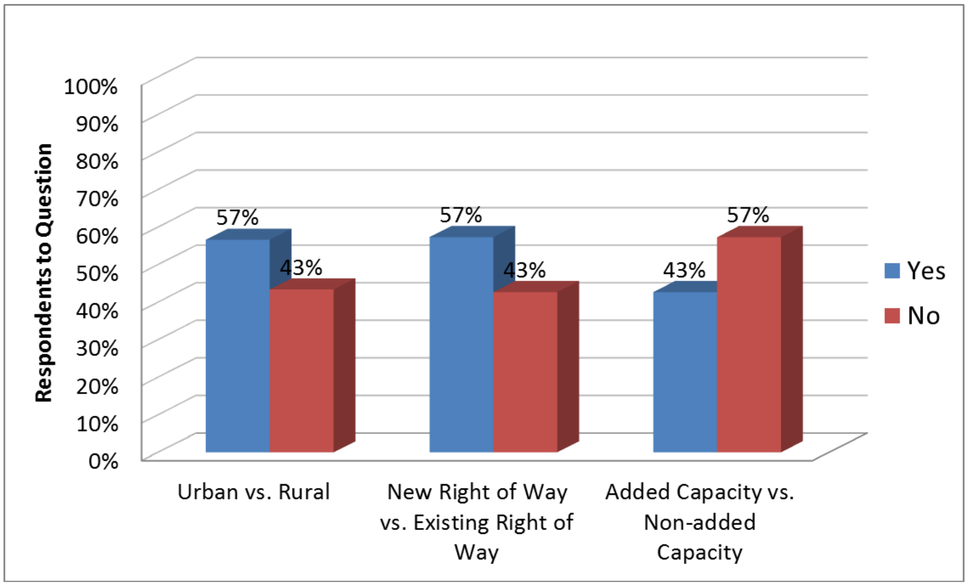


Figure 14. Utility Investigations: Project Factors that Make a Difference.

Figure 14 shows that survey respondents slightly favored the notion that procedures for utility investigations differed for urban projects compared to rural projects as well as for projects involving new right-of-way compared to those on existing right-of-way. Interestingly, slightly more respondents (57 percent) indicated that utility investigation procedures did not differ for added capacity projects compared to non-added capacity projects.

If respondents provided that there are differences based on these factors, they were asked to describe these further. The following section summarizes these responses.

Projects in Urban versus Rural Locations

Fifty-seven percent of respondents indicated that there was a difference in the procedures for utility investigations for urban projects compared to rural projects. When asked to discuss their response, most respondents indicated reasons *why* there is a different procedure rather than *what* that actually is. Only few respondents commented why they indicated that there was no difference in the procedures. Most respondents gave several reasons as to why the procedures for utility investigations differed for urban versus rural projects.

Reasons for Procedural Differences. The main reason given was the higher probability of increased underground utility facilitates for urban projects. Urban projects are likely to encounter more complex communication systems, underground storm sewer systems, potable water systems, and natural gas systems. Hence, urban projects usually have more utility conflicts that need to be relocated and resolved.

The greater utility congestion in urban areas results in significant design constraints. Moreover, scope of urban projects typically involve more complex design issues and hard roadside improvements, that increase the potential for utility conflicts (e.g., multiple intersecting drives and roads, storm drain systems, retaining walls, curb and gutter, sidewalks, railings, luminaries).

In addition to the increased density of underground utilities and related design complexities for urban projects, available right-of-way is much more limited. The limited right-of-way restricts design options available to districts as well as available space for utility relocations within the right-of-way. Other reasons cited for the varied approach for urban versus rural projects were (1) differences in road design standards for rural vs. urban projects, and (2) better relationships between TxDOT and utility owners in rural areas.

Procedural Differences and Similarities. In general, the process for requesting and conducting utility investigation appears very similar for rural or urban projects. The main difference between the procedures for urban and rural projects is in the level of SUE data typically collected on a project. Due to the higher density of underground utilities, there is a need for a higher level of SUE (QLB and QLA) on urban projects. These higher SUE levels may be required more often and sooner in the process to allow more time for the coordination among several utilities that might need to adjust.

With the reduced funds for SUE, rural projects are less likely to involve higher levels of SUE investigations and all utility investigations might be conducted in-house at a rural district. Utility investigations are often not considered during preliminary design work on rural projects. Most candidate projects for SUE will involve larger, more complicated urban projects. Although rural areas have pipeline corridors, they are well marked and easily investigated.

When urban projects are concerned, there is a need to have frequent coordination meetings (e.g., monthly) with all stakeholders on the project due to the complexities of utilities involved. This typically involves all relevant TxDOT staff (utility coordinators, project manager, and design engineers), private utilities, municipalities, and others. In contrast, there are generally fewer utilities to manage on the rural projects. In general, rural utility owners appear to provide good information and there appears to be a lesser need for frequent coordination meetings. City municipalities are rarely involved in a rural setting.

In addition to the increased frequency of coordination meetings on urban projects, city utility relocation may be included in the highway contract, which simplifies construction and utility relocation. The project manager leads the coordination with the city municipalities while the designer engineers and the utility coordinator provide support.

Municipalities typically do not participate in the One Call system, thus eliminating a possible utility data source for municipal utilities. Although this is not limited to urban municipalities, since rural utilities also do not participate in the One Call program, the situation is more critical on urban projects. These utilities must be contacted through local contacts.

Differences in Utility Investigation Process for New Right-of-Way vs. Existing Right-of-Way Projects

Fifty-seven percent of respondents to the question indicated that there was a difference in the procedures for utility investigations on projects involving new right-of-way acquisition versus projects on existing right-of way. Survey participants identified several issues as contributing to these differences in procedures. These differences pertain to (1) the property issues surrounding the acquisition of the new right-of-way, (2) uncertainties on utility locations in the newly-acquired right-of-way, and (3) differences in design approaches.

Right-of-Way Acquisition. Generally, transportation projects on new right-of-way involve the acquisition of private property. This process poses significant challenges to TxDOT districts. These challenges are a result of (1) the legal issues relating to negotiations with property owners, (2) the need to abide by all federal and state legislation in connection with those negotiations, and (3) potential re-settlement issues, as well as condemnation procedures in case eminent domain proceedings must be exercised. These activities require a greater amount of administrative work, which lengthens the entire project development process and leads to delays in eventual utility relocation. TxDOT districts also need to acquire permission to be on property that has not yet been acquired, leading to more delays in utility investigation procedures.

Identification of Existing Utilities. Another major difference has to do with identifying existing utilities on the new right-of-way. Generally, more importance is placed on projects with new right-of-way acquisition because of the need to identify and possibly reimburse all utilities on right-of-way that must be acquired for a project. For projects on existing right-of-way, TxDOT districts typically have a better knowledge of existing underground utilities and where they are generally located. Due to the lack of knowledge of potential utility conflicts on new right-of-way projects, TxDOT districts tend to do a more comprehensive investigation to identify all utilities within the right-of-way. However, an alternative opinion of respondents was that new right-of-way usually has only few utilities that create fewer conflicts. New right-of-way acquisition for transportation projects is likely to occur in less populated locations, which means there is likely not going to be a high density of underground utilities, as compared to a highly active section of roadway in an urban setting. However, there are some rural locations where new right-of-way acquisition occurs on property that could have abandoned oil and/or gas well production lines.

Design Flexibility. Generally, designers have more flexibility to design on new right-of-way. However, respondents have offered two perspectives. Some designers felt the fact that utilities are likely to be relocated because of new space allows them to disregard existing utility locations. In contrast, other designers see the additional right-of-way as a means to design structures in a way that will avoid existing utilities and/or purchase right-of-way with fewer existing utilities.

Utility Relocation and Relocation Costs. When dealing with projects planned for new right-of-way, TxDOT districts often encounter utilities that are eligible for reimbursement if they need to relocate. Existing utilities on new right-of-way are likely to have a prior property right (e.g., easement). Alternatively, for existing right-of-way projects, except federally-sponsored ones, utilities will largely be responsible for their own relocation. Thus, from TxDOT's point of view, projects on new right-of-way tend to be more costly since it is more likely that utilities will need to be relocated when new right-of-way is needed and will do so at TxDOT's expense. The funding required for relocation can be an incentive for TxDOT to collect better utility data to avoid a utility relocation.

A benefit of projects on new right-of-way is that due to the likely compensable utility relocation for such projects, TxDOT typically experiences increased assistance and cooperation from the utility owners in the utility adjustment process.

There is more flexibility when dealing with new right-of-way projects as utilities are likely to be relocated regardless of their exact position, thus eliminating the need to obtain QLA location data. For projects requiring new right-of-way, utilities are generally relocated while some crossings may remain in place. However for projects using existing right-of-way, utilities could remain in place if these are not in conflict with the alignment of the new roadway and structures. These utilities will be relocated or modified only where in conflict with drainage structures, and other design features to accommodate the new construction. Thus, there may be a need for precise location of existing utilities using QLA.

Differences in Utility Investigation Process for Added Capacity vs. Non Added Capacity Projects

Less than half (43 percent) of respondents expressed that there are different utility investigation procedures for non-added capacity projects versus projects that involve additional capacity construction. Differences centered mainly on the idea that added capacity projects tended to be larger and involve additional right-of-way (or land), hence creating likelihood for utility conflicts. However, if a project adds capacity without any or only little additional right-of-way, the project will reduce the amount of available right-of-way, creating facility crowding. This will most likely result in stricter installation tolerances and space assignments, and in turn provide a need for QLA investigation.

Added capacity usually means reconstruction and widening. Problems with utilities typically arise if the vertical profile of the roadway changes, culverts are replaced or extended, storm drains are relocated or added, retaining walls are required, drill shafts for bridges are required, the pavement is widened, or any excavation for roadway construction is necessary. Consequently, QLB and QLA may be required more often, and sooner in the process to allow more time for the often intricate coordination among several utilities needing to adjust. Added capacity projects normally require a widening of the roadbed, which likely impacts adjacent longitudinal utilities. Any project element located outside the current pavement structure could encounter new utilities, therefore requiring more investigation.

Generally, non-added capacity projects (rehabilitation, restoration, preventive maintenance) most often work inside the existing ditch line, which does impact the utilities along the back slope and right-of-way line. However, non-added capacity projects typically will not acquire additional right-of-way and will typically have minimal conflicts. If no pavement widening or drainage work is done, normally a detailed utility investigation will not be needed. Knowing the approximate location of utilities is sufficient to allow district staff to work around it. As a result, there is less use of contract SUE work for non-added capacity projects.

Factors Influencing Decision to Use or Request SUE

Factors determining the use of SUE for TxDOT projects were explored through the survey. Respondents were asked to list factors influencing the decision to use or request QLB and QLA data collection for a project. Responses are summarized below.

Factors Influencing Decision to Use or Request QLB Data Collection

Based on the responses from survey participants, several factors were identified as influencing their decision to use or request a QLB utility data collection for a project. These factors are generally related to the type of project and level of prior knowledge of utilities around the project area.

The vast majority of respondents noted that generally the type of project plays a big role in determining whether a higher level of utility data (i.e., QLB) will be requested and/or collected as part of the project development process. For instance, if the project is large and involves excavation of an area with a potentially dense matrix of underground utility facilities, SUE contracts are set up to handle QLB level utility data collection. When planning for a project in an area with a known history of high underground utility facilities (for instance, in a high density urban area), TxDOT districts tend to be more cautious in the utility data gathering process. This is also the case for complex projects involving a lot of underground activity and construction of large drainage structures, because there is a greater chance of damaging an existing underground utility facility.

Survey participants noted that when the amount of utility data available to the district from existing records QLD (e.g., existing records search) and QLC (e.g., field surveying) is not sufficient to provide needed accuracy and detail about underground utilities, districts may decide to pursue QLB utility data collection. This also includes situations when utility owners have insufficient accurate knowledge of the vertical and horizontal locations of their facilities. In addition, when QLD and QLC utility data show there is a potential for underground utility conflicts, districts are likely to pursue QLB utility data collection.

Another factor was the type of utilities on a particular project. When high pressure gas pipelines or high pressure water mains are potentially located within a project area, there is more urgency to request and use higher quality levels of utility data such as QLB. Collecting the data ensures that the safety of construction workers is not compromised and also prevents major service disruption to utility customers. Collecting QLB data also helps to protect highly valuable utility infrastructure in the project area (e.g., a main communication duct). Other factors that survey participants noted as impacting on the decision to use or request QLB utility data are the following:

- **Cost of Conducting QLB Utility Data Collection.** With cuts in district budgets, higher levels of utility data collection are becoming a luxury at most districts.

- **Costs to Adjust.** When the costs associated with adjusting a utility are going to be incredibly high, there is an attempt to design around the utility and there is a need to have more accurate information on the utility’s location.

- **Prevention of Delays to Project Construction.** For high-impact projects with limited delivery time, districts are more likely to use QLB utility data collection to ensure that the construction phase does not encounter unknown underground utilities that could delay the project.

- **Allocated Time for Completion of a Project.** TxDOT efforts to compress the project development process have led to less time available for detailed utility data collection. Some utilities may not be identified during design stages and are passed on to be handled during construction.

- **Amount of Right-of-Way Available.** When acquiring new right-of-way, there is a need to perform QLB utility data collection to obtain accurate information on areas that were previously easements.

Factors Influencing Decision to Use or Request QLA Data Collection

From a pre-selected list of factors, survey participants were asked to indicate how much a factor impacts their decision to request QLA data collection for a project. Level of impact could be expressed on a scale from 1 to 5, 1 for *no impact*, 2 for *low impact*, 3 for *medium impact*, 4 for *medium to high impact*, and 5 for *high impact*. Results of this question are shown in Figure 15, which summarizes the percentage of respondents that rated a factor either *medium to high* or *high*.

Figure 15 shows that the potential safety threat posed by accidentally damaging a utility is the leading factor considered in requesting SUE QLA data collection. Estimated density of underground utilities, excavation depth on right-of-way, and type of utility are also important. Least considered factors include the material of utilities, the ease of access to utilities, and the estimated age of utilities.

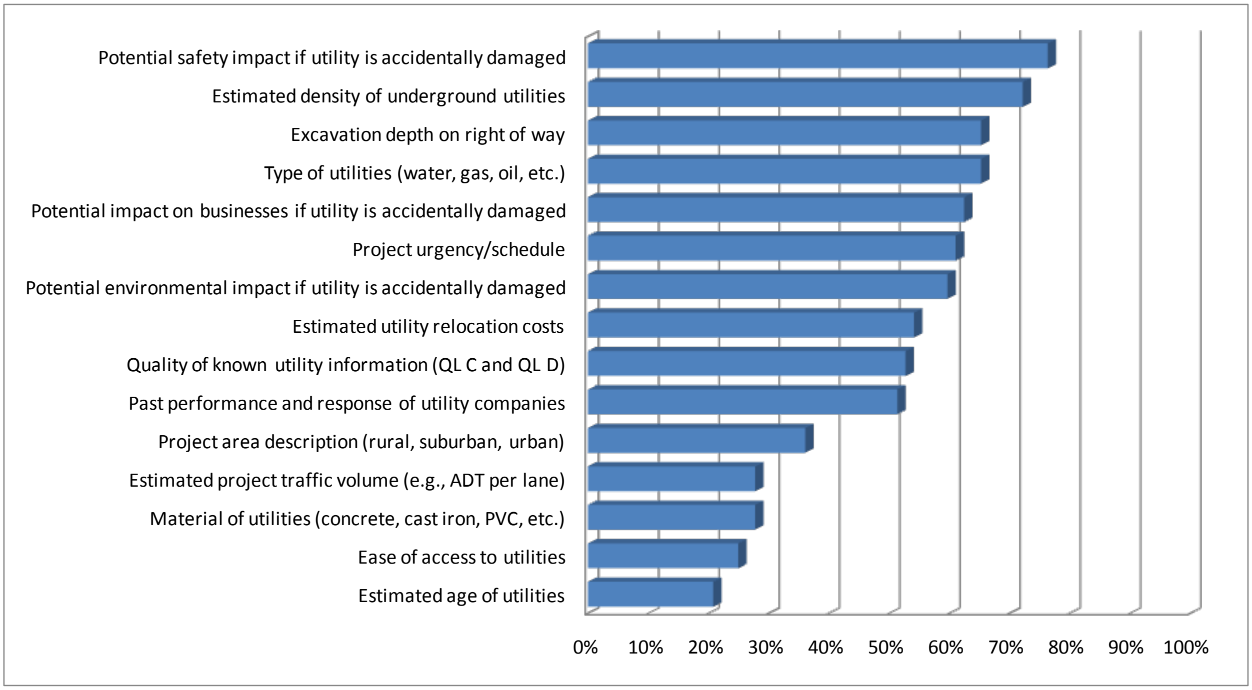


Figure 15. Factors Influencing Decision to Use or Request Quality Level A (QLA) SUE Data Collection.

Procurement Process for Requesting and Using SUE

Researchers asked questions about the process currently in place at TxDOT districts and regions for requesting the use of SUE, and what utility investigations are outsourced to consultants as compared to being performed by in-house staff.

Participants were asked if there was a formal checklist, flowchart, or other procedure to determine what type of utility investigation data to collect and when. A large majority of those who responded (79 percent) indicated that there was no formal checklist or other procedure to help determine what type of utility investigation data to collect and when. Twenty-one percent said they had a formal process in place to determine what type of utility investigation data to collect and when.

In addition, respondents were asked to describe the type of checklist, flowchart, or other procedure. Respondents mentioned district procedures, FHWA documentation, district checklists, and overview flowcharts developed at the district. Respondents also mentioned the *Utility Manual* and *Project Development Process Manual*, but stated a lack of detail to determine the type of utility investigation needed for a project.

Responsibility for Collecting Utility Data Information

Researchers asked who is responsible for collecting various levels of SUE data—whether this was done in-house or outsourced to a SUE consultant. The results are shown in Figure 16.

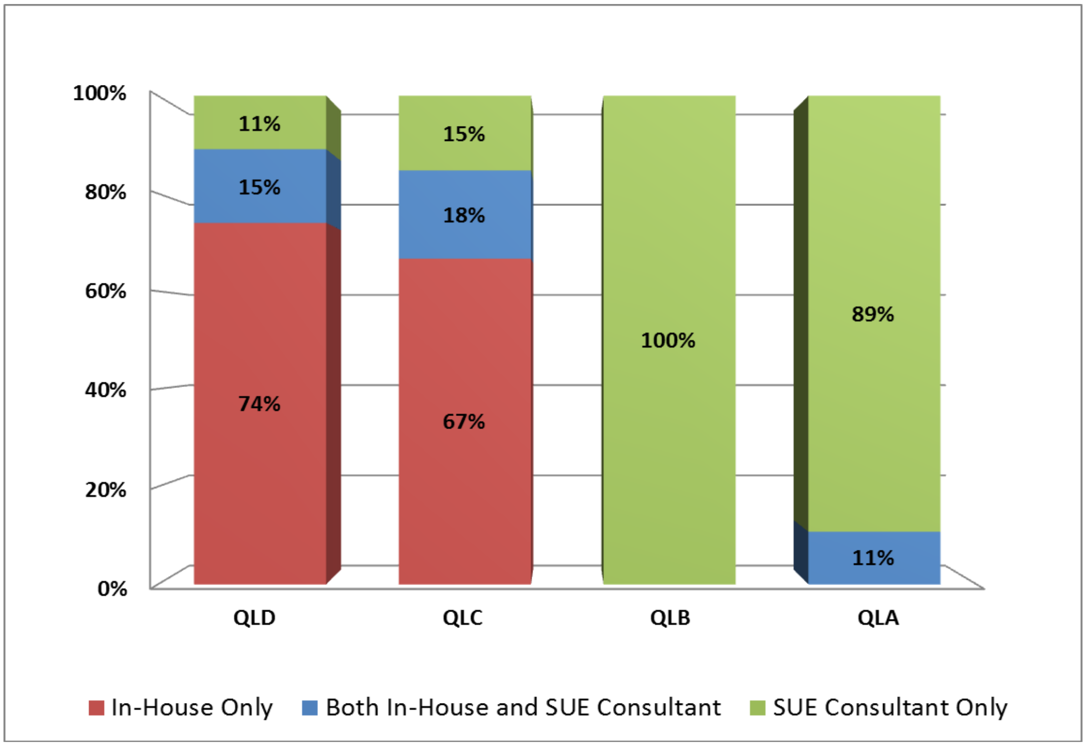


Figure 16. Contracting of SUE Data Collection.

Initially, the results in Figure 9 were rather different. For instance, 30 percent of survey responders indicated that their districts performed QLB utility data collection in-house-only and 24 percent noted they collected QLA utility data in-house only. Subsequent follow-up conversations clarified the responses and provided the updated figure shown in Figure 9.

From Figure 16, over 70 percent of respondents indicated that only TxDOT internal staff performs QLD utility data collection, while over 65 percent indicated that this is also the case for QLC utility data collection. In terms of districts, 24 districts indicated that they perform QLD utility data collection internally only, while 22 districts perform QLC data collection internally only. In contrast, in most districts, SUE consultants (and in some cases utility owner contractors) collect QLB and QLA data. In fact, none of the survey respondents indicated that they had the skills or equipment to perform QLB data collection in-house using district staff. At least five districts (Yoakum, Pharr, Waco, Paris, and Amarillo) indicated that they do a joint QLA utility data collection process, where the utility contractor digs the test hole and TxDOT surveys the utility on site. Most respondents suggested that TxDOT staff lacked the needed equipment and expertise to carry out QLA and QLB utility data collection.

The survey asked participants whether they have been involved with the procurement of SUE consultant services and about half of those who responded to that question (47 percent) responded in the affirmative. The survey asked these participants about the overall effectiveness of different types of procurement practices for SUE services. Figure 17 shows the results of the survey responses.

From Figure 17, the most effective procurement practice selected by respondents is the evergreen contract involving multiple SUE consultants per district. The next most effective practice is a project-specific (not evergreen) engineering services contract with a SUE consultant.

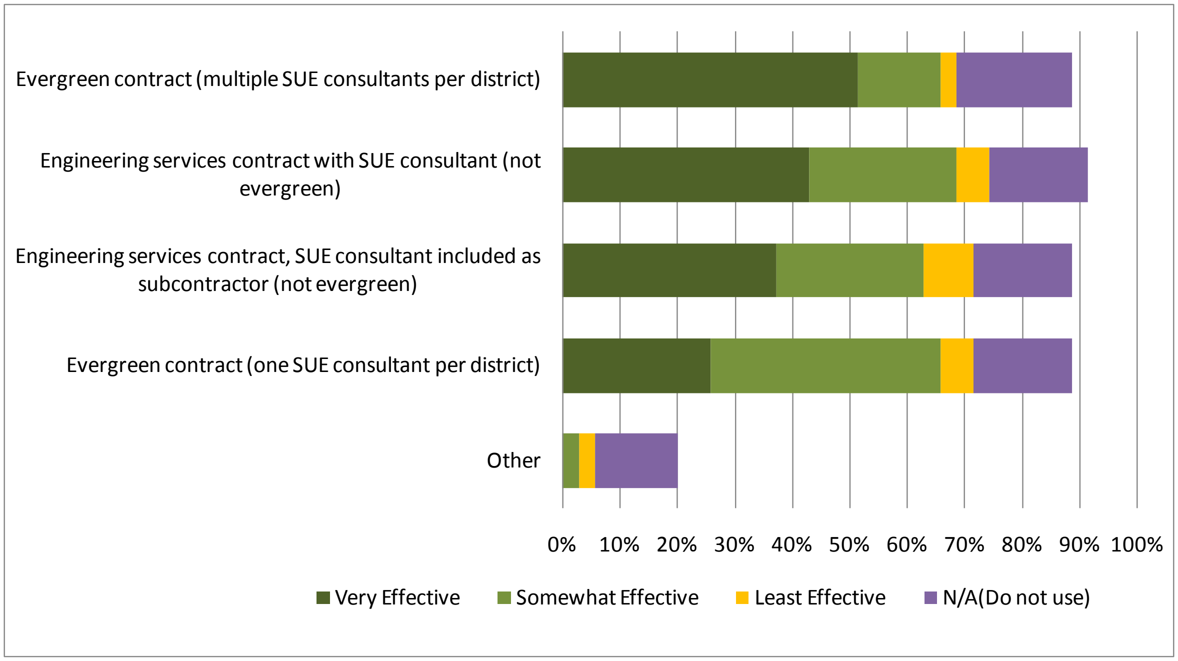


Figure 17. Effectiveness of Procurement Practices for SUE Services.

Managing SUE Contract Task Orders

The survey requested information on some of the challenges and recommendations for managing SUE contract task orders for survey participants involved in the management of these contracts. Survey respondents gave insight into challenges and provided recommendations. The challenges included:

- **Cost.** One of the challenges that numerous respondents cited is the cost of SUE services. The more accurate the utility investigation data that the district requested, the higher the expenditure needed to perform the work. With current budget constraints at TxDOT, this is preventing a lot of higher quality (QLB and QLA) utility investigation from being performed. Currently at a lot of districts, it is only feasible to use SUE contractors on high-cost and limited-time projects.

- **Turnover in SUE Industry.** There was concern expressed at the staff turnover rate of project managers at several SUE companies. This does not foster continuity for the districts in dealing with the companies and might create gaps in the company's knowledge base.

- **Length of Negotiations on Contract.** Some TxDOT districts spend significant time negotiating hours and linear feet of utilities because of the inherent unknowns. Further, there were comments indicating a concern about the time that the ROW Division requires to approve a SUE work authorization or contract. Time required providing a proper review of invoices was also an issue stated about current SUE contracts.

- **Ineffectiveness of SUE Contractor.** Incompetent and/or inexperienced SUE contractors can create significant problems for utility coordinators and other staff involved in project development. In this case, TxDOT staff is forced to spend significantly more time in the utility investigation process and follow-up with the contractor.

- **Inconsistent Quality of SUE Deliverables.** Several survey participants mentioned the variation in the quality of SUE survey from one provider to the next. There were also comments about differences in expected versus actual contract deliverables, e.g., locating all unknown utilities by use of sweeps versus locating only known utilities.

The recommendations included:

- **Check Reliability and Reputation of SUE Consultants.** There is a need for districts to properly evaluate SUE consultant to ensure that they are capable of producing quality utility data investigation. SUE contractors need to be accurately evaluated based on the quality and accuracy of work received at the district.

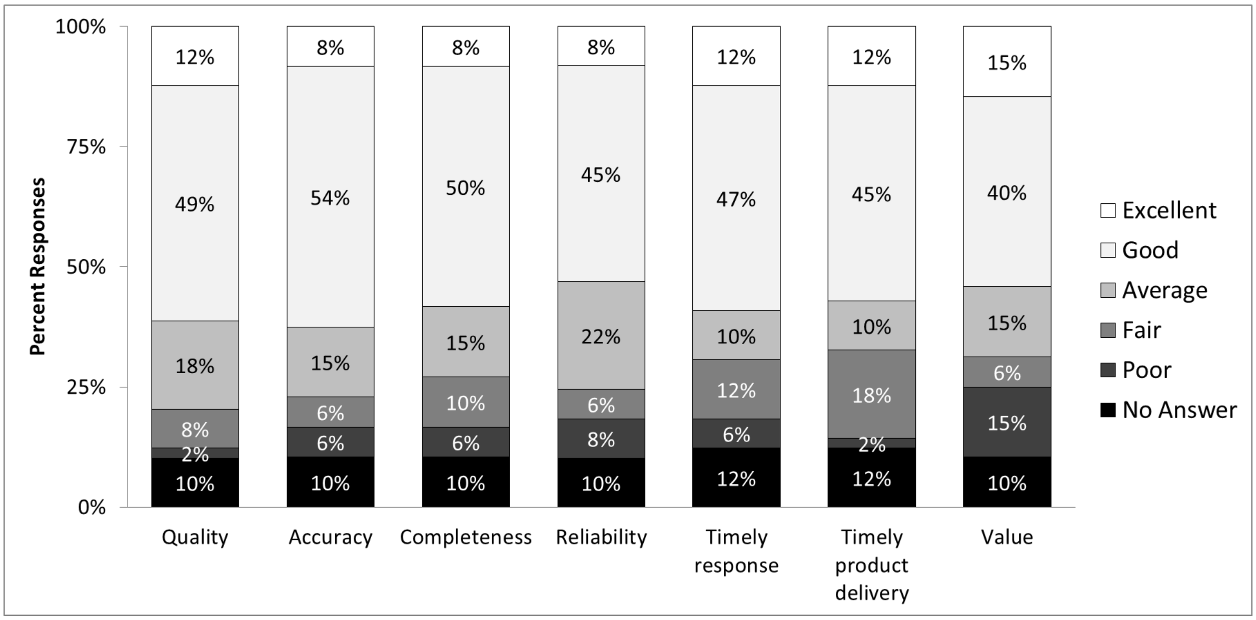
- **Make SUE Consultants Accountable.** Even though errors of SUE consultants can take up to several years to be discovered (usually during construction), it is important to provide the legal framework to hold these SUE providers accountable for their work.

- **Monitor Projects Adequately.** Regular monthly or weekly status report meetings need to be scheduled to monitor progress and ensure work is being accomplished on time, ensuring that the SUE consultant is meeting all requirements and activities. TxDOT needs to properly define a scope of work, including tasks and activities and associated timelines for consultants to meet the related tasks in the scope of work. In some cases, it might be prudent to allow for addition or amendments to the contract to account for unforeseen issues such as additional technology usage to identify a specific type of utility. In addition, progress payments should only be made when a like percentage of work has been completed.

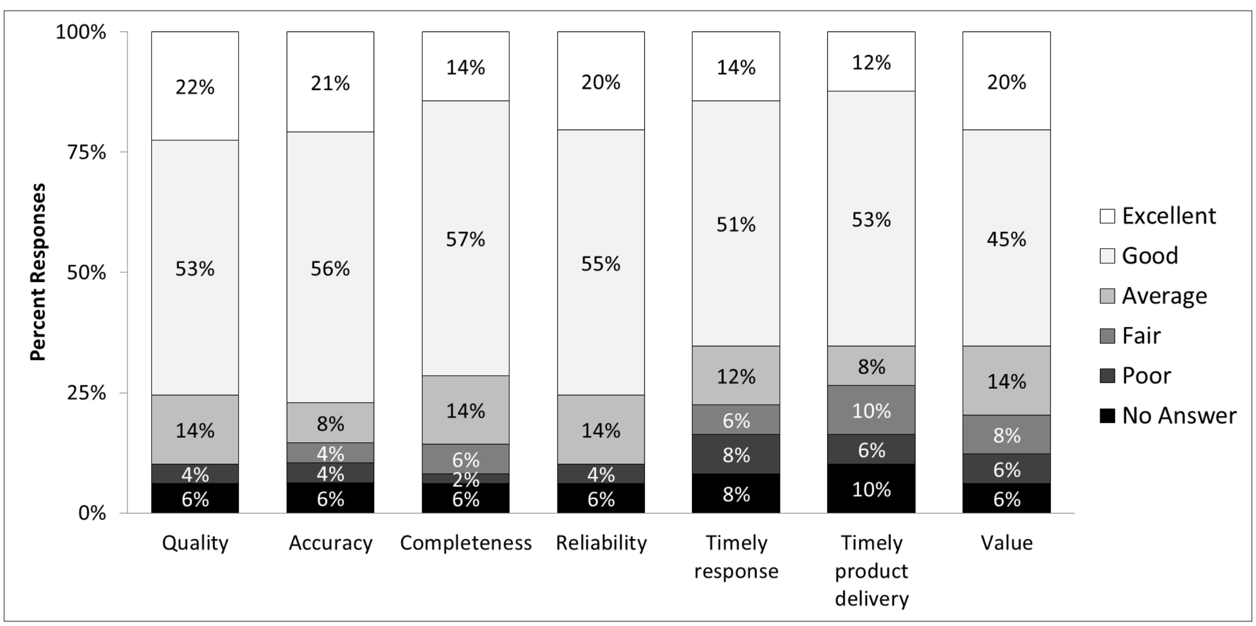
- **Establish Good Coordination with SUE Consultant.** Establishing adequate coordination with the SUE contractor involved with the utility data collection is critical to the success of the contract. There is a need for communication with the local TxDOT area office in some cases, as well as with utility companies when they have inadequate resources to locate their lines. TxDOT needs to maintain good working relationships among all parties involved. As part of this coordination effort, it is important for TxDOT staff to make final decisions on the type of utility data quality level needed.

Assessment of SUE Deliverables

Almost 70 percent of survey participants who responded to a question on SUE deliverables indicated that they had received either a QLB or QLA SUE deliverable in the past. The survey asked those who had received such deliverables to rate their satisfaction with the QLB and QLA data collection deliverables in the past. Figure 18 shows results for the satisfaction of TxDOT staff with QLB and QLA data collection deliverables.



Quality Level B Deliverables



Quality Level A Deliverables

Figure 18. Rating of Deliverables from Subsurface Utility Engineering Data Collections.

From Figure 18, a majority of survey participants (at least 50 percent) rate QLB deliverables either good or excellent, regardless of the factor, which indicates a high level of satisfaction of TxDOT staff with QLB deliverables. The factors quality and accuracy received the most rankings of good or excellent, while the factors reliability and value received the least. At least 60 percent of respondents indicated that they found SUE QLA data collection deliverables either good or excellent, regardless of factor. This indicates an even higher level of satisfaction of TxDOT staff with QLA deliverables, as compared to QLB deliverables. Highest satisfaction ratings were given to accuracy and quality, while timely response to request for data collection and value received lower satisfaction ratings. Overall, there appears to be a high level of satisfaction among TxDOT staff with both QLB and QLA deliverables.

Process for Reviewing SUE Deliverables from Consultants

Of all survey participants involved with reviewing SUE deliverables, 63 (about 82 percent) indicated that there was no formal process for reviewing these deliverables. Researchers separated the responses from the five large metro areas in Texas (Dallas, Fort Worth, Houston, Austin, and San Antonio) to determine if there was a difference between these and smaller districts. Figure 19 shows that twice as many large districts (26 percent vs. 13 percent) have a formal process for reviewing SUE deliverables from consultants.

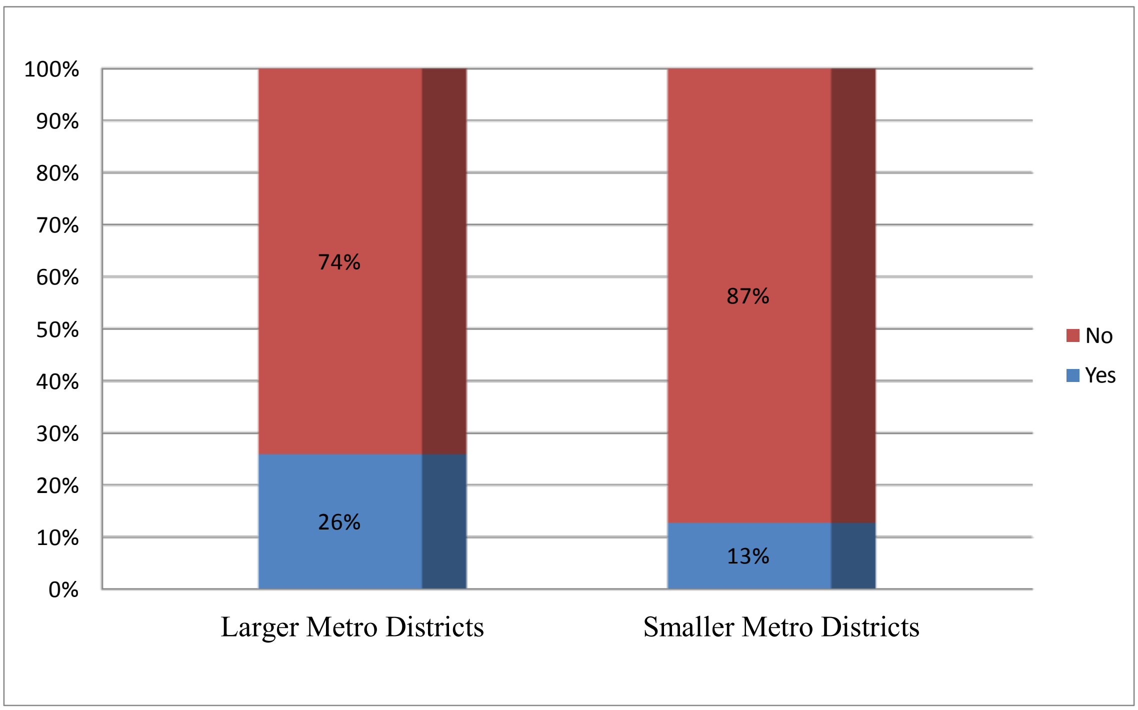


Figure 19. Formal Review Process for SUE Deliverables from Consultants.

Thirteen respondents provided some insight into what the process for reviewing SUE deliverables was. Generally, such reviews follow the district's normal transportation consultant deliverable process. The review will typically compare the vertical and horizontal data for potential conflicts and is usually included in the district's PS&E review process. Part of the aim of any review is to ensure that the scope of work was adequately accomplished in the deliverable. An assessment is made of the quality of the SUE work performed and a determination of whether the consultant provided more than was asked. An emphasis is also placed on the timeliness of the deliverable, and the clarity in its presentation and organization.

Typically, before the deliverable is accepted, both TxDOT staff and the utility companies involved in the utility coordination process review it to ensure the accuracy of the information that the SUE contractor had provided. At TxDOT there is usually a team of reviewers made up of the utility coordinator(s), project manager, and design engineers. If the project manager is not satisfied with the survey, the SUE provider may be requested to provide additional survey work.

Perceived Benefits of SUE

Researchers attempted to determine the reasons why QLB and QLA utility data investigations were not used more frequently at districts and regions. This information should provide more insight as to whether TxDOT staff think there is some value in pursuing higher quality level utility data collection and how that might affect the use of relevant technologies to gather that kind of data.

Reasons Why QLB and QLA SUE Not Frequently Used on TxDOT Projects

A few respondents noted that their districts are actively pursuing QLA and QLB utility data collection through SUE contracts; although a majority indicated that their districts are either using it very selectively or not using it at all. Several respondents noted that the utility owners on TxDOT projects usually perform QLA data collection (primarily potholing). Having utility owners locate their own facilities provides more reliability because they have an incentive to protect their investment.

Budget Constraints. By far the most common reason given focused on costs that the district incurred while pursuing QLB and QLA utility data collection. TxDOT typically lacks the internal capability to do QLB and QLA utility data collection, so it is usually outsourced to SUE consultants. Due to SUE contractual work being considered a professional service, there is a lack of a competitive bidding process for these services. In addition, overall budget constraints within TxDOT often result in a need to eliminate discretionary spending. As a result, hiring SUE contractors to perform higher quality utility data collection has been considered a luxury in several districts. Alternatively, some districts have determined that calling the One Call program (e.g., Texas 811) and requesting pothole depth from the utilities is sufficient and much cheaper than paying for a SUE contract. On large projects where manpower is low and funding is high, SUE contracts are more seriously considered.

Quality of SUE Deliverables. Some of the respondents indicated that there is a great deal of variability in the quality of deliverables that SUE contractors provided, with a good amount of them lacking the required quality. It was suggested that QLB data in particular did not provide the desired level of accuracy. For example, Figure 18 shows that about 12 percent of respondents rated QLB deliverables to be typically of fair or poor quality in terms of accuracy. Because of this, some districts rely more on the utility companies themselves (or their selected location/adjustment contractors for both QLB and QLA) to provide the needed information.

Thus, given the cost of hiring a SUE contractor and the questionable accuracy of the information they provide, some districts tend to avoid such contracts.

Perception of TxDOT Project Development Staff. While the cost of performing a proper QLB and QLA SUE data collection is a significant burden on project budgets, there was a perception that design engineers and project managers did not place enough emphasis on getting accurate underground utility information early in the project development process. At the divisional, regional, and district level, a better understanding of the potential benefits associated with accurately identifying utility conflicts early in the project development process would be desirable. There were also statements requesting training to better understand when and how to use QLB and QLA to optimize returns on investment. Some respondents stated that TxDOT engineers do not consider utilities or utility impacts to the degree that would be most beneficial, and that there is a sense that risks associated with unidentified utility conflicts early in the project development process are minimal.

Project Schedule and Delivery Constraints. Another reason given is the shortened length of the project development and delivery process. This has made detailed utility data collection early in the development process a difficult undertaking. Typically, a significant amount of design needs to be completed (i.e., drainage design around the 60 percent design completion stage) before accurate utility information is requested. With the shorter time allocated for the entire project development process, design plans are not completed in time to allow for more investigation of utility conflicts. It is difficult to meet PS&E deadlines while waiting on SUE data deliverables.

Other reasons given why QLA and QLB are not frequently collected on TxDOT projects include the following:

- For a large majority of rural projects, locates are performed with assistance from utility companies.
- Only large projects with potential to impact major underground utility facilities need QLB or QLA. Smaller projects do not require QLB and QLA and have often information about existing utilities. A majority of TxDOT projects do not have a potential to disturb underground utilities. For example, less than 25 percent of the Houston District's projects require QLB or QLA data collection.
- The cost of non-reimbursable adjustments is often assumed by utility owners. Thus there is less urgency from project managers and design engineers to locate utility conflicts early in the project development process through the use of SUE contracts.
- A smaller number of projects requiring new right-of-way results in a lesser need for QLB and QLA utility data collection. Most of the current projects are within the existing pavement bed with little change to depth.

Return on Investment for SUE

Researchers intended to obtain information on how TxDOT staff perceived the benefits of using SUE QLB or QLA on a project in terms of return on investment. The survey participants were asked to give an estimate of the expected return on investment when using SUE QLB or QLA (i.e., project cost savings to SUE expenditure). For example, a 10:1 ratio means an expected project cost savings of $10 for every $1 spent on SUE. Figure 20 shows a summary of the responses received.

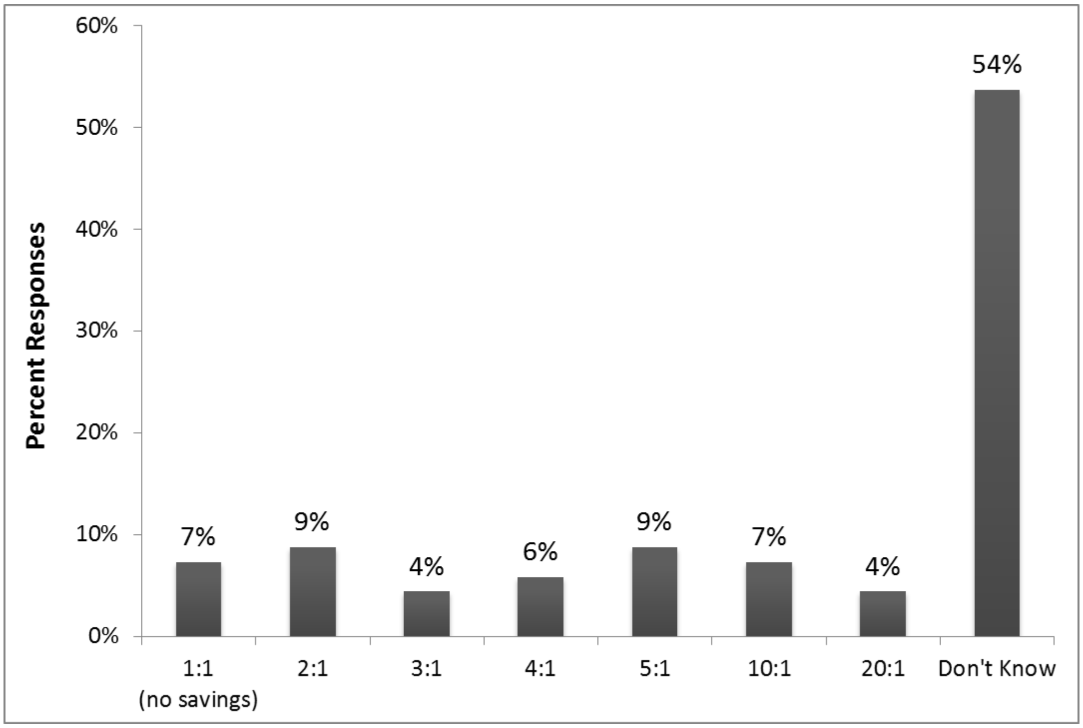


Figure 20. Expected Return on Investment (Savings/Expenses) for SUE QLB or QLA.

As shown in Figure 20, more than half of respondents (54 percent) were not able to quantify an approximate return on TxDOT's investment in SUE. There was no clear distinction between the other choices as respondents were split on the various net savings options. This shows that a large proportion of TxDOT districts and regions do not have a clear understanding about potential cost savings resulting from the use of SUE technologies. Interestingly, only about 7 percent of participants indicated that they did not expect any net savings to the project when using SUE.

Issues Associated with Utility Data

Researchers inquired about the issues concerning utility data that districts most frequently encountered. Figure 21 shows the results for issues that are encountered frequently or sometimes at TxDOT. From the figure, issues with utility data collection are, by far, the most frequently encountered by staff at the various TxDOT districts and regions. Over half of all respondents indicated that they had issues with utility data collection. The issue second most frequently encountered is utility data sharing outside TxDOT. In addition to this, about a quarter of respondents indicated frequent issues with utility data reliability and utility data sharing within TxDOT.

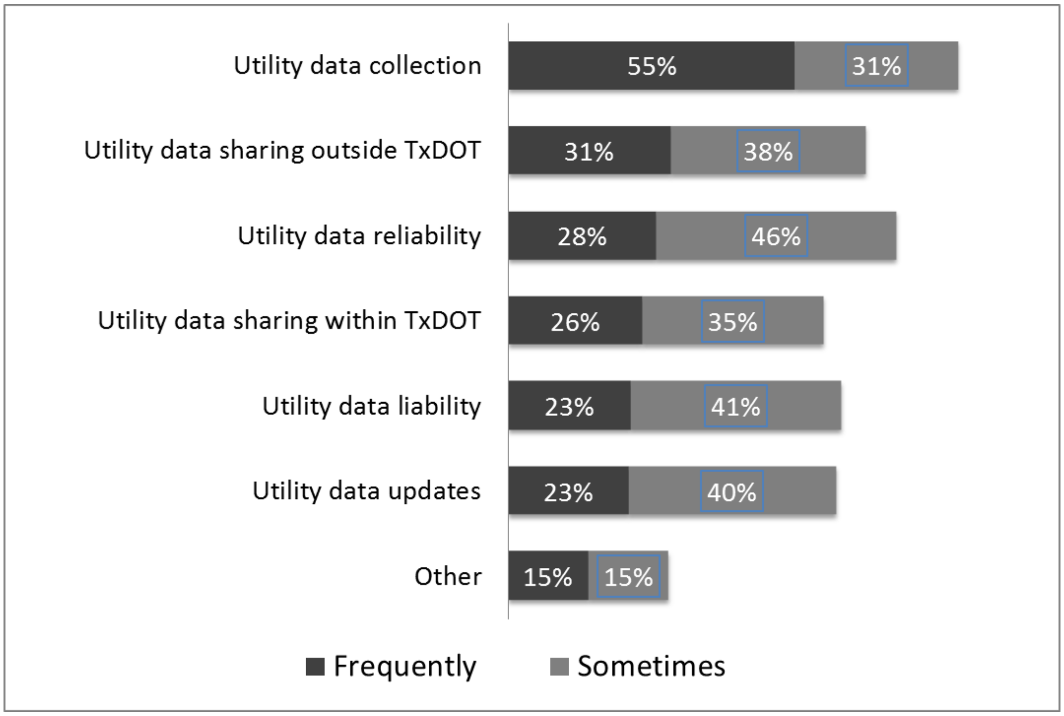


Figure 21. Utility Data Issues Encountered Frequently and Sometimes at TxDOT Districts.

Survey participants were asked about how much of a priority or concern the management of confidentiality and/or security of utility data were at the district or region. Figure 22 shows that based on the responses received, about two-thirds of the respondents either do not see it as an issue or perceived it to be a low concern/priority, while about one-third believes it is a medium or high concern issue.

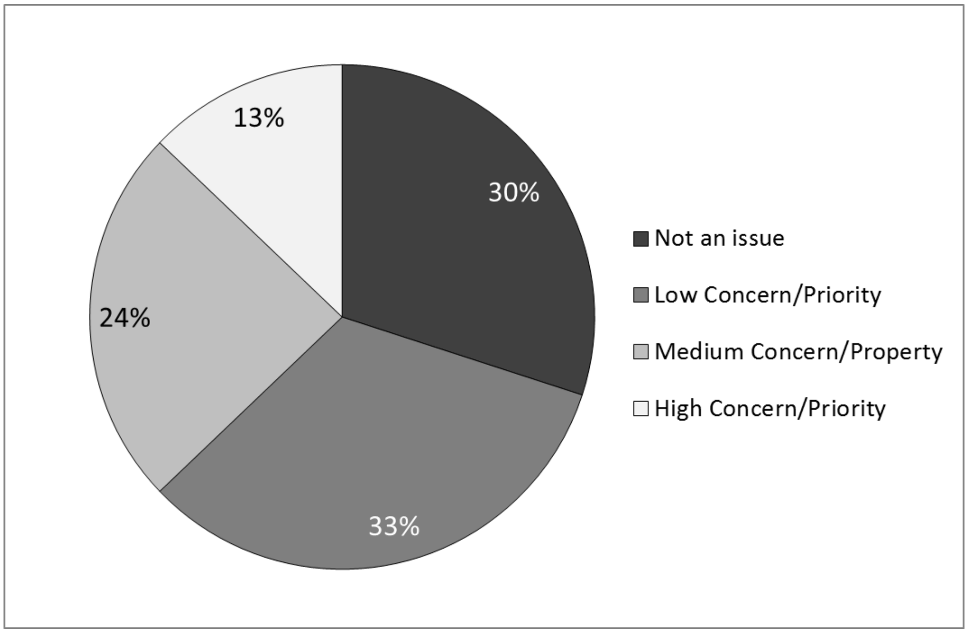


Figure 22. Concern about Management of Confidentiality of Utility Data.

Best Practices at the Districts and Regions

Twenty-seven survey respondents provided a best practice for utility investigations. The most common and innovative of these practices are briefly described below.

- **Early Involvement of Utilities.** Several respondents noted that involving utility owners early in the project development process benefits the utility coordination process. In practice, this is not the case though, as some utility owners do not typically participate in the project development process prior to the detailed design phase. Respondents noted that it is a best practice to work with all stakeholders as early as is possible to allow for comprehensive discussions of potential major relocation, for instance.

- **Early Start of Utility Investigations.** Respondents indicated that it is important to start utility investigation early (during preliminary design) and supplement data prior to the 30 percent design complete phase. If conflicts exist, getting accurate information and coordinating with utilities as early as possible is critical. Time spent doing a thorough utility investigation during the preliminary design phase and the detailed design phase can provide huge benefits when the project undergoes construction. In contrast, a lack of utility considerations can adversely affect project construction immensely.

- **Establishing Good Coordination and Communication.** Ensuring the district maintains good communication channels with the utility owners, SUE contractors, utility coordination consultants and other stakeholders is critical for making progress in the utility adjustment process. Because TxDOT frequently requests information from utility companies, it is important for TxDOT districts to develop excellent communication with utility owners and cultivate good contacts at the utility company to ensure needed information is provided. Some district utility coordinators establish good working relationships with utility owners and their contractors which lead to an easier exchange of ideas and concerns.

In order to do this, one responder suggested visiting project sites with the utility company representative. One hour of on-site visits can provide better results than three weeks of emails and phone calls. Another way of improving communication is to discuss the possibility of designing around utility owner facilities and making an effort to avoid any major utility when possible.

- **Use of SUE Investigation.** The collection of higher quality levels of underground utility data was suggested as one of the best practices. This included the use of QLA and QLB data. Districts should start with a QLD investigation first and proceed to higher quality levels as needed, based on initial findings and other preliminary design information. It is also important to plan services needed from surveying consultant by preparing utility records research data for use by the consultant, including a plot of utilities and highway improvements, if appropriate.

  In addition to this, matching the needs for utility locates to the specific project being developed saves money and provides the optimum use of available funds. QLA and QLB utility data collection is costly and must only be used when needed and providing the most benefit for a project. One responder suggested that for smaller projects, TxDOT designers should exhaust in-house resources to discover utilities and their location within project limits before requesting SUE provider services. On smaller projects, it may be necessary to limit the SUE provider to only QLB and QLA. On larger projects, it is usually feasible for SUE providers to conduct QLD through QLA.

- **Develop Clear Scope of Work for SUE Consultant.** The need to develop a clear scope of work for SUE consultants was also cited as a best practice. One responder noted that preplanning the need and scope of the utility investigations is the most overlooked area, but is an important step in establishing measures for evaluating a SUE deliverable.

Respondents also suggested these additional best practices:

- Include CSJ numbers in the online UIR form so that utility adjustments necessitated by construction projects can be distinguished from utility-generated rehabilitation and expansion projects. The records will still be maintained in the UIR system.
- Follow the FHWA guidelines on SUE investigation.
- Use of One Call verification where feasible.
- Conduct field visits to confirm utility locate plots by design engineer.
- Coordinate QLB and QLC data collection with surveyor.
- Conduct a thorough review of SUE deliverables and request supplemental information, including QLA data, if needed.
- Coordinate between TxDOT design and right-of-way staff.

Challenges with the Use of SUE at the Districts and Regions and Suggested Improvements

About a third (34 percent) of respondents indicated that they had encountered challenges with the use of utility investigations or SUE technology, as follows.

Challenges Experienced with the Use of SUE Technology

Survey participants were asked to describe any challenges they have encountered with the use of utility investigations or SUE technology. The following section briefly describes some of these challenges.

- **Quality and Accuracy of Utility Investigation Data.** Several respondents identified the quality and completeness of the utility investigation reports including survey reports. The accuracy of the data that SUE consultants provided can be questionable especially for anything less than QLA and for dense urban areas. This relates to the failure to correctly assess underperforming consultants, thereby causing TxDOT to continue to use them. Sometimes, SUE consultants provide a different level of utility investigation from what TxDOT requires (for instance, QLC instead of QLB).

  In addition to this, respondents expressed some concern as to the ability of SUE consultants to investigate different utility types. In one instance, a new location freeway was to be located through an oil field. The district's usual SUE consultant was unable to handle the complexity of the oil field piping system. This forced the district to spend extra funds to obtain assistance from a contractor that specialized in the oil and gas industry.

- **Timely Response from SUE Consultants.** Not only is the accuracy of SUE deliverables a challenge, the timely delivery of utility investigation data was noted as an issue for district staff. This is becoming more critical with the shortened project schedules.

- **Coordination Issues.** Several respondents identified coordination among the various stakeholders as a challenge when dealing with utility investigation. This includes coordination between:

  - TxDOT and utility owners.
  - TxDOT and consultant utility coordinators.
  - TxDOT with SUE consultants.
  - SUE consultants and utility owners.

  These challenges in coordination can make an already complex process even more daunting.

Other challenges listed include the following:

- Abandoning of facilities by the oil and gas industry without notifying TXDOT.
- One Call provides inaccurate line markings and has a slow response time.

- Limitations of some SUE technologies. For instance, GPR technologies seem to have limited capabilities in soils with high clay content. In addition, standing water can limit the effectiveness of SUE technology.

Improving Current Utility Investigation Practices

In addition to this, researchers asked survey participants if they knew of any current utility investigation practice in the district or region that could be improved. Only about a quarter of respondents to this question (24 percent or 18 respondents) indicated that this was the case and shared practices that could be improved or reviewed at their district or region.

Of the 74 respondents to this issue, less than a third (24 percent) indicated that there were practices needing improvement at their district or region. Note that a few had expressed their responses in previous questions and might have been reluctant to repeat them. Respondents described some practices at their districts and regions that could be improved. Such practices are described briefly below.

Utility Staffing. There has been a downsizing of utility staff at several districts, mostly due to budget cuts experienced across TxDOT. In some instances, this has led to serious reduction in utility relocation and coordination expertise. Downsizing has reduced the level of staffing at some district utility sections to a bare minimum that is not sufficient to perform utility relocation and coordination work properly. Some of these personnel are leaving for more lucrative positions with utility coordination consultants and utility companies that value the expertise they have gained with TxDOT. As a result, in some districts there are currently no utility coordinators, and designers have to be increasingly involved in a process they sometimes do not understand or care much about. There was a suggestion to provide full-time utility coordinators for each design section that only focus on utility coordination for assigned projects.

SUE Contract Funding. Several respondents noted that there is value in pursuing higher levels of utility investigation. There was a suggestion that TxDOT needs to commit to funding SUE provider contracts. There was also an acknowledgement that the current funding levels do not allow districts to pursue significant underground utility investigation work. There needs to be a better understanding of the impacts of not doing SUE work early in the project development process. This might spur the decision makers at TxDOT to provide the needed funding for SUE investigations. A few respondents cited the inability of districts to secure SUE provider services as a hindrance to designing certain projects, as well as increasing the overall project cost. Sometimes an engineering solution could have been used to avoid a utility conflict if SUE data were available.

Enforcing Responsibility of SUE Consultant. There was some discussion on the need to make SUE consultants responsible for pursuing further utility investigation when their original deliverable is not sufficient. In addition, there was a desire to hold SUE consultants accountable for previously poor deliverables and for the district to have the right to refuse a particular firm for previously poor work.

Involvement of Utility Owners in Preliminary Design. There was a desire to improve involvement of utility owners in the preliminary design stage of the project development process.

The need to incorporate the impacts of major utilities on the project during preliminary design or even earlier will allow for a better understanding of the relocation impacts as well as the challenges of any redesign. Respondents also mentioned the benefits of being proactive by asking utility companies about their facility upgrades or new construction.

Other suggested improvements include the following:

- TxDOT should commit to their plans to let a project. Projects that are planned to be let but end up not being let can cause significant, unnecessary burden on utility owners, and can very negatively impact the working relationship between TxDOT and utility owners.
- Emphasize the utility investigation process that FHWA outlined, and review past performance of TxDOT and other states.
- Personal communication with utility owners can often be improved. More useful and detailed data could be obtained from utility appurtenance surveys, if survey crews and consultant contract administrators received adequate training on utility investigation techniques.
- The entire process needs to be standardized and there needs to be more consistency to utility investigation throughout the design sections.

Policies and Regulations that Constrain or Obstruct Use of SUE in Project Development Process

A large majority of survey participants (82 percent of 73 respondents) also indicated that there were no policies and/or regulations that constrain or obstruct the use of utility investigations in the project development process. Of the 13 respondents that noted the presence of such policies and/or regulations, 11 of them provided feedback including the following:

- There are old, outdated policies that have hindered TxDOT cooperative relationships with public utilities.
- New, innovative approaches to obtaining data are not encouraged and sometimes obstructed.
- Intra-departmental communication is lacking and should be improved.

In addition to this, TxDOT's current policy of doing more with less was mentioned several times. This results in a lack of funding set aside for SUE contracts to do the needed utility investigations and a lack of human resources to handle the utility agreements and relocations.

Documentation Guidance for Utility Investigations during Project Development Process

Researchers asked survey participants about types of documents and manuals used as guides during utility investigation procedures at the districts and regions. Figure 23 shows the various documentation and guidance used for utility investigations. Initially, several responders indicated that their district had standard operating procedures (SOPs) and/or a District Policy relating to the use of utility investigations during the project development process. Further conversations with these responders revealed that the majority of these SOPs and/or policies were in fact, undocumented, and these were subsequently reclassified as "Unwritten District

Practice/Policy/Procedures." Responders from the Atlanta District confirmed the availability of a district policy/SOPs on the process for requesting utility investigations.

From the figure, the most used documentation or guidance is the *TxDOT ROW Utility Manual*, followed by unwritten district policy/practice/procedures. Memorandum of Understanding with SUE providers is the least often used documentation. Surprisingly, only 10 percent of the respondents mentioned the ASCE 38-02 SUE standard, which includes much guidance on SUE technology and uses. This demonstrates that many respondents were not familiar with the standard. Documentation mentioned in the other category included the Texas Administrative Code, Railroad Commission site, and research reports.

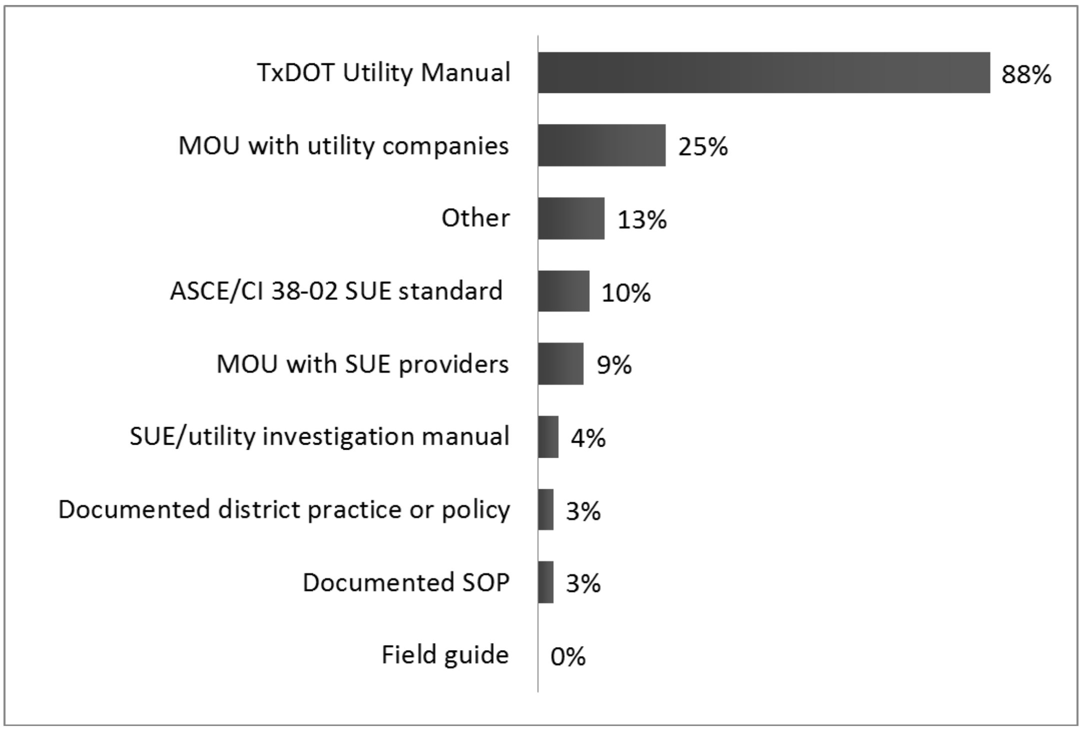


Figure 23. Documents Used for Utility Investigations during Project Development Process at TxDOT Districts.

Information Management Systems

Survey participants were asked about the type of information management system used at their districts or regions to record, identify, and/or manage utility investigation data. Figure 24 shows a summary of the responses received for moderate to heavy use. From the figure, the most frequently used system is CAD software, which includes AutoCAD® and MicroStation®. About 80 percent of respondents mentioned CAD software as being moderately or heavily used. Spreadsheets such as Excel® are also heavily used in recording, identifying, and/or managing utility data. The least used application was server-based databases such as SQL Server, Oracle, and MySQL.

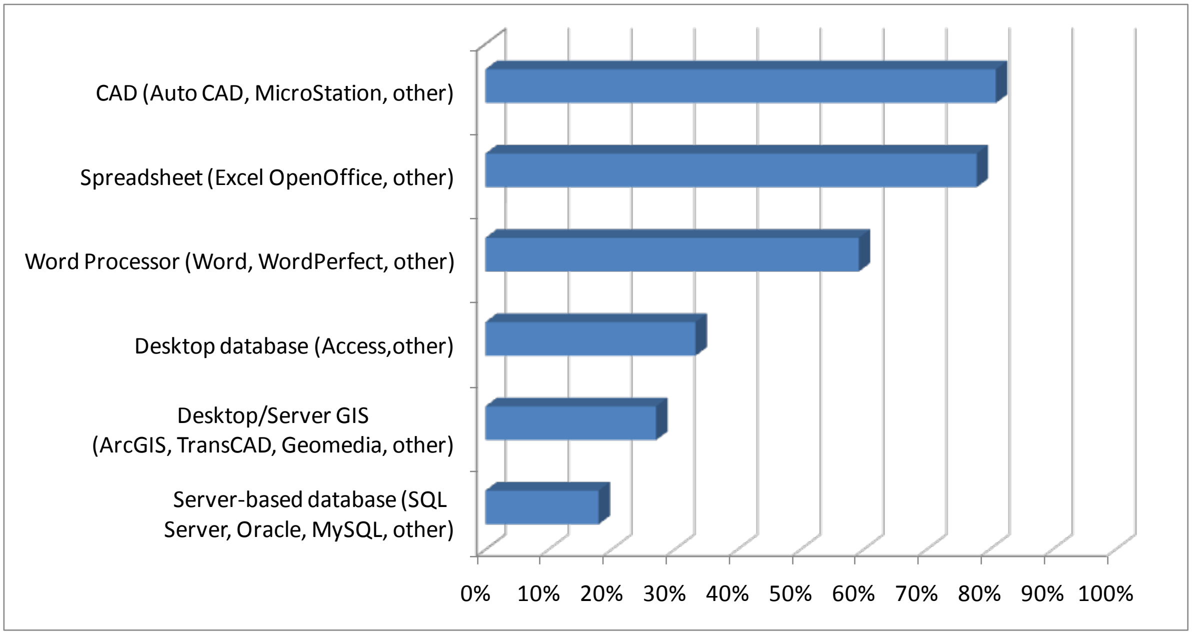


Figure 24. Information Management Systems Used to Record, Identify, and/or Manage Utility Investigation Data (Respondents Indicating Heavy or Moderate Use).

SUMMARY OF UTILITY INVESTIGATION PRACTICES AT TXDOT

In summary, the research team made the following conclusions about current utility investigation practices of TxDOT organization units:

- **Confusion among Stakeholders about SUE Terminology.** Based on the responses from survey participants, it appears that there is considerable confusion about basic SUE terminology. Some participants were unfamiliar with the acronym SUE itself. Several others thought of SUE data collections as QLB or QLA data collections, but did not consider QLD or QLC data collection to be part of SUE as well. QLD and QLC data collection requires equipment that is typically available at TxDOT, so project managers frequently perform these types of data collections using in-house staff. QLB and QLA data collections require specialized equipment that may not be readily available at TxDOT, so project managers typically hire a SUE contractor to collect this kind of data. This fact may also contribute to a common confusion that SUE data collection only refers to activities that produce QLB and QLA data. Other responses from participants displayed confusion about QLB or QLA data collections versus One Call services, which were occasionally thought of as data collection at QLB or QLA.

- **Unfamiliarity with Current QLB and QLA Technology Options.** Several respondents indicated a lack of knowledge about the different types of technologies that are in use for QLB or QLA data collections.

- **Lack of Knowledge or Experience about Best Use of QLB and QLA Technology.** Several responses indicated that stakeholders had not sufficient knowledge or experience to determine the best use of a particular technology for QLB or QLA data collections. Some respondents asked SUE providers to determine the best technology and appeared frustrated with results. This may be a result of unrealistic expectations on TxDOT's side, a lack of performance or experience on the SUE provider's side, or a combination of both. Another example is the use of QLA data collection during construction, which survey participants selected more often than any other phase of the project development process. During the construction phase, however, QLA cannot be as effectively used to avoid project delays and cost increases as during earlier process phases.

- **Use of QLB and QLA SUE Technology Is Relatively Infrequent.** Responses showed that some districts appear not to use certain SUE technologies at all. Since there are no detailed statewide guidelines on the use of SUE, this issue may be related to a lack of knowledge about the technology and its benefits.

- **Use of QLB and QLA SUE Technology Has Declined.** Based on responses and follow-up interviews, it appears that the use of SUE for TxDOT projects has significantly declined over the last few years. This is apparently due to significant reductions in funding for utility investigations.

- **Uncertainty about Benefits of QLB or QLA SUE.** Survey respondents indicated a general lack of certainty about the benefits of QLB or QLA SUE, particularly final benefits in terms of return on investment. More than half of respondents were unable to quantify any return on investment, while about one third of respondents expected an average return on investment of 2 or higher. However, only 7 percent did not expect a positive return on investment by using QLB or QLA SUE.

- **Need for Training and Education.** A lack of knowledge about SUE technology by many survey participants is evident, as is a lack of its best uses. Training and educational materials could close the gap between the options that TxDOT has at its disposal and make more effective use of project funds. Further, given that cost was the most frequently cited factor prohibiting more frequent use of QLB and QLA SUE, it appears that education about the benefits of SUE and expected return on investment could have a significant impact on the use of SUE by TxDOT officials.

CHAPTER 4: UTILITY INVESTIGATION PRACTICES AT OTHER STATES

To identify best practices that are used in the United States to perform utility investigations, the research interviewed state department of transportation officials from California, Illinois, Florida, Georgia, Maryland, North Carolina, Ohio, Pennsylvania, and Virginia. To facilitate the interviews, the researchers used an interview guideline and questionnaire (Appendix C). During the interviews, the research team gathered information, sample documentation, and data related to utility investigation practices and evaluated potential strategies to implement utility investigation techniques into the TxDOT project development process. The following sections provide an overview of best practices and use of utility investigation practices at eight states that provided feedback.

GENERAL OBSERVATIONS

All states interviewed collect some type of SUE data on all or most of their projects. The research team found that the use of the ASCE standard for collection and depiction of SUE data, including the use of four data quality levels (QLD, QLC, QLB, and QLA), is prevalent at most DOTs (*4*). However, there remains some confusion at state DOTs about these different types of SUE data. For example, during interviews with stakeholders, the research team noted that frequently stakeholders think of SUE data as the equivalent of QLB or QLA data, but not QLD and QLC data. This may be attributable to the fact that in many cases, DOTs use in-house staff to collect QLD and QLC data, and use a SUE consultant to collect QLB and QLA data.

The research team confirmed that in general, state DOTs start data collection at QLD during preliminary design, followed by QLC data collection that may be included in the activities to complete a right-of-way map for the project. An approved right-of-way map is typically a requirement to move a project from the preliminary design into the detailed design phase. In many cases, the QLC data collection efforts are complete at the end of the preliminary design phase (Figure 25).

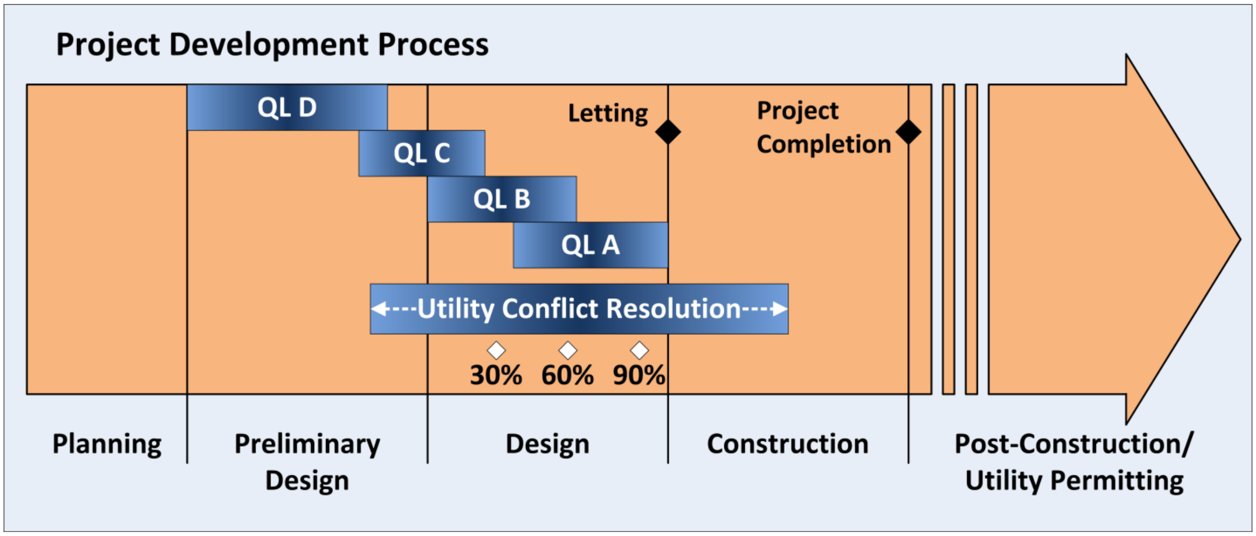


Figure 25. Utility Conflict Resolution during Project Development.

While QLD and QLC data collections for utilities are often standard procedure, the use of QLB and QLA data collection varies greatly among the states interviewed for this research. The main factor that makes the use of QLB and QLA data less prevalent at state DOTs appears to be the fact that these data collection activities, for the most part, require the services of a consultant. This in turn requires monitoring of the consultant contract and contract deliverables, and thoughtful planning to determine locations where data collection at these quality levels will provide a reasonable return to the DOT on the funds invested in the consultant activities. The return on the investment, however, is directly related to the quality of utility conflict management and data collection that the DOT produced up to the point where the consultant is hired. For example, a QLB data collection may provide a higher payoff in an area of a project where the DOT has knowledge about the existence of utilities but not their location, as compared to an area without any utility installations. As a result, the research team found that DOTs appear to be more inclined to invest in QLB and QLA services if they have a detailed process in place that outlines utility investigation activities at all quality levels throughout the project development process.

Many states are using utility conflict matrices to manage utility data collected during the project development process. The structure of these matrices and content that state DOTs manage vary considerably, not just between states but also between districts of the same states. At the moment, use of these utility conflict matrices is mostly voluntary and often limited to internal use of the state DOT. A current Strategic Highway Research Program 2 (SHRP2) project "Identification of Utility Conflicts and Solutions," that is scheduled to complete in July 2011, is focusing in part on trends and best practices regarding the use of utility conflict matrices at state DOTs (*22*). To avoid redundancy with the findings of this report, this technical memorandum will only briefly summarize activities of state DOTs with regard to use of utility conflict matrices.

UTILITY INVESTIGATION PRACTICES AT SAMPLE STATES

California Department of Transportation

General Utility Practices

The California Department of Transportation (Caltrans) collects a small amount of utility data during the planning phase, but the majority of utility data are collected during the preliminary design phase. During the planning phase, utility data investigation is limited to data that are needed to provide a utility cost estimate for a summary project data sheet that Caltrans prepares for each project. During preliminary design, Caltrans compiles existing as-built information and adds these data to project plans to determine potential utility conflicts. The utility engineering workgroup and survey group perform the surveying of aboveground utility features, which is typically complete by 30 percent of the detailed design phase. Caltrans then forwards this information to affected utility companies, who in turn mark up the plans and return them to Caltrans.

Caltrans High/Low Risk Policy

California has a policy that determines utility data requirements based on the risk to the public if an underground utility facility is accidentally damaged, sometimes called the "high/low risk policy" (*23*). This policy relates to Section 4216 of the California Government Code, which provides the requirement for statewide one-call system and include definitions for high priority utilities (*24*). High risk utilities are high-pressure natural gas pipelines; petroleum pipelines; pressurized sewer pipelines; high-voltage electric supply lines, conductors, or cables; and hazardous materials pipelines, e.g., pipelines transporting oxygen, chlorine, or toxic gases.

Caltrans' high/low risk policy provides clearance requirements that provide a minimum distance to high-risk facilities during construction activities (Table 4). To determine these clearance requirements, the horizontal and vertical location of utility facilities must be determined at intervals. High-risk utilities have more stringent vertical and horizontal location requirements. Such utilities within a construction area must be exposed using a so-called "positive location contractor" to determine and survey the vertical and horizontal location. High-risk facilities crossing a highway must be located on each side of an undivided highway, and on each side of the median of an undivided highway. Additional location determinations must be made if the spacing between locations is greater than 100 feet. High-risk longitudinal installations must be determined at sufficiently spaced intervals but not greater than 100 feet.

Low-risk utilities may be located using QLB. For example, Caltrans normally does not procure potholing services for culverts and cross-drains. However, a greater level of investigation may occur if the project engineer appeals to his or her supervisor. Exceptions to this policy that would result in a lower level of investigation are also possible, but the chief of the design division must sign these, and they occur only very rarely.

Table 4. Minimum Clearance Requirements for Utility Facilities on Caltrans Construction Projects (23).

High-Risk Utility Facilities	
Facility Location	**Clearance Requirement**
Below the grading plane	18 inches
Below disturbed ground, and in areas of unsuitable material	12 inches
Below the grading plane of drainage structures	12 inches
Below flow line of unlined ditches	18 inches
Horizontally from face of pile or from side of excavation	24 inches
Low-Risk Utility Facilities	
Facility Location	**Clearance Requirement**
Any location	As determined by project engineer.

Positive Location Contracts and Procedures

Positive location is a procedure to determine the horizontal and vertical location of a utility and ensure applicable construction clearances. Applicable methods include potholing, probing, electronic detection, as-builts, and other methods. Potholing and probing involves the exposure of a facility using a vacuum excavator or other method and determining the exact location of the facility. Electronic detection provides only an estimate of the facility location and is used only to determine if a facility is well outside construction limits or required clearances. As-builts can be accepted in place of potholes or probes if the utility owner certifies the accuracy of the drawings, and other methods may be applicable if they meet the approval of the project engineer.

In order for positive location procedure to apply, Caltrans must have an agreement with the utility company that covers positive location. Language in the state regulations enables Caltrans to sign agreements with utility companies, which allow Caltrans and its contractors to uncover utility facilities if there is a need during the development or construction of project, and if Caltrans has paid for these. If the utility does not want a Caltrans contractor to uncover the utility facility, it must hire its own contractor to do so.

Typically, Caltrans offers one-year contracts for bidding to SUE providers, which then receive task orders for location activities throughout the contract year. Contracts include both QLB and QLA data collection activities although QLB data collection is the exception; most data collection involves potholing at QLA. A Caltrans surveyor will typically provide the final mapping for locations and will survey the locations of utility facilities based on stakes that the SUE provider had set. Sometimes Caltrans surveyors will be on-site with the SUE providers; at other times, the surveyors will survey locations after the SUE provider has left. Contracts have an annual funding limit. If there is a need for additional funding, contracts can be amended once annually.

Some districts use multi-provider contracts where yearlong contracts exist with multiple companies. If the need for a positive location procedure arises, the district official can call any of the providers, which can tremendously improve the turnaround time for services. Turnaround times have been the main issue with single-provider contracts, which has led to the use of multi-provider contracts.

Positive location activities are paid with funds from the project's budget for right-of-way costs. As a result, designers often request more location services than what the high-/low-risk policy would require. In that case, the Caltrans utility coordinator will work with the project engineer and determine how many locations are actually needed. These negotiations follow the criteria in the high-/low-risk policy but also take into account other factors such as project location, type of facility, and topography. There are no funding formulas to determine the necessary level of utility investigations, and depending on the project, expenditures can be a significant portion of the right-of-way funds. Caltrans aims to collect sufficient, accurate data to help the designer determine if the facility is in conflict or not. Since positive location contracts can only be amended once in a budget year, there is a level of cost control not so much from the limit of project funding but more so from the limit of the contract funding. Following the negotiations between right-of-way and design groups, the right-of-way group issues a task order to a contractor to perform the locating activities. Occasionally, utilities suggest performing their own electronic location service. If the project engineer agrees with the process, Caltrans does not use any positive location contractors.

Before setting up these contracts, it was necessary for Caltrans to validate internally that its staff did not possess the expertise and equipment necessary to perform these services. Once the process of validating was complete, Caltrans was able to have SUE contracts. However, it is important that any SUE provider does not provide any services that Caltrans staff could perform. Therefore, consultant contracts are limited to services that require QLB or QLA data collection, and there are no contracts that would include surveying or preliminary data collection.

Contract with Underground Service Alert Providers

Recently, Caltrans has set up a contract with the Underground Service Alert (USA) Providers, or One-Call system of California. Caltrans pays an annual subscription fee, which allows Caltrans to use the service on any project. Caltrans can now call this provider in the preliminary stages of a project and ask for general utility information, without actually having to break ground or excavate. The USA provider typically sends Caltrans a list of utility companies with facilities in the project area, which gives the district a great starting point for coordination with utility companies.

Setting up the contract with USA providers was difficult at first but, according to Caltrans officials, this service has been tremendously beneficial to the project development process. Since Caltrans is not a member, it took some time to convince the systems of the benefits to allow Caltrans access to the data without actually excavating. In some districts, access to the USA data is limited in that there is a designated Caltrans contact to request data from a USA provider.

Utility Facility Databases

Some Caltrans districts have developed local databases of utility facilities, but there is no central state repository of utility facilities. Since the September 11, 2001, attacks, utility companies have been more reluctant to share exact locations of utility facilities. As a public agency, all records provided to Caltrans are potentially accessible by the general public, which can be an issue for utility companies.

Data sharing between utility companies and Caltrans continues to be a significant issue. On one hand, Caltrans wants an open and efficient bidding process that provides as much information to contractors as possible; on the other hand, it must protect critical utility infrastructure information. Caltrans has proposed a system that would allow Caltrans designers to store utility information on layers that can be turned on or off, but this has not been completely convincing to utility companies.

Utility Conflict Matrix

Caltrans has been using spreadsheets to track and manage utility conflicts for 18 years. These utility conflict matrices may vary from district to district, are used on a voluntary basis, and are mostly used by districts in urban environments. A new Caltrans policy that is currently in draft format will make the use of utility conflict matrices mandatory for all Caltrans districts. Specifically, Article 5 of the Caltrans Encroachment and Utility Policy will mandate that the project engineer must provide the district utility coordinator with a utility matrix for all projects on the California state highway system (*25*).

Utility Engineering Work Group

Caltrans has started working on a utility engineering work group effort to establish a group of engineers within each Caltrans district that focus on issues with utilities. The idea is to provide a liaison between the design engineer and the utility coordinator and thus remove an existing disconnect between the two groups. At Caltrans, most utility coordinators are right-of-way agents who typically do not have an engineering background. The purpose of the group would be to give utility issues a higher priority during the project development process and better convey utility issues to project engineers, who are often not familiar with utility issues and are mostly focused on the design of the highway facility. The Caltrans utility engineer would be able to raise awareness about utility issues, better inform the project engineer about how different types of utilities can impact the design, and provide recommendations for resolving utility conflicts.

Florida Department of Transportation

General Utility Practices

The Florida DOT uses SUE extensively throughout its project development process and has developed an efficient process of ensuring adequate utility investigation is provided in support of project development. FDOT in-house staff or a district's consultant contracts handle most utility coordination. In general, SUE consultants perform SUE field services at all quality levels. In some instances (e.g., in-house design work), in-house district utility staff perform QLD. Utility investigations are procured through district-wide multiyear consultant contracts, a district General Engineering Contract (GEC), or through the individual stand-alone consultant design contracts. FDOT requires all consultants to follow the ASCE 38-02 guidelines for SUE work (*4*).

For limited access capacity improvements, FDOT uses QLD and QLC project-wide within project limits during the survey phase at the beginning of design. FDOT uses QLB and QLA at about 60 percent design, but not for all projects. By comparison, for a non-limited access capacity improvement project, QLD, QLC, and QLB are used throughout the project limits during the survey phase at the beginning of design, and QLA is emphasized heavily at about 60 percent design. On non-added capacity such as resurfacing projects, QLD and QLC are used throughout the project limits during the survey phase but rarely QLB and QLA. Project size in terms of cost has no bearing on the use of SUE; for example, a small intersection upgrade with a new traffic signal foundation may require extensive SUE investigation. Liability is addressed by requiring the design consultant and the SUE consultant to carry errors and omission insurance.

SUE Standards and Deliverables Checklist

Each FDOT district develops its own SUE standards and deliverables checklist. FDOT's District 2 has developed detailed SUE standards (based on the ASCE 38-02 guidelines) and a deliverables checklist identifying key items that SUE consultants are to provide in their services. The district requires QLB during the initial design phase up to 60 percent design to identify potential utility conflicts. QLA is performed only after 60 percent design. This reduces the cost that might be incurred by performing unnecessary QLA before conflict location can properly be identified during design.

The SUE standards also require SUE services and deliverables to be in accordance with the FDOT current procedures. It requires all field survey data to be gathered using the electronic field book and in a Computer-Aided Civil Engineering (CAiCE) software readable format. The SUE consultant is responsible for depicting the subsurface utilities utilizing the ASCE standards FDOT identified for a particular project (*26*).

FDOT requires all QLB data to be recorded on a "Designating Form" designed for that purpose. The department notifies the consultant of which form should be used on a project by project basis, based on FDOT needs for the particular project. In addition to the Designating Form, the SUE consultant provides a report detailing any discrepancies found between existing utility owner plans and what was designated in the field.

District-wide SUE Scope of Services Quality Control

Each FDOT district has a SUE contract with multiple SUE providers. These contracts are specific to the district and the standards are also specified for that district. As part of their district-wide SUE scope of services, FDOT requires SUE consultants to have a stringent quality control process including the following elements (*27*):

- **Quality Reviews.** The consultant is required to make quality reviews to ensure the organization complies with the requirements cited in the scope of services. The quality reviews must evaluate the adequacy of materials, documentation, processes, procedures, training, guidance, and staffing included in the execution of this contract.

- **Quality Assurance Plan.** The quality assurance (QA) plan details the procedures, evaluation criteria, and instruction to the organization to assure conformance with the contract. Significant changes to work requirements may require the consultant to revise the QA plan. The plan must include, among other things:
  - A description of the consultant's quality control organization and its financial relationship to the part of the organization performing the work under the contract.
  - The consultant's QA methods to monitor and assure compliance of the organization with the contract requirements for services and products.
  - The types of records that the consultant will generate and maintain during the execution of the QA program.
  - The methods that the consultant used to control the quality of the subcontractors and vendors.

- **Quality Records.** The consultant is required to maintain adequate records of the QA actions that the organization (including subcontractors and vendors) performed in providing services and products under this contract. All records shall indicate the nature and number of observations made, the number and type of deficiencies found, and the corrective actions taken. It is also noted that all records are subject to audit review and are required to have a second level of peer review.

Utility Conflict Matrix

In Florida, utility conflicts are typically identified and resolved during the design phase of the project development process. FDOT uses a utility conflict matrix during the utility investigation process to track and manage utility conflicts. The purpose of the utility conflict matrix is to provide adequate information on utility information within a project's intended right-of-way to enable design changes and also to avoid such utility conflicts. FDOT uses utility conflict matrices on all projects and, in particular, for projects that involve higher level of SUE data collection (i.e., QLB or QLA).

These details of the utility conflict matrices may vary for the various FDOT districts; however, it is an important component of the utility investigation process. FDOT notes that conflicts they had identified in the UCM do not relieve the utility company or owner from the responsibility to identify all conflicts with their facilities.

Florida Utilities Coordinating Committee

Florida established the Florida Utilities Coordinating Committee (FUCC) in 1932 (*28*). The FUCC is a confederation of:

- Public and private utilities.
- Public works departments.
- One-call service companies.

- Railroad companies.
- Consulting engineers.
- Contractors.
- State, city, and county governmental agencies who all work together through coordination, cooperation, and communication to resolve problems and develop standards for coexistence in public rights-of-way.

The FUCC meets every quarter to discuss and coordinate general utility related issues within the state of Florida and specific project related issues as needed. The FUCC also has the objective to accomplish the construction and reconstruction of roadways in Florida with the least amount of problems and setbacks. FDOT typically has district utility engineers present at such meetings for districts that might have critical utility related issues on current or upcoming projects. The FUCC has a website to help provide an online network for information exchange between governmental agencies and the utilities that provide infrastructure in Florida.

Georgia Department of Transportation

The research team contacted officials from the Georgia Department of Transportation (GDOT) to discuss best practice for utility investigations. GDOT officials answered the research team's questions and provided a wealth of information that was useful to describe the following best practices.

Utility Investigations in the Project Development Process

GDOT has two procedures to collect utility data: (a) the traditional procedure and (b) the SUE procedure. Using the traditional procedure, GDOT sends utilities a set of project plans, the utility provides markups of utility facilities, and GDOT staff transcribes the markup into the project CAD file. This procedure is useful for projects with few utility installations within the project limits and similar to procedures that other state DOTs have in place. For all other project, GDOT uses the SUE procedure, which outlines a series of steps on how to collect QLB data that QLA data then supplements in locations where the designer needs information that is more accurate. The determination to use the traditional or SUE procedure on a project is largely driven by a risk analysis using a risk management matrix.

GDOT has formalized the SUE procedure in several manuals and flow charts. Figure 26 provides an overview of the procedure. In addition, Figure 27 and Figure 28 provide a detailed process model of the procedure that the research team developed using several documents and information provided by GDOT officials (*29*, *30*, *31*). If GDOT uses the SUE procedure on a project, contractors typically collect QLB data project-wide. Only in less than 10 percent of all projects that use the SUE procedure it is not necessary to collect project-wide QLB data.

In general, QLB data collection can begin after control points and preliminary project limits are established, which typically occurs at about 10–30 percent of the detailed design phase. However, SUE QLB and QLA services can be requested at any time during the project development process. Figure 26 shows that the QLB data collection is followed by a utility impact analysis, which is normally the responsibility of the consultant. This analysis provides a deliverable, which is the utility conflict matrix. The utility impact analysis can be completed once preliminary drainage, erosion control, staging, structures, and construction limits are completed, which typically occurs around 30–60 percent of the detailed design phase. The utility conflict matrix is used during the Preliminary Field Plan Review (PFPR) meeting, and helps GDOT designers decide if there is a need for any QLA data collection. Following the PFPR, utility relocations may begin and if needed, a QLA SUE consultant might be hired to perform potholing, followed by an update of the utility conflict matrix. Once GDOT accepts the QLA deliverables, there might be a second utility impact analysis (if needed) that the project engineer performed, followed by a third update of the utility conflict matrix. GDOT then uses the utility conflict matrix during the Final Field Plan Review (FFPR) to finalize the design and resolve any remaining conflicts.

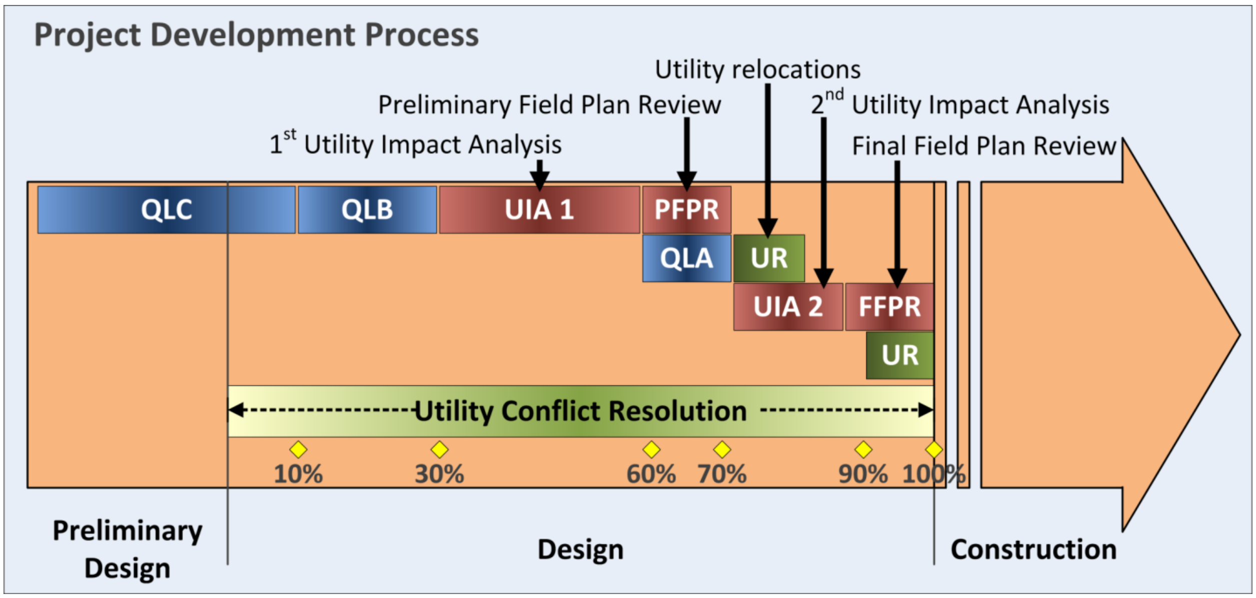


Figure 26. Utility Conflict Resolution in the GDOT Project Development Process.

Process to Request SUE

GDOT has formalized the process to request SUE services for a project. Any GDOT employee involved with a project may identify a candidate for SUE services. However, only a project manager, district utilities engineer, or state subsurface utilities engineer can actually submit a request for SUE services.

Requests can be made any time during the project development process, as soon as project enters the six-year Construction Work Program (CWP), i.e., during concept development, preliminary design, final design, or construction phase. All that is required is to fill out a request form, including requested quality level, utility impact rating, and current project development phase, and submit the form to the state subsurface utilities engineer, who has a two-week approval time frame to approve or deny the request.

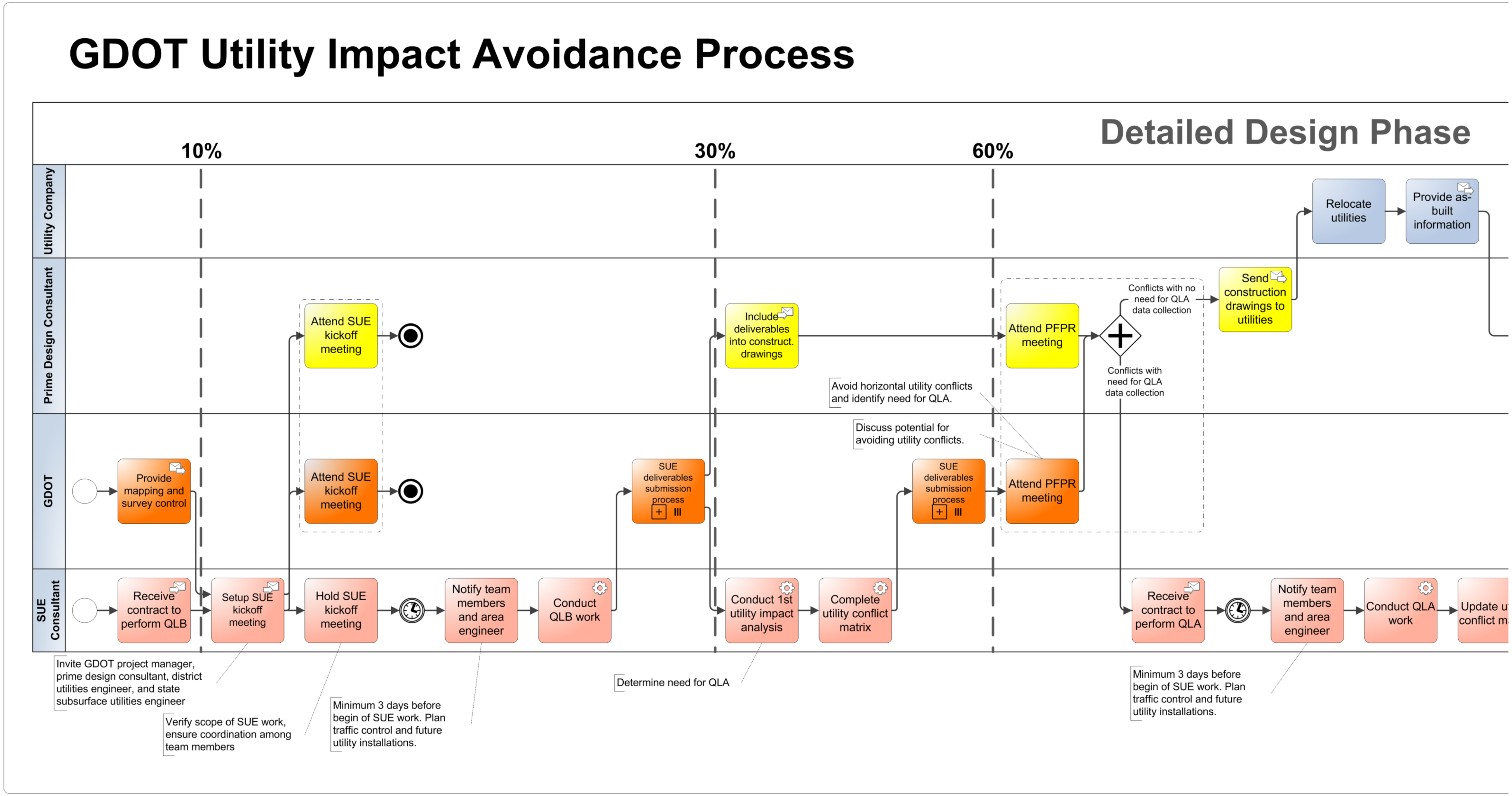


Figure 27. GDOT Utility Impact Avoidance Process.

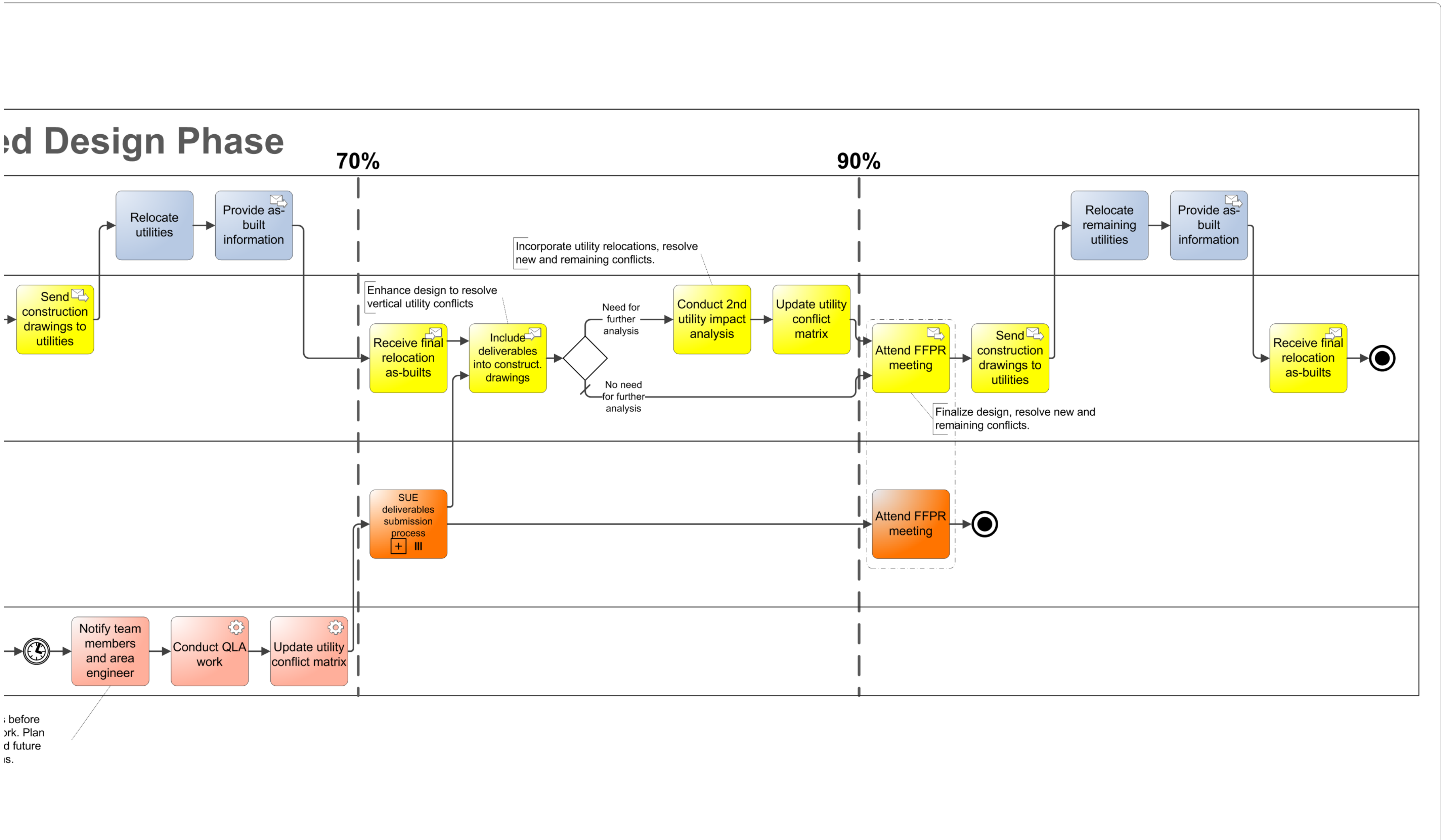


Figure 27. GDOT Utility Impact Avoidance Process (Continued).

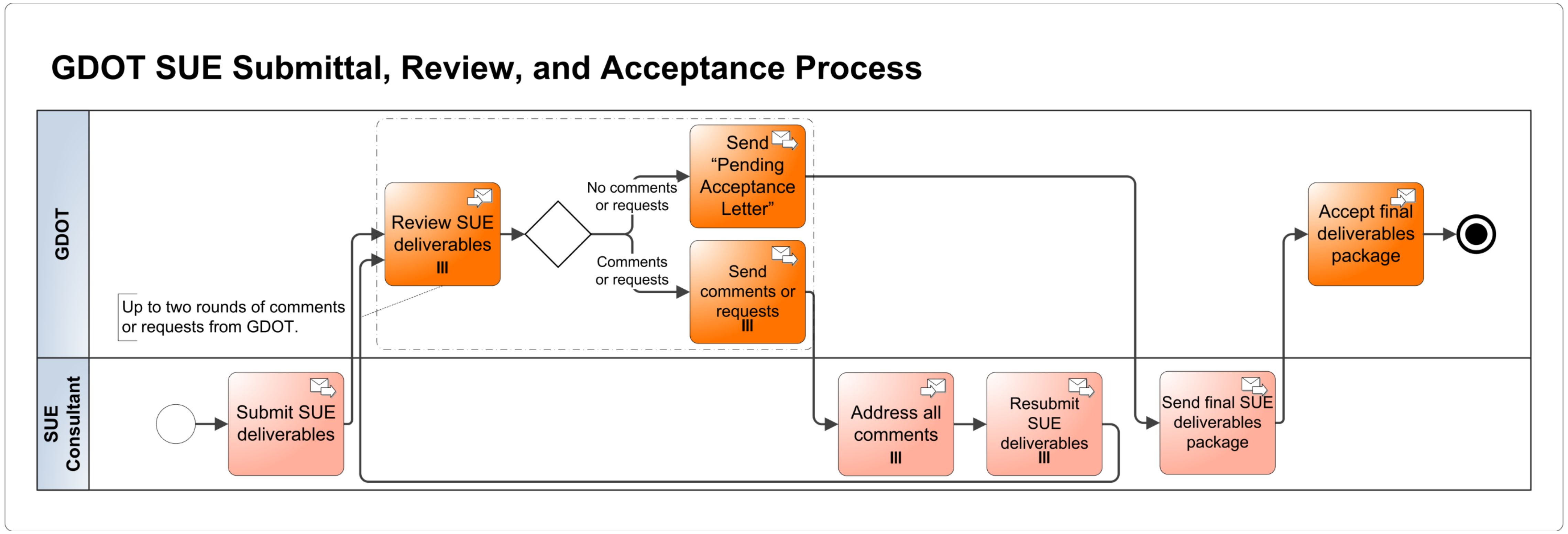


Figure 28. GDOT SUE Submittal, Review, and Acceptance Process.

Utility Impact Score

To estimate the approximate impact of utilities on project delivery time and costs, GDOT has developed a utility impact score system. To determine the utility impact score of a project, GDOT has a list of 10 questions that can be answered on a scale of 1 to 3 indicating an impact of low to high (*32*). GDOT developed the list of questions for the utility impact scores based on past project experience. Project characteristics where SUE services provided a good return on investment include the following:

- Projects in urban or suburban areas.
- Projects with a high expected level of utility congestion.
- Projects with anticipated issues due to previous poor experience with utility owners to provide timely and accurate information.
- Projects with a high estimated utility relocation cost.
- Projects with a high probability to retain utility installations in place.

Upon answering these questions, a simple utility impact score (UIS) is calculated by weighing the frequency of each type of answer using the following equation:

$$\mathrm{UIS} = \frac{(\mathrm{L} \cdot 1 + \mathrm{M} \cdot 2 + \mathrm{H} \cdot 3)}{10}$$

where

L = Number of low responses.
M = Number of medium responses.
H = Number of high responses.

GDOT takes the utility impact score into consideration when determining whether to approve a request for SUE services. Table 5 provides a description of the Utility Impact Score.

Table 5. GDOT Utility Impact Score (*32*).

Utility Impact Score	Utility Impact Description
1	Project minimally impacted by utility issues.
2	Project moderately impacted by utility issues.
3	Project severely impacted by utility issues.

Utility Conflict Matrix

GDOT has been involved in the development of a utility conflict matrix concept since about 2005. The purpose of the utility conflict matrix is to provide designers sufficient information to develop design changes and avoid utility conflicts. GDOT uses the utility conflict matrix on all projects that involve QLB or QLA data collection. In practice, it has been a challenge to update the utility conflict matrix with information from the design group. GDOT is planning to make changes to the process to facilitate the tracking of changes to the utility conflict matrix made by the design group, which will also allow the determination of cost savings to the project due to the use of the utility conflict matrix.

GDOT has developed a training course called "Avoiding Utility Project Impacts" that provides guidance on how to effectively use the utility conflict matrix and how to perform a utility impact analysis. The training course shows how to weigh the cost of adjusting a major utility against a change in the roadway design and is now mandatory for all GDOT designers.

As a future enhancement, GDOT is considering a system that would allow a project contractor to report the number of utility conflicts discovered on a project once construction starts. This tool would help determine the cost effectiveness of SUE and provide performance evaluation criteria for SUE providers, by comparing projects that used the SUE procedure with those that used the traditional procedure.

Other Recommendations

Based on past experience with SUE providers, GDOT has developed detailed scope of services contracts and a detailed SUE deliverables checklist that is used for all SUE procurements. Both documents are essential to receive type, format, and quality of SUE information that is needed during the project development process.

Maryland Department of Transportation

General Utility Practices

The State Highway Administration (SHA) of the Maryland Department of Transportation (MDOT) uses SUE work at various stages of their project development process. The SHA currently does not use geophysical methods such as ground penetrating radar, primarily because the SUE consultants under contract have not yet proposed to use them. As part of an administrative policy, Maryland requires SUE investigations on all projects. Typically, internal SHA staff performs SUE QLD at the 15 percent design stage. SHA's preliminary engineering staff takes great care with this initial QLD data gathering to provide a basis for informed decisions about higher quality level SUE work later in the project development process such as expensive QLA.

Using the ASCE 38-02 standard, SUE consultants perform QLC and QLB at the 30 percent design stage and QLA at the 60 percent and 90 percent design stages (*4*). The specific project details largely drive the level and type of SUE work performed. Typically, the SHA determines the SUE scope of work once the initial set of plans is developed. Usually at the end of the preliminary design phase there is a comprehensive assessment by the design team and the utility coordinators to see how much and what type of SUE work is required.

Multi-Year SUE Contracts

The Maryland DOT has six SUE contracts with various SUE consultants that are valid for three years. The contracts have a value of $2 million each for the duration of the contract, or a total of

$12 million. The multi-year, multi-company contracts allow the state to procure SUE work on short notice. The Maryland DOT ensures that the SUE consultants have the necessary qualifications, experience, and technology to meet the data collection standards defined in ASCE 38-02 (*4*).

The scope of services for SUE contracts is not limited to only utility investigations. For instance, SUE consultants are sometimes contracted to design preliminary utility relocations or "design concepts" for the SHA. In other cases, they are contracted to assist in developing preliminary cost estimates for utility relocations. These preliminary analyses help the SHA judge a project's potential for utility conflict impacts and the options for relocating utilities.

The preliminary utility relocation design concept that SUE consultants developed is subsequently presented to the relevant utility companies as input into their own relocation design process. At the beginning, MDOT faced a lot of resistance from utility owners who were concerned about possible encroachment into a field of their responsibility. To address these concerns, representatives of MDOT organized meetings and sessions with utility owners to emphasize the purpose of the preliminary utility relocation design: support for the utility owner's process to relocate facilities and equipment. In recent times, the utility relocation design concepts that SUE consultants developed have served as a helpful input into the utility relocation process.

Internally, the SHA assigns task managers to specific tasks such as coordination with consultants. The task manager then contacts various consultants about the level of SUE needed. The SHA selects SUE consultants based on the cost estimate that SUE consultants provide as well as the consultant's previous track record with SUE data collection.

Need for Training and Certification of Utility Coordinators

MDOT has found that staff training and certification is a critical need but no suitable program to train and certify utility coordinators exists as of yet. MDOT representatives expressed frustration about this lack of a formal training and certification program specifically designed for state DOT and other agency staff involved with utility investigations, relocation, and coordination. This certification program should acknowledge the highly specialized skills that are required for utility coordination staff to conduct thorough utility investigations. Other specialized areas of the project development process such as right-of-way, construction, planning, and design already have some type of certification program at MDOT. The lack of certification in the utility coordination field means there is no way to identify coordinators that have necessary experience and current knowledge of the utility process, including the knowledge about when and how to use SUE for maximum benefits to the project development process.

Developing a structured training program and certification for utility staff would allow DOTs, utility owners, and SUE contractors to learn about the latest and best practices in utility coordination and investigation. It would also help train new staff in a more structured way within the utility coordination program.

North Carolina Department of Transportation

General Utility Practices

The North Carolina Department of Transportation (NCDOT) adopted SUE practices in 1991, and since that time, SUE has become an integral part of the highway design process. Most projects undergo a minimum of some QLB data collection and depending on a review of data needs, design parameters, and project considerations, additional QLA data collection. The NCDOT Utilities Section makes the decision to collect QLA data on a case-by-case basis. Some projects do not require any QLB or QLA data collection.

NCDOT attempts to initiate the SUE data collection as early as possible in the project development process, which is usually initiated concurrent with or shortly after preliminary design, but always prior to the 30 percent detailed design stage. In general, QLD and QLC data are collected concurrently with environmental investigations, and the goal is to complete both processes at approximately the same time.

NCDOT uses approximately 10 SUE contractors statewide, which are selected based on qualifications using a typical request for proposal procurement process. After contractors submit bids, the most qualified firms are selected. The most common technique used to perform QLA utility investigations at NCDOT is potholing. For QLB data collection, NCDOT makes limited use of GPR. More recently, NCDOT has experimented with the use of 3M radio frequency identification (RFID) marker balls.

SUE Best Practices

NCDOT has two manuals that provide information and practices about SUE: The *NCDOT Highway Design Branch Policy and Procedure Manual* and the *NCDOT Highway Design Branch Design Manual* (*33*, *34*). In addition, NCDOT provides a general guideline on SUE and the activities included in data collection at a particular quality level (*35*). These documents have been useful for project managers that are new to the SUE process, and have helped to make information about best practice available to a wider audience within NCDOT.

NCDOT makes efforts to combine SUE data collection with environmental data collection. For example, Chapter 20 of the *NCDOT Highway Design Branch Policy and Procedure Manual* provides that the environmental planning document should discuss the magnitude and impact of utility conflicts (*33*). The inclusion of SUE data and identification of utility conflicts in the environmental planning document has been an accepted and useful practice in the past.

The NCDOT Utility Section has recognized the importance of including SUE activities early in the budgeting process so that funding for SUE is included on cost and budget for projects from the beginning, as compared to an add-on later in the project. By getting involved in the programming and budgeting process for projects, the NCDOT Utility Section has helped ensure that SUE is available early in the projects. NCDOT also emphasizes the importance of early involvement with utility companies. In NCDOT's experience, using SUE early in the project development process enables informed decisions about design and enables better design decisions earlier in the process.

NCDOT uses a project management system to improve utility coordination called Scheduling, Tracking, and Reporting System (STaRS) (*36*). The development of the system started in 2001, was implemented as "Project Management Improvement Initiative (PMii)" in 2004, and renamed to STaRS in 2007. STaRS is a centralized, integrated scheduling management tool that uses SAP R/3 software. STaRS provides a flowchart of production networks with activities and activity elements that help with utility coordination activities. For example, the system specifies for each project:

- When preliminary utility relocation plans are due.
- When NCDOT should review these plans.
- When these plans should be discussed with the utility owner.
- When utility relocation plans should be complete.
- When utility permit drawings should be submitted.

Issues with SUE Data

At NCDOT, public access to information about utility facility locations has become a recent issue, especially with telephone companies. NCDOT has found that telephone/communications companies do not want the location of their lines to be publicly available because of concerns about security and competitive advantage. Although NCDOT has exchanged views on the issues with affected companies, the issue has not been resolved.

Ohio Department of Transportation

General Utility Practices

The Ohio Department of Transportation (ODOT) uses SUE extensively in its project development process. ODOT also emphasizes the importance of adequate communication among all stakeholders involved in the project development process and more specifically the utility coordination and investigation processes.

ODOT has placed a high priority on improving the communication with various stakeholders (including utility owners) during the project development process and stresses the importance of stakeholders' active participation in its project development process. As part of this effort, ODOT identified several key concurrence points, which are pre-defined stages of the project development process where the process is put on hold until stakeholders are consulted on key aspects of the project, including utility owners who are involved in this process. Various conflicts, concerns, and issues are discussed and resolved at these stages amid input from these stakeholders. The project is put on hold until all issues are resolved at these concurrence meetings. Concurrence points exist during the utility coordination process to identify and tackle any utility conflicts identified during the SUE process. Figure 29 shows the ODOT project development process and the various concurrent points within the project development process.

Within the larger project development process, ODOT has a well-defined utility investigation process in which highway plans are provided to utility owners along with a request to review and provide pertinent as-built or other existing QLD utility information. The next point of concurrence in the process is a face-to-face meeting and preliminary discussion of potential utility conflicts with utility coordinators who represent districts on all utility investigation issues. The goal of the meeting is to ensure that there is a clear understanding of the potential for utility impacts, resolve conflicts as possible, and discuss the need for SUE at better quality levels.

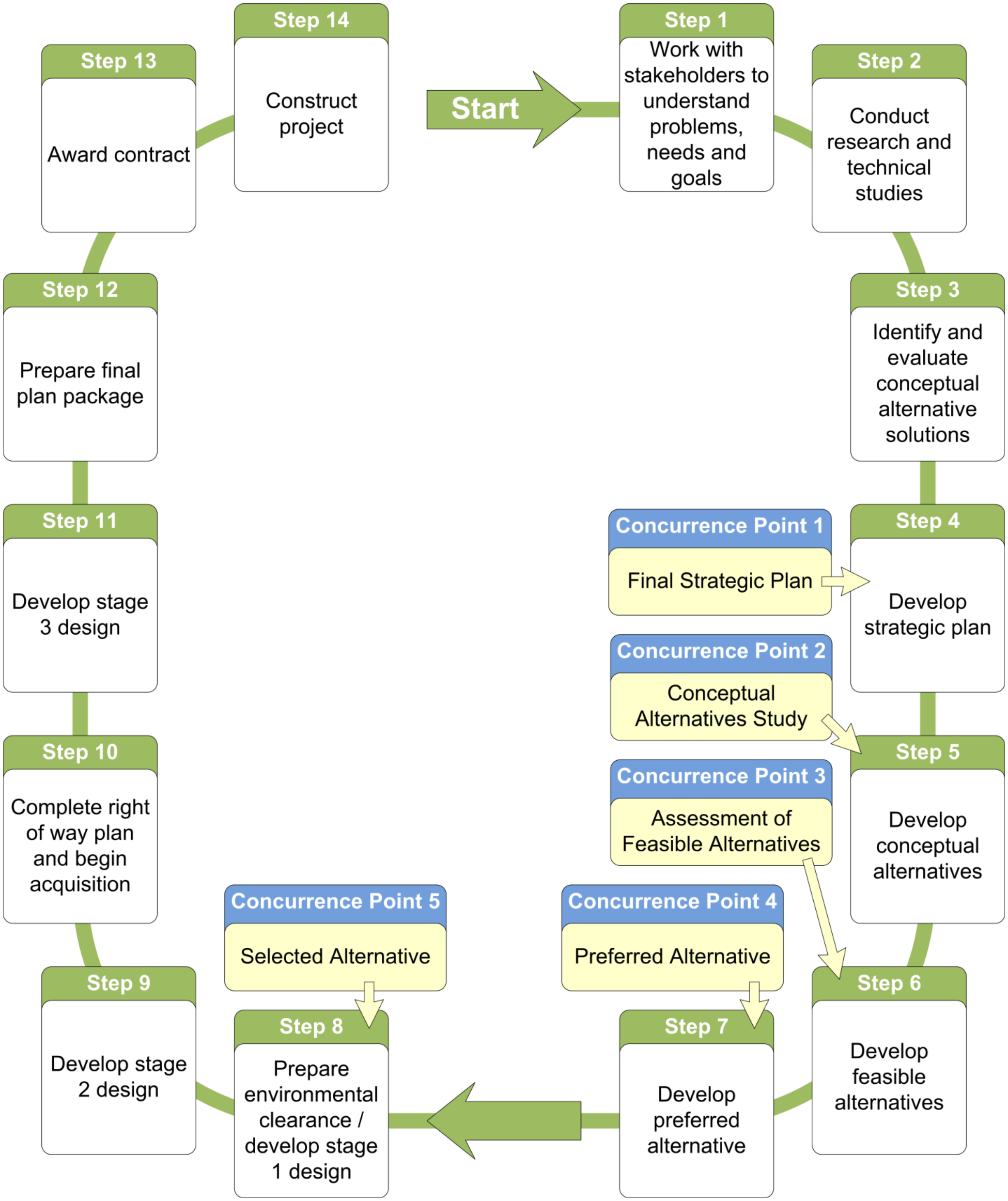


Figure 29. Ohio DOT Concurrence Points during the Project Development Process (Adapted from *37*).

As part of improving the utility investigation process and utility owner participation during this process, ODOT conducts training sessions for utility company staff. The training sessions allow utility company staff to become more familiar with the ODOT design and construction plans and their interpretation. This improved familiarity with ODOT design plans helps utility companies to mark the locations of their utility facilities accurately on ODOT plans, which in turn are used during SUE investigations and construction activities. This training has been of significant benefit in coordinating both utility investigation and relocation efforts.

To request QLB or QLA data collection, the district project engineer fills out a request form that includes information about the requested SUE quality level, utility impact rating, and project development phase. The form is submitted to the State Utilities, Relocations, and Permits Office for approval.

ODOT plans to implement a mechanism to help monitor change orders. This system will make it easier for the department to identify which entity is responsible for project delays. The goal is to ensure that the responsible party is held accountable for the resulting costs associated with these delays.

SUE Consultant Contracts and Requirements

Currently, ODOT has statewide contracts with four SUE providers, which are worth $1.5 million each for the duration of a biennium. The geographical locations of the SUE providers ensure that the entire state is easily accessible to the SUE consultants. A statewide contract is typically used when utilities are found during construction and a higher quality level SUE is immediately required. Every district is encouraged to use QLB and QLA data collection and has access to SUE providers for use in their project development process.

ODOT pays per foot to designate, per test hole to locate, and hourly labor and overheads. Basic deliverables for utility information are generally a CAD file, or a plan sheet that has utility information in plan view for QLA, QLB, QLC, and QLD, and in profile view for QLA. ODOT typically prefers to have the horizontal and vertical locations of mainline subsurface utilities and their associated attribute information collected and placed on construction plans to be utilized for design and utility coordination.

Ohio has strict pre-qualification requirements for all SUE consultants. Consultants must demonstrate that it has the staff, equipment, experience, and resources to perform SUE services at all quality levels, as follows (*38*):

- The consultant must have at least one professional engineer and one professional surveyor both registered in Ohio, that are employees of the firm, each with a minimum of two years' experience in subsurface utility engineering.
- A minimum of two additional full-time staff, each with a minimum of two years' experience in successfully providing all quality levels of subsurface utility engineering using the equipment specified in number 3 below.
- Equipment available to perform the full range of SUE services including one geophysical prospecting vehicle equipped with various electromagnetic/acoustical designating

equipment (QLB), and one vacuum excavation non-destructive vehicle (QLA), and at least one GPR system.
- The consultant must provide a single project manager to represent the firm in a liaison capacity with the department.
- Capability of providing both electronic and certified hard copy deliverables in acceptable ODOT electronic and plan presentation format.
- Documented company plan for current quality assurance and quality control procedures.

Identification of Major Issues in the Project Development Process

ODOT attempts to identify locations with major issues as early in the project development process as possible. These so-called red flag locations may have environmental, right-of-way, utility, or engineering issues that could cause revisions to the following (*37*):

- Anticipated environmental, design, and construction scope of work.
- Proposed project development schedule.
- Estimated project budget.
- Potential impacts of the project on the surrounding area.

Red flags do not identify issues in locations that must be avoided but rather locations that may require additional study coordination, creative management or design approaches, or increased right-of-way or construction costs. The project manager typically consults with the appropriate specialists to determine the level of concern for each red flag item. Locations that *must* be avoided are referred to as fatal flaws. A fatal flaw could involve significant economic, environmental, or historical impact in an area.

There are several ways to identify red flag locations. ODOT recommends that the first data source consulted should be a so-called secondary source, such as aerial mapping, existing right-of-way plans, original construction plans, historic geologic reports, Federal Emergency Management Agency (FEMA) flood plain study mapping, and United States Geological Survey (USGS) topographic mapping (*37*). The next level or source for red flag analysis is a site visit conducted during the planning phase. More in-depth analysis, requiring additional work such as borings or excavations, is typically conducted during later steps of the project development process (*37*).

Potential red flags include utility locations, existing structures, drainage problems, waterways, geotechnical issues, topography, and existing right-of-way and/or land use issues. Figure 30 shows an example of a red flag summary sheet for utility issues. Although a written red flag summary is required for both major and minor projects, it is optional for very small projects although red flag issues must still be identified. All projects require a field review. Each specialty area of the red flag summary is completed by individuals who possess sufficient experience to correctly identify and evaluate issues arising from the field review.

Red Flag Summary		
UTILITY ISSUES:		
Indicate if the following utility issues are present or should be considered during project development. Provide additional comments as needed.		
	Design Issue	**Comments**
☐Yes ☐ No ☐ Possible ☐ Not Applicable	Do existing utilities need to be relocated? *If so, please identify.*	
☐Yes ☐ No ☐ Possible ☐ Not Applicable	Is it impossible to minimize utility conflicts? (e.g., by careful placement of storm sewer and underdrains)?	
☐Yes ☐ No ☐ Possible ☐ Not Applicable	Would the project benefit from subsurface utility engineering (SUE)?	
☐Yes ☐ No ☐ Possible ☐ Not Applicable	Are there existing utilities on an existing structure that need to be relocated?	
☐Yes ☐ No ☐ Possible ☐ Not Applicable	Are there any specific utility requirements or concerns? *Specify.*	
☐Yes ☐ No ☐ Possible ☐ Not Applicable	Is additional right of way needed to accommodate utility relocations?	
☐Yes ☐ No ☐ Possible ☐ Not Applicable	Are there water or sanitary lines that will be relocated as part of the ODOT contract?	
☐Yes ☐ No ☐ Possible ☐ Not Applicable	Are there any other utility issues? *Specify.*	

Figure 30. Red Flag Summary for Utility Issues in Ohio (*37*).

Multilevel Memorandum of Understanding

ODOT is currently pursuing a new system of Memoranda of Understanding (MOUs) with utility companies. The idea is a multilevel MOU process that representatives of state DOTs and FHWA first identified on a recent international scan to Australia and other countries (*39*). While state DOTs in the United States have been using MOUs for some time, the ODOT example (adapted from the international scan recommendation) features a multilevel MOU initiative that identifies and recognizes the importance of good utility relocation practices to provide efficient and cost-effective highway project delivery for ODOT. This recognition begins at the highest levels of leadership of the department and the utility company, and ensures that utility work is performed in a manner that provides benefits to both the utility company and ODOT. The MOU initiative provides an opportunity for each agency to understand one another's concerns, and use the resolution of those concerns to save time, money, and resources for both parties.

The MOUs are created at various levels of operation between the parties. In the first level, the leadership of both agencies signs, and sets forth general principles and intent of parties to work together cooperatively. It also emphasizes identifying efforts that are created to address the needs of each party. In the second level MOU, middle management of both parties signs, and defines the roles and responsibilities of each as well as standards, specifications, and general procedures for conflict resolution. The third level MOU is project specific; project leaders from both parties sign this document. The content details specific provisions of the construction contract and utility relocation schedule. This overall effort fully integrates utility relocation activity into all aspects of operation for both the DOT and the utility company.

ODOT has a pilot initiative with three First Energy Company subsidiaries that serve Ohio to evaluate the potential for such a process to provide benefits to the companies and to ODOT. The goal is to reach agreement on working together to identify, prioritize, and resolve major issues for both parties and to document these issues and agreed outcomes in a leadership MOU. A steering committee consisting of key representatives from each agency oversees and directs the development of the MOU. The steering committee will appoint a working group of technical experts from each agency that will create a draft MOU that will be based on the items the steering committee identifies as being beneficial to the overall utility relocation process. Once the draft is completed, the steering committee will approve the document. ODOT's statewide utilities program manager and his counterpart from the utility company will be members of that working group (*37*). The working group will then identify and prioritize major issues that are impeding good working relationships. When all members of the working group and steering committee have discussed and resolved these issues through agreed outcomes, a meeting of high level officials from First Energy and ODOT will be convened. The chairperson of the steering committee will then present the issues and outcomes for senior management from both agencies to consider.

The steering committee will advance the draft MOU to top management for both agencies and recommend that the document be reviewed. A meeting of the top leadership will be scheduled so that, if adjustments are needed, these will be made during the meeting. The leaders of both agencies will then approve the draft MOU and authorize the steering committee to document such approval in an MOU that identifies the primary issues, agreed outcomes, implementation strategy, and benefits to be gained. The director of ODOT and the CEO of the utility company will then sign the MOU. While the MOU is not a legally binding document, its contents have cornerstones for utility relocation activity that will result in efficient and cost-effective activities, which will provide substantial benefits to both agencies and, ultimately, the public they both serve (*37*).

Once this top-level MOU is executed, planners will use a similar process to create a mid-level MOU that will define the roles and responsibilities of each agency as well as standards, specifications, and general procedures for conflict resolution. The steering committee will draft and approve this MOU, the contents of which will reflect the items contained in the leadership MOU but will be more specific to the needs of the three subsidiary companies. Both the top level and mid-level MOUs will be reviewed on an annual basis, and benefits associated with the performance of both parties on highway project delivery and effective utility relocation will be measured and evaluated (*37*).

The third MOU will be project specific. The leadership of the ODOT district in which the highway project is being built and the individual company subsidiary that will perform the relocation work will create and approve this document.

Pennsylvania Department of Transportation

General Utility Practices

The Pennsylvania DOT (PennDOT) adopted SUE practices in the 1990s. Nearly all projects in the state undergo a minimum of QLD or QLC data collection. Beyond QLD and QLC, the need for SUE is determined based on the outcome of an impact analysis using a spreadsheet called the "SUE Utility Impact Form." The Pennsylvania Transportation Institute of the Pennsylvania State University (PSU) developed this procedure in 2007 based on an in-depth benefit-cost analysis of 10 SUE projects that the PennDOT districts have executed (*40*). The PSU research shows that, compared to the projects not utilizing SUE, the total cost savings of SUE projects may range from 10–15 percent on a typical project. The study did not find any relationship neither between SUE benefit and SUE cost, nor between utility complexity level and the total project cost. However, there appeared to be a strong relationship between SUE benefit-cost and utility complexity level. The benefits and cost of SUE increases as the utility complexity level of the project increases. The conclusion in the research is that QLA and QLB should be used based on the complexity of the buried utilities at the construction site to minimize risks and obtain maximum benefits. The PSU study estimated that an average of $22.21 is saved for every $1.00 spent on SUE. When the overall cost of the project is taken into consideration, the money spent on SUE is minor compared to the cost savings of avoiding unexpected utility conflicts and unnecessary utility relocations.

Utility Impact Analysis

The SUE Utility Impact Rating Form is designed to recommend appropriate quality levels of SUE based on a utility impact score. The SUE Utility Impact Form was developed to address the legal requirements and comply with the state and federal laws (*41*). The SUE Utility Impact Form provides an analysis to determine if SUE use is practicable, when SUE should be considered on a project, and what utility quality levels should be utilized based on an analysis of project criteria. The form is utilized to provide compliance with the Pennsylvania "underground utility damage prevention law" (*42*). Utility impact rating refers to the utility complexity for a given project, section, or location.

The SUE Utility Impact Form involves three steps in which users answer a series of questions. Depending on the answers, a user might continue from one step to the next or might screen out of the process. Figure 31 through Figure 35 provide an overview of the spreadsheet, including form instructions and the list of questions for each step. If step 3 of the process is required, the form calculates a utility impact score (UIS) based on a series of so-called complexity factors that in combination provide an estimate of the project's complexity with regard to utilities. Answers can be provided on a range from 1 to 3 indicating the expected utility impact for that question (e.g., low to high, simple to complex, or good to fair.)

SUE Utility Impact Form Instructions
The SUE Utility Impact Form contains three steps of progressively detailed analysis. Steps 1 and 2 are screening processes, and Step 3 is an evaluation of the project passing Steps 1 and 2. Step 1 determines whether SUE QLB and/or QLA should be considered for a project. If Step 1 indicates further analysis is required, conduct Step 2. Step 2 looks at additional factors to determine whether SUE QLB and/or QLA should be considered for a project. If Step 2 indicates further analysis is required, conduct Step 3.
Step 1
Project information such as title, cost, description (general summary), and scope (actual work scope) should be filled out. If the scope of the project is changed, the utility impact rating analysis should be done again for that project. Step 1 determines whether SUE QLB and/or QLA should be considered for a project. The questions in Step 1 can be answered with traditional utility information QLD and/or QLC provided by a one-call system, utility companies, site visits, or a SUE provider. If there are no boxes checked in Column 2, then it is generally not cost-effective to perform a SUE QLB and/or QLA investigation. If any boxes in Column 2 are checked, the utility impact rating analysis proceeds to Step 2 to conduct further analysis of the project.
Step 2
Step 2 further analyzes and determines whether SUE QLB and/or QLA should be considered for a project by asking five additional questions. The questions can be answered with traditional utility information (QLD and/or QLC) provided by a one-call system, utility companies, site visits, or a SUE provider. If there are no boxes checked in Column 2, then it is generally not cost-effective to perform SUE QLB and/or QLA mapping. If any boxes in Column 2 are checked, the utility impact rating analysis proceeds to Step 3 to calculate a utility impact score and determine the appropriate SUE quality levels.
Step 3
Step 3 determines which SUE QLB or QLA should be selected for a project/section/location. Title, cost, description (general summary), and scope (actual work scope) should be filled out before answering the questions. The Step 3 questions are answered for a project, a section, or a location, while all questions in Step 1 and Step 2 are for a project. One project can have several sections or locations that have different utility impacts. Step 3 should be conducted for each section or location so that SUE quality levels can be selected for each section or location.

Figure 31. PennDOT SUE Impact Form Summary Instructions (*41*).

SUE UTILITY IMPACT FORM – STEP 1					
Steps 1&2 are screening processes and Step 3 is an evaluation of the project passing Steps 1&2. STEP 1 determines whether SUE (quality levels A & B) should be utilized for a project or not.					
MPMS Number/Title:					
County/SR/Section:					
No.	**QUESTIONS**	**Column 1**		**Column 2**	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)	○	**NO**	○	**YES or Unknown**
2	Does the project require any excavation "regardless of depth"? Note: This includes any temporary construction easements (TCE) or other easements.	○	**NO**	○	**YES or Unknown**
- For each question, check the box that best describes the project conditions. - If there are no boxes in Column 2 checked, then it is generally not practicable to perform a SUE quality levels A and B investigation. - If one or both boxes in Column 2 are checked, please proceed to STEP 2 to conduct further analysis.					

Figure 32. PennDOT SUE Impact Form Step 1 (*41*).

SUE UTILITY IMPACT FORM-STEP 2					
Steps 1&2 are screening processes and Step 3 is an evaluation of the project passing Steps 1&2.					
MPMS Number/Title:					
County/SR/Section:					
No.	**QUESTIONS**	**Column 1**		**Column 2**	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.	○	**≤ 18”**	○	**> 18”**
2	What is the confidence level that the utility owners in the project area will be able to accommodate the project’s schedule in regard to depicting their utility facilities on PennDOT plans?	○	**Confident**	○	**Doubtful**
3	What is the likelihood that project will have impact on the existing subsurface utilities?	○	**No Impact**	○	**Impact**
4	Do the utility owners in the project area have accurate utility information?	○	**Yes**	○	**No**
- If there are no boxes checked in Column 2, then it is generally not practicable to perform a SUE quality levels A and B investigation. **- If any boxes in Column 2 are checked, please proceed to STEP 3 to calculate utility impact score and determine the appropriate SUE quality levels.**					

Figure 33. PennDOT SUE Impact Form Step 2 (*41*).

SUE UTILITY IMPACT FORM – STEP 3 DETAILED ANALYSIS								
-Check the utility impact rating to the right that best fits your opinion of the issue. If the answer for the complexity factor is unknown, always check Column 3. -Refer to page 9 for a detailed description of the complexity factors. -When using an electronic version for the Step 3 analysis, place cursor over the cell on the spread sheet for a detailed description of the complexity factor.								
No.	**Complexity Factors**	**Column 1**		**Column 2**		**Column 3**		
1	Density of Utilities (number)	○	Low	○	Medium	○	High	
2	Type of Utilities	○	Less Critical	○	Sub Critical	○	Critical	
3	Pattern of Utilities (number)	○	Simple	○	Medium	○	Complex	
4	Material of Utilities	○	Rigid	○	Flexible	○	Brittle	
5	Access to Utilities	○	Easy	○	Medium	○	Restricted	
6	Age of Utilities (year)	○	New	○	Medium	○	Old	
7	Estimated Utility Relocation Costs (% of total project cost)	○	Low	○	Medium	○	High	
8	Estimated Project Traffic Volume (ADT per lane)	○	Low	○	Moderate	○	High	
9	Project Time Sensitivity	○	Low	○	Medium	○	High	
10	Project Area Description	○	Rural	○	Suburban	○	Urban	
11	Type of Project/Section/Location	○	Simple	○	Moderate	○	Complicated	
12	Quality of Utility Record	○	Good	○	Fair	○	Poor	
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)	○	Low	○	Medium	○	High	
14	Estimated Business Impact	○	Low	○	Moderate	○	High	
15	Estimated Environmental Impact	○	Low	○	Moderate	○	High	
16	Estimated Safety Impact	○	Low	○	Moderate	○	High	
17	Other Impact-Specify:	○	Low	○	Moderate	○	High	

Figure 34. PennDOT SUE Impact Form Step 3, Detailed Analysis (*41*).

SUE UTILITY IMPACT FORM – STEP 3 SUMMARY ANALYSIS

*STEP 3 determines which SUE quality level should be selected for a project/section/location. *NOTE-step 3 analysis can be conducted at the project level, or for a specific location within the project (e.g., intersection, utility crossing, etc.). Conduct Step 3 detailed analysis as necessary for each potential impact location.*

MPMS Number/Title:	
County/SR/Section:	
SUE Impact Location*- Description & Scope: ***(leave blank when using step 3 for overall project level impact analysis)***	

STEP 3 UTILITY IMPACT SCORE RESULTS		
Utility Impact Score:	**Recommended SUE Quality Level:**	**Relative Cost Factor:**

UTILITY IMPACT SCORE CALCULATION DESCRIPTION			
1: Total Box Checked	Sum of Column 1	Sum of Column 2	Sum of Column 3
2: Utility Impact Score	[(1 x Sum of Column 1) + (2 x Sum of Column 2) + (3 x Sum of Column 3)] / *n*		

This Table demonstrates the process for calculating the utility impact score based on response.
n = Number of the complexity factors considered/checked

UTILITY IMPACT SCORING LEVELS AND FACTORS

This table demonstrates the project complexity level, recommended SUE level to be used and relative cost of using SUE quality level, and project risk level based on the utility impact score.

Utility Impact Score	1.01-1.67	1.68-2.33	2.34-3.00
Recommended Minimum SUE Quality Levels	QLB	QLB/A	QLA
Relative Cost Factors	16.67	33.33	66.67

Figure 35. PennDOT SUE Impact Form Step 3, Summary Analysis (*41*).

The utility impact score is calculated by weighing the frequency of each type of answer using the following equation:

$$UIS = \frac{(L \cdot 1 + M \cdot 2 + H \cdot 3)}{n}$$

where

L = Number of low responses.
M = Number of medium responses.
H = Number of high responses.
n = Number of responses.

Note that this equation is very similar to the equation that GDOT used to determine the utility impact score. Depending on this score, the form provides a recommended minimum SUE quality level and a corresponding relative cost factor (Table 6). The cost factors describe the relative cost of a SUE unit price at a particular quality level. For example using QLA is about four times the cost of using QLB per unit (*40*).

Table 6. PennDOT Utility Impact Score (*41*).

Utility Impact Score	Recommended Minimum SUE QL	Relative Cost Factors
1.01–1.67	QLB	16.67
1.68–2.33	QLB/QLA	33.33
2.33–3.00	QLA	66.67

Note that PennDOT uses the utility impact score to determine a recommended level of SUE as compared to GDOT, which uses the utility impact score to describe the estimated impact of utilities on a project (see Table 5). Project managers use the PennDOT SUE Utility Impact Form in coordination with the District Utility Relocation Unit, as soon as QLD and QLC information is available. Since QLD and/or QLC data are necessary to begin the SUE Utility Impact Rating process, the project manager must put obtaining these data on a critical path. The project manager may elect to use the district utility unit, a consultant, or a SUE provider to obtain and depict these data as outlined in ASCE 38-02 (*4*). The form is typically completed during the planning and preliminary engineering phase of a project. At this time, the form provides the greatest benefit and provides input for good decisions regarding line and grade that could help avoid costly or time consuming utility relocations.

The project manager makes the final decision to conduct SUE QLB and/or QLA at the district level. However, Section 6.1 of Pennsylvania Act 287 requires that sufficient quality levels of SUE must be used on all projects greater than $400,000 (*42*). Specifically, the law requires the following:

> It shall be the duty of each project owner who engages in excavation or demolition work to be done within this Commonwealth…to utilize sufficient quality levels of subsurface utility engineering or other similar

> techniques whenever practicable to properly determine the existence and positions of underground facilities when designing known complex projects having an estimated cost of $400,000.00 or more.

Each DOT district procures their own SUE contractors, who are frequently subcontractors to the design firm. SUE contractors are procured through bids responding to a request for proposal and contractors are selected based on qualifications. The most common techniques, or technologies used to perform utility investigations is potholing and some limited use of geophysical techniques.

Utility Relocation – Electronic Document Management System

A notable practice at PennDOT is the use of a web-based electronic document management system called Utility Relocation Electronic Document Management System (UREDMS) (*43*). The system is designed to work with utility relocation documents using IBM® FileNet® software. UREDMS functions largely as an electronic filing cabinet. The electronic storage and indexing of these documents allows for easier search and retrieval, faster document transfer, better revision control, and saves storage space. It also eliminates lost and misplaced files. The UREDMS external web interface provides PennDOT's business partners with the ability to securely submit and view utility relocation documents using the Internet.

Virginia Department of Transportation

General Utility Practices

The Virginia Department of Transportation (VDOT) contacts utility owners during the design phase of a project where major relocations are anticipated. This allows designers to understand relocation needs and to identify major right-of-way corridor requirements for anticipated relocations. This process has worked particularly well for major power transmission and petroleum pipeline relocations. For smaller projects involving only a few utilities, VDOT has had only limited success involving utilities early. VDOT also negotiates and obtains any required utility easements outside the right-of-way directly with the land owners in conjunction with proposed highway projects.

VDOT uses several processes to ensure that horizontal locations of utility facilities are included in the project plans. For example, when the scope of work for mapping services is prepared and procured, VDOT includes requirements that the mapping contractor identify utilities not typically marked by utility owners or their one-call contractors. Additionally, the data collection is timed to correspond with project needs so that the mapping services and utility location data are available to the design team when needed, and not as a supplemental request for more detail. Designers and planners have the data needed to make design decisions without waiting for or requesting more detail. VDOT includes protection clauses against errors or omissions in the utility mapping data within the scopes of work and mapping services contracts. The survey data and CAD mapping comply with established standards and VDOT provides utility owners and consultants with licenses for their project CAD platforms to ensure the data are provided efficiently.

VDOT construction contractors must use the one-call system for damage prevention purposes. This is an important state-mandated process that provides utility owners a final opportunity to protect their facilities and identify utility changes and additions within project limits after design is complete but before construction begins.

SUE Contracts

VDOT was one of the first DOTs to use SUE and has a long history of using SUE services and consultants. VDOT has established regional contracts for SUE contractors. The SUE contracts include regional topographical survey contracts as well as horizontal utility mapping. This enables VDOT to move its collection of utility data into the planning stages of the project and to start using that data early for planning and preliminary design decisions. The regional SUE contracts are also used for conflict verification through physical exposure (test holes), which takes the burden of identifying the utility from the utility owners and places it with the SUE contractor. Utility owners are still included in correspondence and meetings and can take control of aspects of these services when they desire. In this way, VDOT projects are not delayed by waiting for utility owners to provide location information.

Right of Way Utilities Management System

The VDOT Right of Way and Utilities Management System (RUMS) is a system that was implemented in 1999 and is based on proprietary software that VDOT developed (*44*). RUMS provides up-to-the-minute highway project status reports through ad hoc queries served over a secure intranet. RUMS also enables forms processing and web-based reporting. VDOT also developed a web-enabled version of RUMS that has an intuitive user interface simple enough for a new user to quickly become familiar with the system and powerful enough for an advanced user to quickly navigate to specific information. Key functions of RUMS include the following (*44*):

- Providing metrics of current highway project status.
- Centralized management of appraisal forms, letters of correspondence, and other documentation, which allows right-of-way and utilities staff to generate, customize, store, and retrieve documents.
- Automated assignment and reassignment of work to division agents.
- Interfacing with VDOT's mission-critical project and program management system.

In addition to utility management functions such as easements and utility adjustments, RUMS helps manage right-of-way functions including appraisal, acquisition, improvement removal, relocation, legal, and donation. RUMS also assists in assignment tracking (assignee, due, and complete dates), contract management (contracts, task orders, and subcontractors), and property management (sale, lease, property grouping, and historical tracking). More importantly, RUMS allows VDOT management to focus on key highway project dates and shift resources to ensure that right-of-way and utility activities are completed in time.

Utility Investigations in the Project Development Process

VDOT integrates utility investigation within its entire project development process. The VDOT project development process is referred to as the Project Development Concurrent Engineering Process (PDCE) (*45*). Two excerpts from the PDCE process screenshots are shown in Figure 36 and Figure 37. Figure 36 is a high-level display of the PDCE process showing that utility assessments are conducted concurrent preliminary design tasks and environmental documentation efforts.

The PDCE process provides an example of how SUE can be integrated with project development early and throughout the process, as compared to an add-on used on an ad-hoc basis. The PDCE is mapped in a process flow chart to show all major steps in the process. The PDCE process chart shows when and how SUE should be used during project development, and provides links to documents and forms that are required. The PDCE process is well documented and supported through the RUMS managements system and its process manuals. Forms that the project manager or staff must complete are kept within RUMS so that current project information can be easily obtained. Figure 37 displays a close-up of the PDCE process indicating that utility designation and utility impacts are conducted concurrent with hydraulic studies and environmental functions.

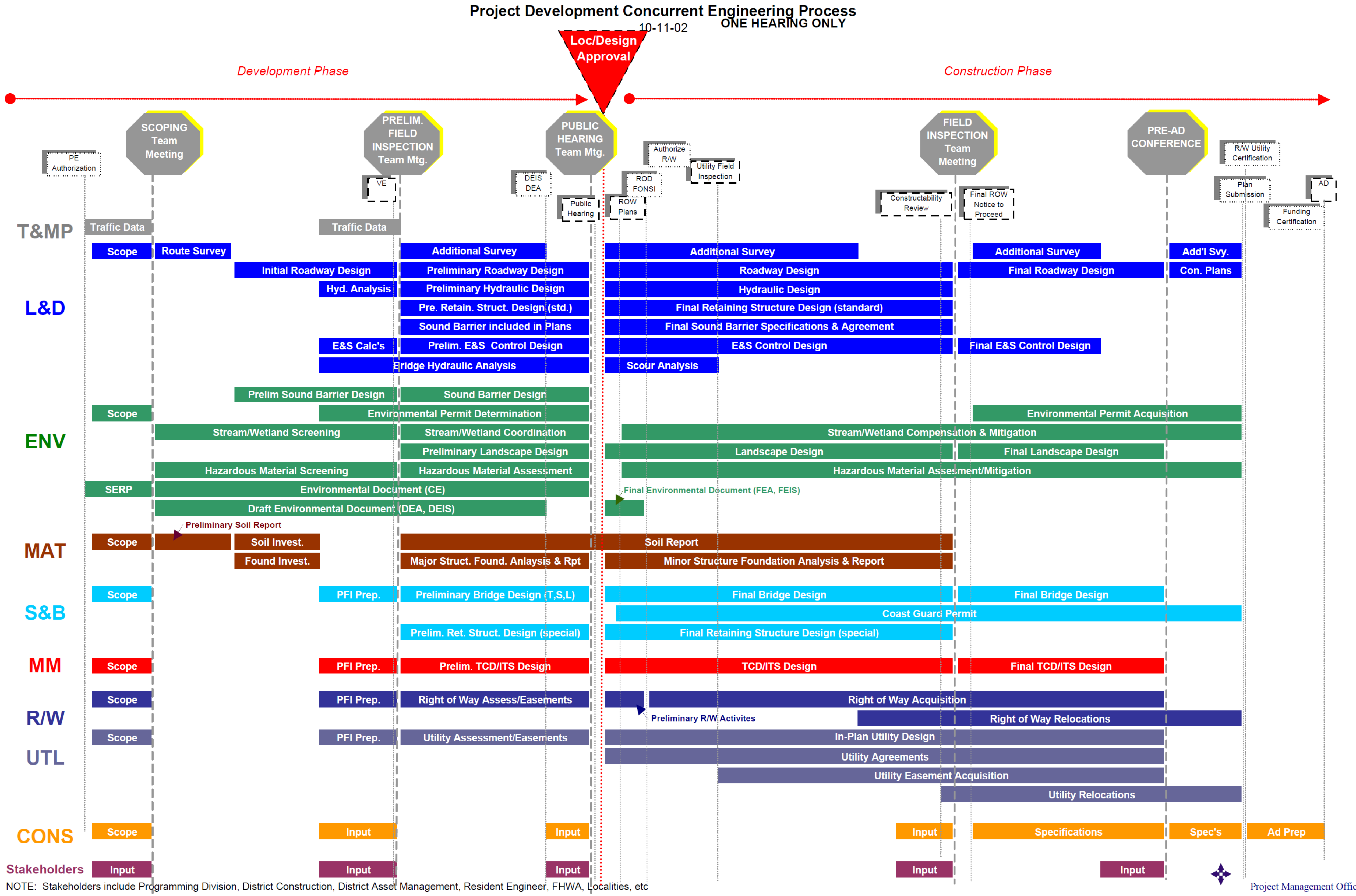


Figure 36. Overview of Project Development Concurrent Engineering Process (45).

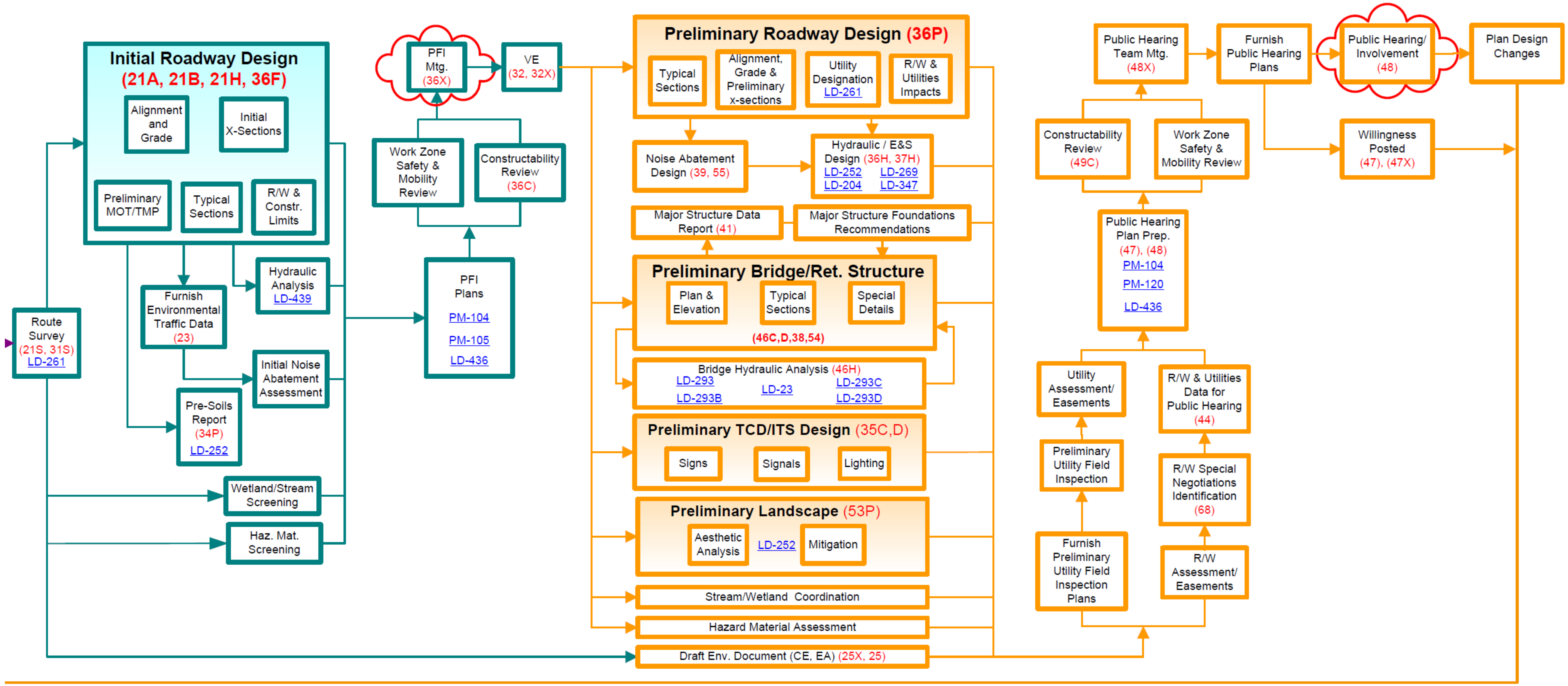


Figure 37. VDOT Project Development Concurrent Engineering Process: Initial and Preliminary Roadway Design (*46*).

During the preliminary project development phase, there are two critical forms that VDOT uses for almost all projects, as described in the VDOT *Road Design Manual* (*47*). These forms are the VDOT Field Review and Scoping Report, and the VDOT Risk Management Form (*48*, *49*). The Field Review and Scoping Report is a 10-page document to help a team of project specialists collect comprehensive project information including a determination if the project has any potential utility or environmental impacts and if an engineering field office is warranted. With regard to utilities, the project engineer must determine the following:

- Who is the responsible party in the field review team for the location and design of utilities?
- Should utilities be designated?
- Are major utility conflicts or problems anticipated?
- Are utilities present that may be attached to bridges?
- What is the estimated cost for right-of-way including utility relocations?
- What are the names of the utility owners within project limits?

The VDOT Risk Management Form provides a chart to evaluate risks for risk events identified on projects (Figure 38). The form provides several methods that can be selected to respond to a risk, including avoidance, transference, enhancement, acceptance, and mitigation. The form also provides a field for the name of the risk owner or responsible person to manage the risk.

To determine the risk response method, a project manager must provide a description of the risk event, the significance of its impact on the project, and the probability of this impact. Impact must be rated from 1 to 5 (low to high) and probability must be rated from 0 percent to 100 percent (uncertain to certain). Using the chart provided in Figure 38, the program manager can then determine the risk exposure. Risk exposure can also be calculated using the following formula:

$$RE = p \cdot i$$

where

RE = Risk exposure.
p = Probability of a risk event.
i = Impact of a risk event.

A risk exposure of 0.5 or lower is considered a low risk and does not require a risk response (green area in Figure 38). A risk exposure of higher than 0.5 and up to 2.5 is considered a medium risk and must be addressed using a risk response method and risk response action. A risk exposure of higher than 2.5 is considered a high risk and must also be addressed using a risk response method and action.

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~~PMO Form 3~~

Risk Management

PROJECT UPC	PROJECT NUMBER	PREPARED BY	DATE PREPARED

Risk Event
Description:

Significance of Project Impact:

Probability of Project Impact:

Risk Response Method

☐ Avoidance

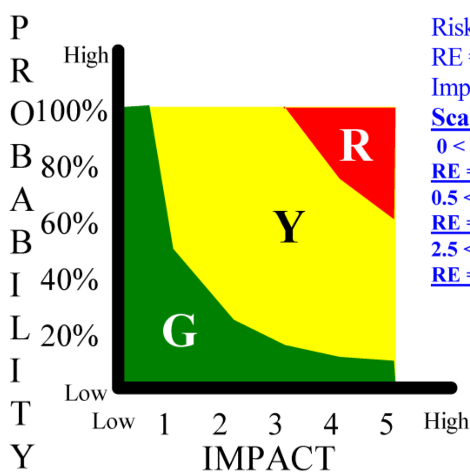
☐ Transference

☐ Enhancement

☐ Acceptance

☐ Mitigation

Evaluation Chart



Risk Exposure = RE
RE = Probability * Impact
Scale
0 < RE ≤ 0.5:
RE = Green, else
0.5 < RE ≤ 2.5:
RE = Yellow, else
2.5 < RE ≤ 5.0:
RE = Red

Probability: __% (x) Impact: 0.0 = Risk Exposure: 0.0

Estimated Cost of Risk Event

$

Additive to Contingency (Estimated Cost * Probability)

$

Risk Response Action

Assumptions

Risk Owner
Name Function/Organization
Phone Number E-mail

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Figure 38. VDOT Risk Management Form (*49*).

Virginia Utilities Coordinating Committee

The Virginia Utilities Coordinating Committee (VUCC) provides an inexpensive and informal forum to improve communication, cooperation, and coordination among utilities and others with whom they interact (*50*). The VUCC is organized as a two-tier committee with one committee for state and national issues, and another for local issues. The VUCC is an example of how utility coordination can be accomplished among different utility stakeholders including private commercial utility interests such as electric cooperatives, communication providers, natural gas operators, as well as VDOT and local governments. The major goals of the VUCC are (*50*):

- Improve communication and exchange information among all responsible parties, trade professional associations, and the general public.
- Minimize damage to utility and street structures.
- Coordinate scheduling of capital improvement and maintenance projects.
- Improve safety conditions.
- Develop suggested standards for accommodating utilities with common corridors.
- Be a liaison network hub for members and potential members for this committee and regional and local committees by exchanging information.

The VUCC has created statewide committees that work with independent local utility coordinating committees (UCC) to focus on statewide issues. Local problems and issues have been shared with other local UCCs and the state steering committee. In turn, statewide and national issues have been communicated back to local UCC and member groups. Members of the VUCC have established an electronic notification system and created an ID tagging system.

CHAPTER 5: EFFECTS OF UTILITY INVESTIGATION SERVICES

The research team collected and reviewed data from a number of TxDOT projects to examine the effects of utility investigation services on project costs, project efficiencies, and project delivery time. This chapter summarizes the results of that effort.

LITERATURE REVIEW OF UTILITY INVESTIGATION BENEFITS

The benefits and cost-effectiveness of using utility investigation services to collect data of existing utility facilities have been documented in several studies. The Pennsylvania Department of Transportation (PennDOT) funded a study between 2006 and 2007 that quantified the cost-benefit ratio of using SUE in highway projects (*40*). Based on data of 10 projects that used SUE, the researchers identified saving of $22.21 for every dollar spent on SUE. They also found a relationship between SUE benefit-cost ratio and the complexity of buried utility facilities at project sites. The study took into consideration the following cost/saving items:

- Utility relocation cost, which is the cost caused by unnecessary utility relocations and by unidentified utility conflicts due to inaccurate/insufficient utility data. SUE reports and interviews were used to estimate this cost item.

- Utility damage cost, which includes person injury costs, equipment damage costs, and third-party damage costs. This cost was estimated based on interviews and historical data.

- Emergency restoration cost, which includes utility restoration costs and project delay costs due to unexpected utility damages. Interviews and historical data were used to estimate this cost item.

- Traffic delay cost, which is the cost for road users due to increased travel delays caused by project delays as a result of utility emergencies. This cost was estimated based on interviews and sample projects that did not use SUE.

- Business impact cost, which is the cost incurred by business enterprises resulting from loss of business activities due to unexpected utility damages. This cost was estimated based on interviews and sample projects that did not use SUE.

- User service cost, which is the monetary value for users' inconveniences incurred by loss/delay of utility services due to utility damages. This cost was estimated based on interviews, historical data, and projects without SUE.

- Environmental impact cost, which is the cost to restore/remediate the environmental damages caused by utility damages. This cost was estimated based on projects that did not use SUE.

- Information gathering and verification cost, which is the additional cost for gathering and verifying utility information if SUE was not used. This cost item was estimated based on interviews and projects that did not use SUE.

- Legal and litigation cost, which is the cost on negotiation, arbitration, legal and litigation process to resolve disputes due to utility damages. This cost item was estimated based on interviews and sample projects that did not use SUE.

- Additional design costs due to insufficient/inaccurate utility data. SUE reports and interviews were used to estimate this cost item.

- Other utility related costs and benefits, such as savings in risk management and insurance, digital mapping accuracy, and comprehensive utility management systems estimated based on interviews.

Purdue University published a study of SUE cost-effectiveness in 1999 that FHWA had funded (*51*). The study found a total of $4.62 in savings for every dollar spent on SUE based on data of 71 projects from Virginia, North Carolina, Texas, and Ohio. A later reevaluation of the collected project data suggested a more significant return of $12.23 in average for each dollar spent on SUE (*52*). For both studies, the research team obtained the total cost for utility investigation services (i.e., costs of designation and locating), which was compared against potential time, cost, and/or user savings that were attributable to the use of SUE, such as:

- Reduction in the number of utility line relocations.
- Reduction in project delay due to utility relocations.
- Reduction in construction delay due to utility cuts
- Reduction in contractor's claims and change orders.
- Reduction in project contingency fees.
- Lower project bids.
- Reduction in costs caused by conflict redesign.
- Reduction in travel delays to the motoring public.
- Reduction in the cost of project design.
- Improvement in contractor productivity and quality.
- Reduction in utility owners' costs to repair damaged facilities.
- Minimization of utility customer's loss of service.
- Minimization of damage to existing pavements.
- Minimization of traffic disruption and increase in DOT public credibility.
- Improvement in working relationships between DOT and utility owners.
- Increase in efficiency of surveying activities by elimination of duplicate surveys.
- Improvements in electronic map accuracy and as-builts.
- Inducement of savings in risk management and insurance.
- Introduction of the concept of a comprehensive SUE process.
- Reduction in right-of-way acquisition costs.
- Reduction in probability of environmental damage.
- Reduction in damage to existing site facilities.

Many of the aforementioned potential savings were qualitative costs and could not be estimated with any degree of certainty. The researchers estimated the remaining saving items based on existing project data, interviews with personnel involved in the projects, and historical cost data.

In 2005, the Ontario Sewer and Watermain Contractors Association commissioned a study to investigate the cost-effectiveness of SUE on large infrastructure projects in Ontario (*53*). The researchers conducted nine case studies with projects generally characterized by having a value greater than \$500,000, being located in urban settings, and having a large number of buried infrastructure systems. The case studies included interviews with project owners and contractors, studies of project drawings, and comparisons of utility information before and after SUE. Based on the information, what-if scenarios were used to estimate the costs that could have been incurred if the SUE investigations had not been employed. During the cost-benefit assessment, the Ontario study calculated the average return on investment (ROI) as follows:

$$Average\ ROI = \frac{SUE\ benefit}{Cost\ of\ performing\ SUE}$$

Where

$$SUE\ benefit\ = Estimated\ project\ cost\ if\ SUE\ was\ not\ used - Actual\ project\ cost$$

The estimated cost of not performing SUE was calculated based on a summation of the estimated amounts of 13 cost items shown in Table 7. The case studies suggested an average return on investment of approximately \$3.41 for each \$1 spent on SUE.

Based on the literature review, the use of SUE in transportation projects is estimated to yield noteworthy benefits. The estimated benefits by the studies reviewed ranged from \$3.41 to \$22.21 per \$1 spent on SUE services, suggesting a significant return in benefit. Readers should note that most of the previous SUE cost-effectiveness studies relied on information obtained during interviews with personnel involved in the studied projects. The data collected in this manner is inevitably subjective and results can vary significantly, depending on personal opinions and biases of the interviewees. In addition, the studies made multiple assumptions about the cost items, many of which could not be accurately measured. The significant difference between estimated ROI in the studies reviewed is therefore not unexpected. In addition, most of the studies reviewed were based on information of a limited number of projects (e.g., 10 projects in the PennDOT study and nine projects in the Ontario study), limiting the statistical significance of the findings.

Table 7. Descriptions of Cost Items Considered in the Ontario Study.

Abbr.	Cost	Description
Costs that contribute towards increasing the quality of utility information (alternatives to SUE)		
UIC	Utility information cost	The cost and time that the designer or owner would spend to gather information from different utilities and possibly do any field stakeouts using their own crews or by hiring subcontractors.
UVC	Utility verification cost	The cost that the contractor must pay to verify the location of plant (by vacuum excavating, locating, etc.). This cost gets included in the bid price.
Costs directly incurred by the designer/owner		
URC	Utility relocation cost	
DSC	Design cost	When SUE is utilized in the early stages of a project, designers can proceed with more confidence, and the chance for project redesigns due to utility conflicts is greatly reduced.
OCC	Overall construction cost	Information revealed by SUE will sometimes lead to a more efficient design that will decrease overall construction costs.
Costs directly incurred by the contractor		
CCC	Contractor contingency costs	In cases where the SUE information is clearly shown in tender documents, there exists a potential for reduction in contractor bid contingencies due to confidence in subsurface utility information. In some cases, there exists a potential for increased excavation productivity rates, which can result in shortened project durations.
CCO	Contractor claims and change order costs	
CIC	Contractor injury cost	The cost of injuries to contractor staff due to damaging existing utilities. CIC is estimated as $P(CIC)*CIC_{AV}$, where P(CIC) is the probability that a contractor injury occurs due to a hit utility and CIC_{AV} is the average cost of contractor injury due to a hit utility.
Costs directly incurred by users/public		
UDC	Utility damage cost	The cost of damage to existing utilities during construction.
PIC	Public injury cost	The cost of injuries to the public due to damaging existing utilities. PIC is estimated as $P(PIC) * PIC_{AV}$, where P(PIC) is the probability that a public injury occurs due to a hit utility and PIC_{AV} is the average cost of a public injury due to a hit utility.
TDC	Travel delay cost	The cost of travel delays to the motoring public (function of the amount of project delay).
BIC	Business impact cost	The cost of impact on businesses (function of the amount of project delay).
SIC	Service interruption cost	The cost of loss of service to utility customers.

METHODOLOGY

The purpose of this analysis was to collect and review data from a number of TxDOT projects to examine the effects of utility investigation services on project costs, project efficiencies, and project delivery time. During the literature review, the researchers identified several previous studies that involved relatively comprehensive analyses of the cost-benefit of using SUE services in transportation projects. Most of these studies were based on data obtained from states other than Texas, except for the national study that Purdue University conducted in 1999, and relied heavily on estimates from practitioners and project managers. To avoid bias due to personal, subjective estimates, the analysis only used project data obtained through a variety of TxDOT data systems.

To accomplish this objective, the research team developed a large variety of measures of effectiveness (MOEs) and used these MOEs to compare projects that used SUE services and projects that did not use SUE services. Through the comparison, the research team attempted to examine the effects of SUE services on various aspects of project cost and project delivery time. As shown in Figure 39, the researchers developed a road map that visualizes goals, potential MOEs, and required data items to evaluate the effects of SUE on project performance.

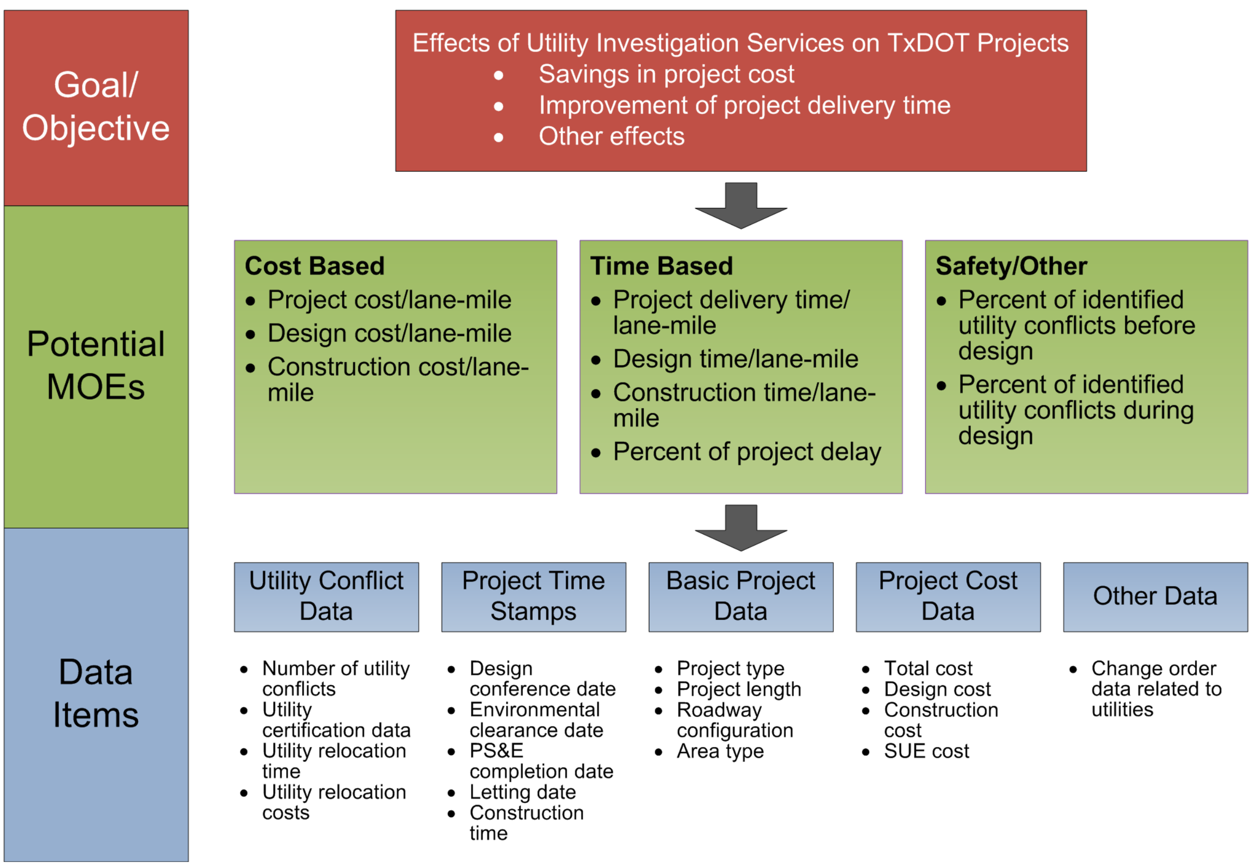


Figure 39. Methodology for Assessing Effects of Utility Investigation Services.

Based on the availability of data, the researchers proposed to calculate several potential MOEs to assess the effect of utility investigation services on TxDOT projects. The MOEs included:

- Project cost per lane-mile, which is the total project cost divided by the total lane-miles of the project.
- Design cost per lane-mile, which is the design cost of a project divided by its total lane-miles.
- Construction cost per lane-mile, which is the total construction cost of a project divided by the total lane-miles of the project.
- Project delivery time per lane-mile, which is the total project delivery time defined as the time from the design conference to the completion of construction divided by the total lane-miles of the project.
- Design time per lane-mile, which is the total design time divided by total lane-miles of the project.
- Percent of identified utility conflicts prior and during design, which is the number of identified utility conflicts prior and during design divided by the total number of utility conflicts.
- Number of utility accidents during construction per lane-mile, which is the number of events where unknown utilities been damaged when constructing a project divided by the total lane-miles of the project.
- Number of utility-related change orders per lane-mile, which is the total number of utility-related change orders divided by the project lane-miles.
- Percent of utility-related change order cost, which is the total cost associated with the utility-related change orders divided by the total project cost.
- Percent of project delay, which is the time difference between the proposed project delivery time (the time from the design conference to the completion of construction) and the actual delivery time divided by the proposed project delivery time.

The research team also identified a number of data items that would be required to calculate the aforementioned MOEs, and potential sources of the data within TxDOT data systems:

- **Utility Relocation Data.** Utility relocation data are necessary for calculating the percent of identified utility conflicts prior and during design. More specifically, utility relocation data include the data items total number of utility conflicts, number of identified utility conflicts, and number of utility relocations after design. Potential sources for this data item include the TxDOT Utility Agreement Database, the Utility Installation Review System (UIR), and project utility clearance certifications.

- **Project Time Stamps.** This data item is used to calculate MOEs such as project delivery time per lane-mile, design time per lane-mile, construction time per lane-mile, and percent of project delay. Necessary data elements include the design conference date, the environmental clearance date, the PS&E completion date, the project letting date, and the construction completion date. Potential data source of these data elements include the Design and Construction Information System (DCIS) and the Contract Information System (CIS).

- **Basic Project Data.** This data item is required to group projects into similar categories (stratification). In addition, the lane-mile information is necessary for calculating several MOEs. Basic project data includes data items such as project type, project lane-miles, roadway classification, and area type. DCIS was a potential source for this data.

- **Project Cost Data.** This data item is necessary for calculating several MOEs such as total project cost per lane-mile, design cost per lane-mile, and construction cost per lane-mile. Project cost data includes the data items total project cost, design cost, construction cost, and SUE cost. Potential sources of cost information are data sources such as DCIS, FIMS, and CIS.

- **Other Data.** Other data items include change orders related to utilities and number of utility emergency repairs during construction. These data items are needed to calculate MOEs such as utility accidents during construction per lane-mile, number of utility-related change orders per lane-mile, and percent of utility-related change order cost. The potential data sources include UIR and SiteManager.

Based on the experience of the research team with TxDOT database systems, the research team created a list of potential data sources to obtain a variety of data elements. Table 8 lists the data elements and potential sources the research team proposed.

Table 8. Potential Data Sources for Data Items.

Potential Data Source	Data Type	Data Element
Bid Analysis Management System (BAMS)	Project Time Stamps	Construction completion date
	Project Cost Data	Construction cost
		SUE cost
Contract Information System (CIS)	Project Time Stamps	Construction completion date
Construction/Maintenance Contract System (CMCS)	Utility Relocation Data	Number of utility conflicts identified during construction
		Number of utility conflicts cleared before letting
		Number of utility conflicts not cleared before letting
		Number of utility relocations before letting
		Number of utility relocations after letting
	Project Time Stamps	Letting date
		Construction completion date
	Basic Project Data	Project type
		Project lane-miles
		Roadway class

Table 8. Potential Data Sources for Data Items (Continued).

Potential Data Source	Data Type	Data Element
Construction/Maintenance Contract System (CMCS)	Project Cost Data	Project total cost
		SUE cost
	Other Data	Change orders related to utilities
Design and Construction Information System (DCIS)	Project Time Stamps	Design conference date
		Letting date
	Basic Project Data	Project type
		Project lane-miles
		Roadway class
		Area type
	Project Cost Data	Project total cost
		Design cost
Environmental Tracking System (ETS)	Utility Relocation Data	Number of utility conflicts cleared before letting
		Number of utility conflicts not cleared before letting
		Number of utility relocations before letting
	Project Time Stamps	Environmental clearance date
		Letting date
	Basic Project Data	Project type
		Project lane-miles
		Roadway class
	Other Data	Change orders related to utilities
Financial Information Management System (FIMS)	Project Cost Data	Project total cost
		Design cost
		Construction cost
		SUE cost
Plans Online	Utility Relocation Data (through Utility clearance certifications)	Number of utility conflicts not cleared before letting
		Number of utility relocations after letting
	Project Time Stamps	Letting date
	Basic Project Data	Project type
		Project lane-miles
		Roadway class

Table 8. Potential Data Sources for Data Items (Continued).

Potential Data Source	Data Type	Data Element
Plans Online	Other Data	Project description
Right of Way Information System (ROWIS)	Utility Relocation Data	Number of utility conflicts identified during construction
		Number of utility conflicts cleared before letting
		Number of utility relocations before letting
		Number of utility relocations after letting
	Project Time Stamps	Environmental clearance date
		Letting date
	Basic Project Data	Project type
		Project lane-miles
		Roadway class
	Project Cost Data	Project total cost
		SUE cost
	Other Data	Estimated right-of-way clearance date
		Estimated acquisition costs
SiteManager Change Order Database(COD)	Utility Relocation Data	Number of utility conflicts identified during construction
		Number of utility conflicts not cleared before letting
		Number of utility relocations after letting
	Project Time Stamps	Construction completion date
	Basic Project Data	Project type
		Project lane-miles
		Roadway class
	Project Cost Data	Project total cost
		Construction cost
		SUE cost
	Other Data	Change orders related to utilities
Utility Agreement Database (UAD)	Utility Relocation Data	Number of utility conflicts identified during construction
		Number of utility conflicts cleared before letting
		Number of utility conflicts not cleared before letting
		Number of utility relocations before letting

Table 8. Potential Data Sources for Data Items (Continued).

Potential Data Source	Data Type	Data Element
Utility Agreement Database (UAD)	Utility Relocation Data	Number of utility relocations after letting
	Project Time Stamps	Letting date
	Basic Project Data	Project type
		Project lane-miles
		Roadway class
	Project Cost Data	SUE cost
	Other Data	Utility adjustment cost
Utility Installation Review System (UIR)	Utility Relocation Data	Number of utility conflicts identified during construction
		Number of utility conflicts cleared before letting
		Number of utility conflicts not cleared before letting
		Number of utility relocations before letting
		Number of utility relocations after letting
District databases	Data not available at other data systems	Data not available at other data systems
Project documents	Data not available at other data systems	Data not available at other data systems
Project-specific spreadsheets	Data not available at other data systems	Data not available at other data systems

The research team proposed a comparison of MOEs between three general groups of projects: projects that used SUE before construction, projects that used SUE during construction, and projects that did not use SUE. To make comparisons between project groups more meaningful, the research team proposed a stratification of project groups, i.e., a division of the project groups into more homogeneous and mutually exclusive subpopulations or categories. The establishment of project categories involved the following project characteristics:

- Project type.
- Project cost.
- Area type.
- Roadway class.
- Number of right-of-way parcels acquired and/or area of right-of-way acquired.
- Total right-of-way cost.
- Total utility relocation cost.
- Funding type.

Table 9 shows the conceptual design of the proposed comparison analysis using MOEs and project categories.

Table 9. Conceptual Design of the Proposed Comparison Analysis.

	Projects with SUE (before construction)	**Projects with SUE (during Construction)**	**Projects without SUE**
Category *1*	[$MOE_{1,1}$]	[$MOE_{1,2}$]	[$MOE_{1,3}$]
…	…	…	…
Category *n*	[$MOE_{n,1}$]	[$MOE_{n,2}$]	[$MOE_{n,3}$]

Note: For each project group and category, multiple MOEs are calculated, e.g.,$[MOE_{1,1}] = \begin{bmatrix} \text{MOE 1} \\ \text{MOE 2} \\ \cdots \end{bmatrix}$

Recognizing the potential difficulty for identifying SUE projects, the researchers also considered an alternative methodology that would be based on case studies, similar to previous research described in the literature review. That methodology proposed to identify the potential savings in project delivery time and monetary cost if SUE had been used during the projects by studying in detail a sample of projects that did not use SUE. During the analysis, the research team would use several projects of different categories as study cases and estimate the potential benefits of SUE for the following scenarios:

- Scenario 1: worst-case scenario that would be the current project conditions.
- Scenario 2: assuming at least 50 percent of the utility facilities within the project limit would be identified if SUE had been used prior to construction.
- Scenario 3: assuming 75 percent of the utility facilities within the project limit would be identified if SUE had been used prior to construction.
- Scenario 4: assuming 100 percent of the utility facilities within the project limit would be identified if SUE had been used prior to construction.

The research team would then divide the selected projects into different categories based on their characteristics and then calculate the MOEs from Table 7 for each category and for each scenario, as illustrated in Table 10. The MOEs would then be compared between different scenarios to identify effects of using utility investigation services during the project development process.

Table 10. Conceptual Design of the Alternative Comparison Analysis.

Comparison Group	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Category *1*	[$MOE_{1,1}$]	[$MOE_{1,2}$]	[$MOE_{1,3}$]	[$MOE_{1,4}$]
…	…	…	…	…
Category *n*	[$MOE_{n,1}$]	[$MOE_{n,2}$]	[$MOE_{n,3}$]	[$MOE_{n,4}$]

Note: For each project group and category, multiple MOEs are calculated, e.g.,$[MOE_{1,1}] = \begin{bmatrix} \text{MOE 1} \\ \text{MOE 2} \\ \cdots \end{bmatrix}$

Since the research team was able to identify SUE projects as described in the following section, the research team ultimately did not use this alternative methodology.

IDENTIFICATION OF SUE PROJECTS

The identification of SUE projects was a challenging process due to the way SUE data are stored on TxDOT data systems and due to the current data retention practices of SUE contracts at TxDOT. In general, centralized data systems at TxDOT do not keep track of historical SUE contract data. Detailed information about such contracts is generally stored at the district level in the format of hard copy records. This information, however, can only be tracked down, accessed, and evaluated using significant resources, and is constrained by the retaining limit for hard copies of contract records. For this reason, the research team used several different options to identify projects that used SUE services, including a review of TxDOT data system, contacting district staff, and reviewing the Contract Information System, as described in the following sections.

Query of TxDOT Data Systems

One possible avenue to identify projects that used SUE was a review and query of several TxDOT data systems. The research team started this effort by identifying potential data systems and then querying these systems using a set of keywords. For this effort, the research team focused on three major TxDOT data systems, the Design and Construction Information System (DCIS), the Financial Management Information System (FIMS), and the Contract Information System (CIS).

Design and Construction Information System

TxDOT uses DCIS to track projects throughout the project development process. DCIS includes a large number of project, contract, and utility screens that enable authorized users to complete data inputs and updates, and run queries and reports. The screens cover a wide range of topics, including project identification and evaluation data, project planning and finance data, project estimate data, and contract summary data. DCIS runs on a Software AG® Adabas® non-relational database platform. There are several files in Adabas that handle data needed for DCIS, including:

- File 121 (DCIS-PROJECT-INFORMATION).
- File 122 (DCIS-WORK-PROGRAM).
- File 123 (DCIS-PROJECT-ESTIMATE).
- File 124 (DCIS-CONTRACT-LETTING).

In recent years, TxDOT has begun to use an Adabas replicator utility to export Adabas data files to a Microsoft® SQL Server® environment. TxDOT has replicated all DCIS files into a SQL Server schema called COMMON_DSGN. For the purpose of this project, TxDOT provided access to the replicated database, which included project data from January 1994 to March 2011.

Financial Management Information System

Like DCIS, FIMS runs on an Adabas platform. FIMS allows the recording of TxDOT accounting events and is the basis for all official departmental financial information. Segment *76 (FIMS-CNS76) – Construction and Maintenance Projects* contains financial data for highway construction projects and maintenance projects managed using construction program procedures. The query for SUE projects was primarily focused on this data file. Similar to DCIS, the researchers were able to access a replicated database of FIMS with project data from January 1994 to March 2011.

Contract Information System

CIS is a TxDOT legacy system that the Construction Division manages. It stores information about various types of TxDOT contracts, including those for highway projects. The *Contract Identification File (File 9)* of the system is the primary data file that contains a record for each contract describing the general contract information and grand totals. Each record contains a control section job (CSJ) number that can be used to establish connection with the project information in other data systems, such as DCIS and FIMS. For the purpose of this project, TxDOT provided access to contract records from January 1998 to March 2011 through a replicated database. Among the large number of data fields in the file, the following were of particular interest to this project (*54*):

- CONTRO-CSJ: This field contains the controlling CSJ (CCSJ), which is assigned when the contract is entered into a TxDOT system (e.g., SiteManager) after letting. The CCSJ is normally the lowest CSJ of all CSJs within a contract and serves as the major contract identification field.

- TYPE-OF-WORK: This field contains a general verbal narrative of the type of work to be performed for the contract.

- TUCP_NAICS_CTGRY_DSCR: This field contains the Texas Unified Certification Program (TUCP) North American Industry Classification System (NAICS) category description, which describes the business type of a TUCP certified Federal Disadvantaged Business Enterprise (DBE). NAICS is the standard that federal and state agencies use in classifying business establishments.

In addition to File 9, the replicated CIS database also included a table named CMCS_AD_TRACKING that contains information about the advertisement posted in relation to each of the contract records in CIS. In this table, the field AD_TEXT includes a description of the work for each contract that was advertised. This field is also used during the search for contracts that potentially involved SUE services.

The research team searched the aforementioned data fields and files of each data system using keywords including: UTILIT, SUE, SUBSURFACE, QL, SURVEY, and UNDERGROUND. During the search, the researchers used the SQL LIKE statement (e.g., LIKE “*UTILIT*”) to ensure all potential records were captured. At the end of this process, the queries of DCIS and

FIMS did not return any records about SUE services. The CIS data query resulted in nine unique contract records containing potential information about SUE contracts. Unfortunately, a closer review of these records found that the keywords were part of clauses intended to describe the qualification of a contractor and therefore did not necessarily indicate SUE contracts. As a result, the query of DCIS, FIMS, and CIS was not helpful to identify projects that used SUE services.

Contact District Staff

The research team contacted all 25 TxDOT districts to request a list of past projects that used SUE services. Since the research focused on the effects of SUE on project delivery, the research team requested projects for which SUE services were performed prior to 2009. That is, assuming that such projects would have finished or at least would be undergoing construction, and would therefore be more suitable for the purpose of this analysis.

Before contacting district staff, the research team developed a list of utility-related officials at each TxDOT district to whom the request would be sent. Each list was developed with the assistance of project panel members, based on the researchers' experience related to other relevant previous and ongoing research, and/or telephone/email inquiries to the district public information offices. The lists mainly included district engineers, district utility coordinators, district design engineers, and area engineers in the case of major urban districts.

At the end of this process, the districts provided a total of 50 CSJs that included the use of SUE. However, many of the projects involved SUE services used in 2009 and 2010 since information about recent projects, and more specifically SUE contract information could be easier recalled than from older projects. A search of these CSJs in DCIS returned 10 project records, indicating that only 10 of the 50 projects were past the project letting phase. When the research team contacted districts for further information about these 10 SUE contracts, district officials were only able to provide very few contract details such as type of SUE and contract amounts, and for only three of the 10 projects. As a result, this approach to collect SUE information did not provide sufficient information for the analysis.

Contact TxDOT Design Division

Given the unsatisfactory results from the aforementioned efforts, the researchers approached the TxDOT Design Division (DGN) for assistance with the research. Based on internal data systems and records, DGN provided the research team with information about three sets of contracts:

- **Contracts for Specific Projects That Included SUE Services in the Contract Description.** These contracts ranged from 2004 to 2011 and had a great probability that SUE services were actually performed under the contracts.

- **Indefinite Deliverable Survey Contracts That Included Both SUE and Other Services.** An indefinite deliverable contract (also known as an evergreen contract) is a contract containing a general scope of services that identifies the types of work that will be later required under work authorizations. Such contracts do not specify deliverables, locations, or timing in sufficient detail to define the provider's responsibilities under the contract. Historically, TxDOT issued indefinite deliverable survey contracts that included SUE services in scope. The contracts that DGN provided were issued between 1997 and 2009.

- **Other Indefinite Deliverable Contracts.** These contracts included a broader range of engineering services in addition to SUE. DGN also identified a set of contracts that were issued after 2005 and included SUE in their original scope. Those contracts included a broad range of engineering services, and there was a relatively high probability that SUE services were not actually performed.

To confirm if SUE services were actually performed for any of the contracts DGN provided and for which project, the research team examined the original work orders issued in association with the contract. Work orders are stored in TxDOT's electronic document management system (EDMS) in form of scanned copies of the original work orders that the department had issued. EDMS is an electronic document management application that supports the storage, indexing, retrieval, management, and archiving of documents (electronic files) in a controlled environment utilizing a storage subsystem and a catalog subsystem. TxDOT officials conveyed that TxDOT implemented EDMS in 2009 and that any records stored in the system would be from late 2009. The research team randomly retrieved work orders of several SUE contracts and found that all the projects for which the contracts were issued had not yet gone to letting. As a result, this approach also proved to be not useful to identify projects that used SUE.

Review of TxDOT Payment Voucher Documents

During separate discussions with TxDOT Construction Division (CST), the research team learned of the possibility to identify SUE projects through TxDOT payment vouchers. Scanned copies of the original payment voucher documents since FY2008 are available through the Imaging Service data system at TxDOT Finance Division (FIN) (see Figure 40). Each voucher document is a collection of payment vouchers, invoices, and other supporting materials that a district submitted during a payment cycle. Voucher documents frequently consisted of hundreds of pages including invoices that contractors submitted with detailed descriptions of work performed and costs. Vouchers were identified using voucher numbers that could be further linked to specific contractors to whom the payments were issued. Figure 41 provides an example of an invoice summary of work that a SUE service provider had performed.

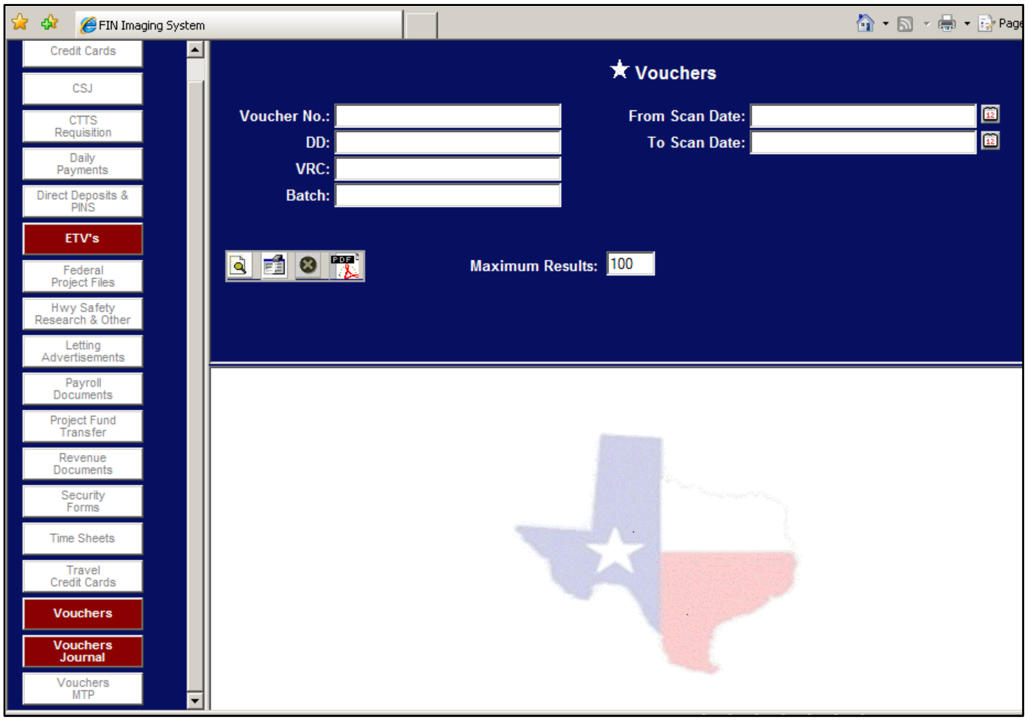


Figure 40. FIN Imaging Service Interface.

INVOICE SUMMARY
SH 31 from 28th Street to Beaton Street
Work Authorization No. 4
CSJ # 0162-04-047
Contract No.18-648P5009

RECEIVED TXDOT
NOV 27 2007
District 18 Acctg.

G&A HOURLY RATES				
Item	Qty.	Unit	Unit Rate	Total
Project Manager	7	HRLY	$ 125.22	$ 876.54
RPLS	33	HRLY	$ 100.00	$ 3,300.00
Survey Technician	0	HRLY	$ 70.00	$ -
Survey Crew (2-Man)	176	HRLY	$ 90.00	$ 15,840.00
Survey Crew (3-Man)	78.5	HRLY	$ 115.00	$ 9,027.50
GPS Crew (2-Man)	11	HRLY	$ 95.00	$ 1,045.00
Jr. utility Coordinator	25	HRLY	$ 64.06	$ 1,601.50
SUE Technician	20	HRLY	$ 43.68	$ 873.60
			TOTAL:	$ 32,564.14

SUE Rates				
Item	Qty.	Unit	Unit Rate	Total
Designate - Level B (including C & D)	13,496	Foot	$ 1.15	$ 15,520.40
Locate - 0 to 5 feet	0	Each	$ 840.00	$ -
Locate - 5 to 8 feet	0	Each	$ 1,060.00	$ -
Locate - 8 to 13 feet	0	Each	$ 1,350.00	$ -
Locate - 13 to 20 feet	0	Each	$ 2,000.00	$ -
			TOTAL:	$ 15,520.40

MISC EXPENSE (at cost)			
Item	Date	Invoice No.	Total
Vehicle Miles (0 mi @ $0.405/mi)		N/A	
		TOTAL:	$0.00
TOTAL INVOICE			$48,084.54

Progress Report

Contract No.: 18-648P5009
Work Authorization No. 004

Dallas District

SH 31
From 28th Street to Beaton Street

Period of Performance: May 30 through August 31, 2007

Summary of Work Performed:

Function Code 130

1. Quality Level A SUE
   - No work this period
2. Quality Level B SUE
   - Designated storm drains
   - Designated utilities 2,000 feet east of 28th Street and 600 feet west of Beaton Street
   - Diagramed storm drain grates
   - Inspected blockages in storm drains

Figure 41. Sample Invoice with Information about SUE Services.

Function Code 150

1. Survey
   - Surveyed storm drain system from 14th Street to Beaton Street and from 10th Avenue to 3rd Avenue

Next Month's Anticipated Activities:

Function Code 130

1. Quality Level A SUE
   - No work anticipated
2. Quality Level B SUE
   - Designate utilities along Main Street

Function Code 150

1. Survey
   - Perform the following survey activities along Main Street
     - cross-sections, Topo, ROW, Utilities, railroad Topo
   - Along the channel
     - Cross sections, property lines and drainage structures

RECEIVED TXDOT

NOV 27 2007

District 18 Acctg.

Figure 41. Sample Invoice with Information about SUE Services (Continued).

TxDOT provided access to a TxDOT computer, through which the researchers were able to access the FIN Imaging Service. To identify payment vouchers associated with SUE services, the researchers first identified a list of contractors who historically provided SUE services to TxDOT. Based on their tax IDs and with the assistance from CST, the researchers were able to obtain a list of voucher numbers through FIMS for each of the contractors. Using the voucher numbers, the research team extracted all voucher documents associated with the identified contractors.

At the end of this process, the research team extracted 346 payment voucher documents associated with SUE contractors that were issued in fiscal year 2008. The rationale for focusing on 2008 vouchers was that such vouchers would reflect SUE services performed during or before fiscal year 2008, and therefore associated projects would have a higher probability of having construction completed. A review of all 346 payment vouchers found that 36 payment vouchers were associated with SUE services. All other payment vouchers were either related to other engineering services such as utility coordination and surveying, or did not provide sufficient information to conclusively identify the services performed. The 36 payment vouchers were associated with 54 project CSJs. An examination of the 54 CSJs found that 35 CSJs went to letting, and that these 35 CSJs in turn belonged to 29 CCSJs.

Final List of SUE Projects

Including the three projects the research team identified with the help from TxDOT districts, researchers were able to identify 32 CCSJs or projects that used SUE in the last 12 years. During this analysis, the researchers used CCSJs as a project identifier since a CCSJ is the identifying CSJ of a group of CSJs that belong to the same project, although each CSJ is a portion of a project that is typically performed through a separate contract.

Table 11 is a list of all SUE projects identified during this research. SUE year, which is the year the SUE services were performed, SUE type, and SUE cost were transcribed from payment vouchers. The table also provides basic project information from DCIS, such as project class, functional class, area type, let year, and bid amount. All dollar values in this table and hereafter throughout the research are values that were converted to reflect December 2011 dollars using the TxDOT Highway Cost Index (HCI) (*55*).

Table 11. List of Identified SUE Projects.

CCSJ	District	SUE Year	SUE Type	SUE Cost (2011 Dollar)	Year Let	Project Class	Functional Class*	Area Type**	Bid Amount (2011 Dollar)	SUE/Bid Amount
003401102	Abilene	1997	AB	$235,617	2000	Interchange	3	U	$10,333,859	2.28%
090833066	Abilene	2008	AB	$104,929	2008	Rehabilitate existing road	5	R	$3,860,323	2.72%
042502029	Amarillo	2007	A	$40,672	2009	Bridge replacement	3	U	$10,048,149	0.40%
090411037	Amarillo	2007	AB	$43,512	2008	Upgrade to standards freeway	5	U	$804,780	5.41%
004906070	Bryan	2008	A and/or B	$16,364	2004	Right-of-way	0	R	-	-
120801017	Corpus Christi	2007	A	$7,288	2010	Rehabilitate existing road	5	R	$12,315,778	0.06%
226302079	Corpus Christi	2007	B	$15,519	2008	Bridge widening or rehab	4	R	$9,000,931	0.17%
226302082	Corpus Christi	2007	B	$7,760	2007	Rehabilitate existing road	4	U	$3,223,828	0.24%
000912073	Dallas	2007	B	$42,382	2009	Interchange	1	U	$20,539,424	0.21%
004801057	Dallas	2007	A	$68,933	2006	Rehabilitate existing road	3	U	$3,423,163	2.01%
009510034	Dallas	2007	AB	$73,336	2008	Interchange	2	U	$13,183,452	0.56%
016204047	Dallas	2008	AB	$17,152	2010	Rehabilitate existing road	3	R	$9,789,025	0.18%
017304025	Dallas	2008	B	$7,648	2011	New location non-freeway	4	U	$15,319,836	0.05%
019607018	Dallas	2008	AB	$84,034	2008	New location freeway	2	U	$39,247,660	0.21%
035304084	Dallas	2007	AB	$37,155	2008	Miscellaneous construction	2	U	$2,241,358	1.66%
036402021	Dallas	2008	AB	$35,710	2007	Upgrade to standards freeway	3	U	$22,471,707	0.16%
058102121	Dallas	2008	B	$86,428	2008	Widen freeway	2	U	$185,426,472	0.05%
156701029	Dallas	2008	B	$2,297	2010	Widen non-freeway	3	U	$58,185,243	0.00%
000802068	Fort Worth	2007	B	$11,476	2008	Traffic signal	4	U	$66,159	17.35%
000814058	Fort Worth	2007	A and/or B	$69,667	2009	Widen freeway	1	U	-	-
001310072	Fort Worth	2008	A and/or B	$9,701	2008	Traffic signal	3	U	$71,535	13.56%
008002052	Fort Worth	2007	A and/or B	$3,318	2008	Bridge replacement	3	R	$1,490,997	0.22%
008112042	Fort Worth	2007	B	$5,973	2010	Traffic signal	1	U	$156,282	3.82%
017201042	Fort Worth	2007	A and/or B	$44,084	2008	Widen non-freeway	4	U	$14,212,665	0.31%
074704059	Fort Worth	2007	A and/or B	$3,318	2009	Widen non-freeway	3	U	$2,971,496	0.11%
133002034	Fort Worth	2007	A and/or B	$1,612	2010	Widen non-freeway	3	U	$7,385,511	0.02%
226602127	Fort Worth	2008	A and/or B	$69,585	2008	Interchange	2	U	$46,291,016	0.15%
002713171	Houston	2007	AB	$10,951	2002	Widen freeway	2	U	$105,254,131	0.01%
027107242	Houston	2007	A and/or B	$29,227	2010	Widen freeway	1	U	$52,034,879	0.06%
005301090	Lubbock	2009	A	$15,144	2009	Widen non-freeway	3	U	$50,083,584	0.03%
013005069	Lubbock	2008	B	$63,368	2010	Rehabilitate existing road	3	U	$10,274,313	0.62%
003916057	Pharr	1999	AB	$269,783	2003	Widen freeway	2	U	$106,081,415	0.25%
Total	-	-	-	$47,936	-	-	-	-	$28,130,654	1.82%

*: 1 – Interstate; 2 – Other Urban Freeway Or Expressway; 3 – Rural Principal Arterial, Urban Connecting Links Of Rural Arterials, Or Other Urban Principal Arterials; 4 – Minor Arterial Road Or Street; 5 – Rural Major Collector Or Urban Collector Street (based on classification in DCIS).
**: U – Urban; R – Rural (based on classification in DCIS)

Table 12, Table 13, and Table 14 show the distribution of SUE projects by SUE quality level, the year the SUE work was conducted, and the year the project was let. As illustrated in these tables, most projects had SUE services in 2007 and 2008, and many of them were let between 2008 and 2010.

Table 12. SUE Projects by SUE Quality Level.

SUE Quality Level	Number of Projects
A only	4
B only	9
A and B	10
A and/or B	9
Total	**32**

Table 13. SUE Projects by Year SUE Conducted.

Year SUE Conducted	Number of Projects
1997	1
1999	1
2007	18
2008	11
2009	1
Total	**32**

Table 14. SUE Projects by Year Project Let.

Year Project Let	Number of Projects
2000	1
2001	0
2002	1
2003	1
2004	1
2005	0
2006	1
2007	2
2008	12
2009	5

2010	7
2011	1
Total	**32**

Of 32 projects that used SUE, Figure 42 and Figure 43 show the mean costs of SUE per project in 2011 (December) dollars, by districts, and by project class. Although the researchers identified projects from rural districts such as Amarillo, Abilene, and Lubbock, most projects were from urban districts such as Dallas and Fort Worth. In addition, SUE projects were most common for project classes such as rehabilitate existing road, widen freeway, widen non-freeway, and interchange. The figures also clearly illustrate that widen freeway, interchange, and new location freeway projects had the highest average SUE cost per project.

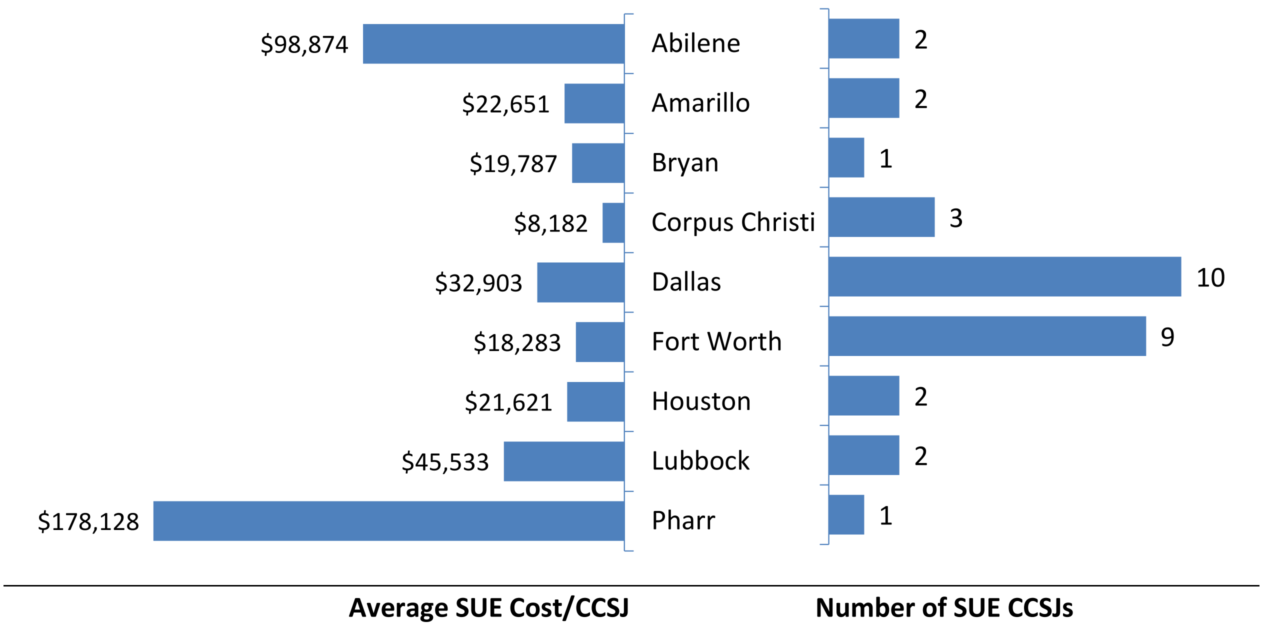


Figure 42. Mean Cost and Number of Projects Using SUE by District.

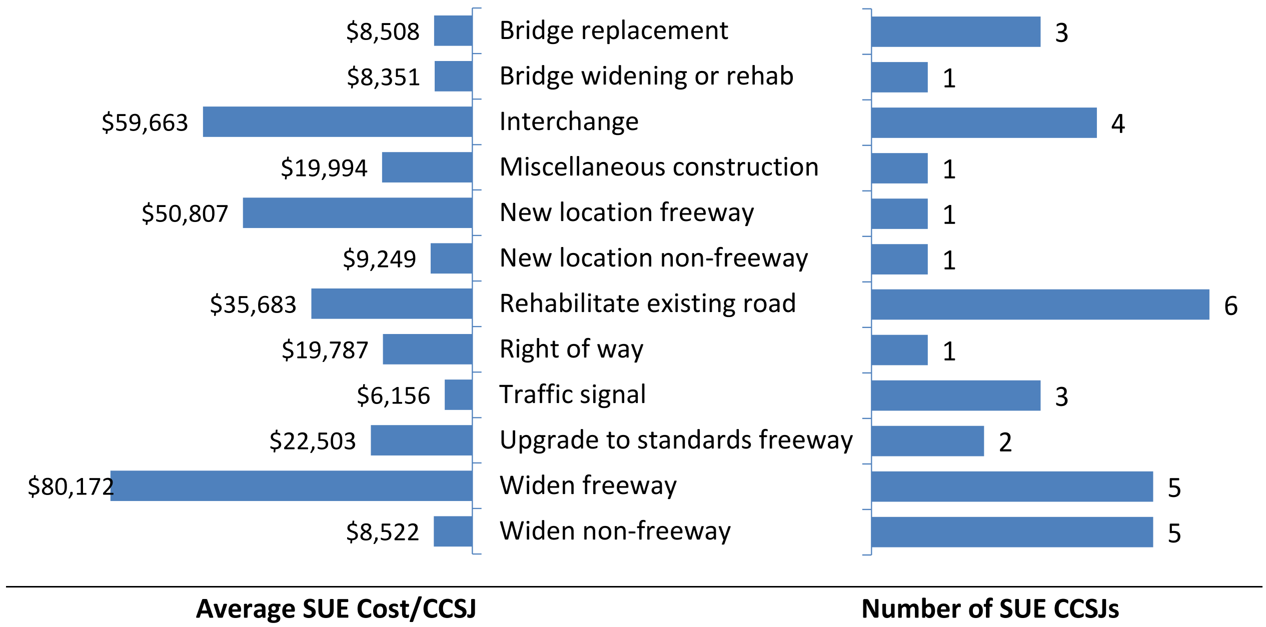


Figure 43. Mean Cost and Number of Projects Using SUE by Project Class.

PROJECT DATA COLLECTION

For the analysis, the researchers needed a control group of projects that did not use SUE so that researchers could compare between projects that used SUE and projects that did not use SUE to assess SUE effectiveness. SiteManager data, including construction cost, construction duration, and change order information, was provided through record searches by TxDOT employees and not available to the research team through direct database access. Due to the time and effort required for record searches, it was not feasible to request and retrieve SiteManager data for an 11-year period from 2000–2011. Instead, the research team limited the request to 6 years of data from 2005 to 2009, which provided a sufficient sample size for the control group. To request the SiteManager data, the researchers extracted all project records in DCIS that were let between fiscal year 2005 and fiscal year 2009, which provided 4,587 CSJs or 2,181 CCSJs. The research team then requested SiteManager data for these CSJs from TxDOT.

As shown previously in Figure 39 and Table 8, the research team proposed to obtain a range of data items relevant to project delivery and utility conflicts from a variety of TxDOT data systems. As the data collection effort proceeded, the researchers found that it was not practical to obtain some of the potential data elements, nor was it necessary to request data from all systems initially considered, for the following reasons:

- **Some Data Items Were Not Available.** Many data elements the research team proposed to request were not available in any of the existing TxDOT data systems. Examples are the project development process time stamps pertaining to design activities, such as design conference date and PS&E date. The researchers are aware of the TxDOT statewide implementation of P6 starting in late 2009, which may provide some of these project time stamps in the future. However, all districts do not utilize the system well, and project development process time stamps included in the current system only reflect projects for which design was started in 2009 or later.

- **Data Required Extensive Processing.** Further examination of certain TxDOT data systems indicated that some data elements might possibly be available in certain data systems, but would require a significant amount of time to process so the research team can derive the information needed. Examples of such data elements include the utility relocation data elements from UIR, which is a system that enables the processing of utility installation requests online. Manually examining the information stored in the system for each individual utility installation request would make it possible to derive some data elements beneficial for this research. However, this would have been too time-consuming and resource-intensive to complete within the scope of this research.

- **Access to Data Could Not Be Obtained in Time.** For various reasons, the researchers could not obtain timely access to the Environmental Tracking System (ETS). However, some of the data elements included in ETS were available from other data systems. Most of the data elements not included in other data systems turned out to be less critical to this research so that the overall impact of not having access to ETS was minor.

- **Multiple Systems included Identical Data Elements.** As show in Table 8, the research team identified all potential sources that could provide a certain data element. As a result, the same data element could be obtained from multiple sources, increasing the possibility of obtaining it. During the data collection process, the researchers would not make requests to additional data sources once a data element was obtained.

Figure 44 illustrates the data sources that the research team queried and the data items the research team acquired for the analysis.

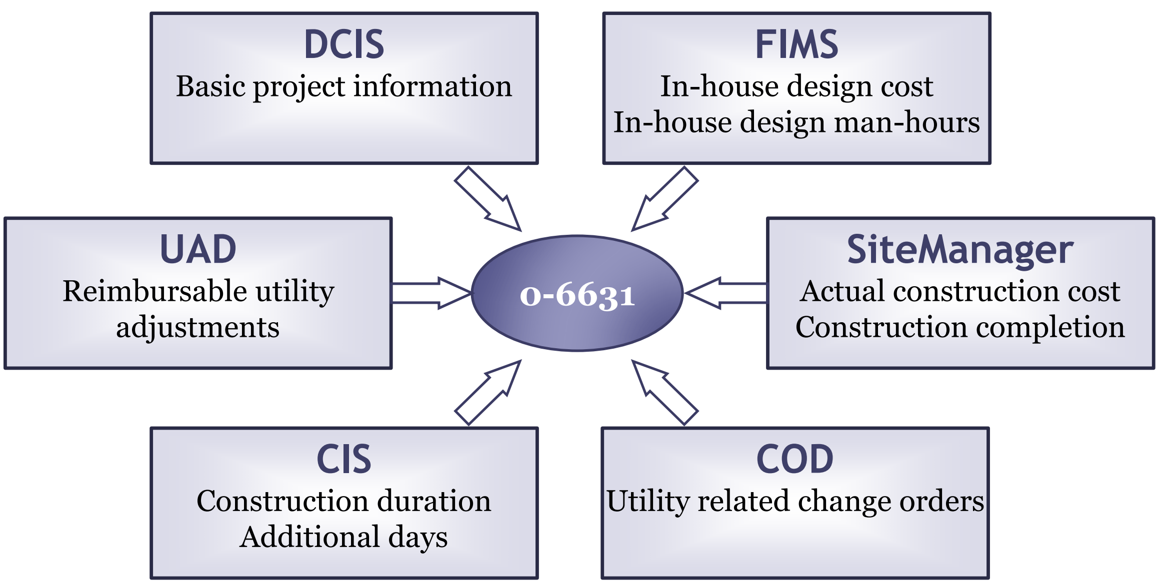


Figure 44. Data Source and Items Used in Analysis.

More specifically, the research team obtained the following data for both groups of projects:

- **Basic Project Information from DCIS.** The researchers used the following major data elements during the analysis:
  - Project class. The researchers grouped the project class observations into five broader project class groups to increase the effective sample sizes (see Table 15).
  - Area type. This data element indicated whether a project was a rural or urban project.
  - Project lane-miles. This data element indicated the extent of a project in lane-miles. In DCIS, for many projects this field was not populated either because the project was a point project (e.g., signal project) or the data was missing. For projects with missing lane-mile information, the researchers populated the field as the product of proposed project length and number of main lanes.
  - Design standard. This data element indicated the TxDOT design standard used for a project, or project type, with values of 2R, 3R, 4R, and other (see Table 16).

Table 15. Groups of Project Class Observations.

Project Class Observations	Description	Group
BR	Bridge replacement	Bridge (B)
BWR	Bridge widening or rehab	Bridge (B)
INC	Interchange	Bridge (B)
NLF	New location freeway	New location (N)
NNF	New location non-freeway	New location (N)
RER	Rehabilitate existing road	Rehabilitate (R)
UPG	Upgrade to standards freeway	Upgrade (U)
WF	Widen freeway	Upgrade (U)
WNF	Widen non-freeway	Upgrade (U)
MSC	Miscellaneous construction	Other
TS	Traffic signal	Other
ROW	Right-of-way	Other

- **Design Effort Data from FIMS.** This data included design man-hours and design costs for projects that were designed in house. TxDOT populated these fields in FIMS based on the timesheets that the TxDOT employees submitted and their salaries. FIMS uses a set of function codes to identify the purpose or reason of each payment recorded in the system. To extract the costs and man-hours associated with design-related functions, the researchers only used payments with a function code between 160 and 181, which reflect design-related activities associated with projects designed in-house (Figure 45).

- **Construction Costs and Completion Dates from SiteManager.** CST extracted the following information from SiteManager for the selected projects:
    - Original bid amount. This data element was the construction amount proposed during letting.
    - Construction expenditures to date. This data element was the actual construction expenditures to the date when the information was extracted. For completed projects this was the actual construction cost.
    - Construction completion date. This data element was the actual date projects finished construction.

Table 16. List of TxDOT Design Standards (*56, 57*).

Type	Description
2R	Non-freeway resurfacing or restoration projects. 2R projects consist of non-freeway work on facilities with an average daily traffic (ADT) of up to 3000 and are not on National Highway System (NHS) routes, which propose to restore the pavement to its original condition. Adding through travel lanes is not permitted for 2R projects. However, adding continuous two-way left-turn lanes, acceleration or deceleration lanes, turning lanes, and shoulders are acceptable as long as the existing through lane and shoulder widths are maintained. 2R projects could include upgrading roadway components as needed to maintain the roadway in an acceptable condition.
3R	Non-freeway rehabilitation projects. 3R projects consist of non-freeway work that extends the service life and enhance the safety of a roadway. In addition to resurfacing and restoration, 3R projects could include upgrading the geometric design and safety of a transportation facility. However, work does not include adding through travel lanes. Work may include upgrading geometric features such as roadway widening, minor horizontal realignment, and improving bridges to meet current standards for structural loading and to accommodate the approaching roadway width. 3R projects address pavement needs and/or deficiencies and substantially follow the existing horizontal and vertical alignments. The scope of 3R projects ranges from thin overlays and minor safety upgrading to more complete rehabilitation work.
4R	New location and reconstruction projects. 4R projects consist of work associated with new locations or reconstructions of transportation facilities such as urban streets, suburban roadways, two-lane rural highways, multilane rural highways, and freeways. In general, the result is a new roadway or upgrade to an existing roadway to meet geometric design criteria for new facilities. In addition to resurfacing, restoration, and rehabilitation, 4R projects could include reconstruction work, which typically involves substantial changes to the road such as additional through lanes, horizontal and/or vertical realignment, and major pavement structure improvements. Reconstruction work includes bridge replacement work.
Other	Projects that did not belong to any of the above standards.

- **Utility-Related Change Order Data from the Change Order Database (COD).** COD is part of the TxDOT SiteManager system and is used to track change orders during the project construction phase. Change orders are significant changes in the character of the work or time extensions during construction due to a large number of potential factors. CST uses a set of change order reason codes to identify the purpose for each change order. The researchers focused on change orders with a code relevant to utilities (see Table 17). This type of data included the following data elements:
    - Change order date.
    - Change order amount.
    - Change order reason descriptions.
- **Construction Duration Data from CIS.** This type of data included the following data elements:
    - Proposed construction length in days.
    - Additional days granted for construction.

Last Update: 09/01/11

Code Chart 12 - Segment 76
Function Codes and Descriptions by FIMS Segments

Function Code	Description
	Preliminary engineering function codes, except for FC130 ROW data
160	Roadway Design Controls (Computations and Drafting) 1. Geometric design A. Horizontal alignments B. Vertical alignments 2. Grading design A. Typical sections B. Design cross-sections 3. Pavement design
161	Drainage 1. Hydrologic studies, discharges 2. Hydraulic Design and documentation of all culverts, bridges, storm sewers and channels 3. Layout, structural design and detailing of drainage features (example drainage, junction boxes, all culverts whether greater or less than 20 feet, etc.) 4. Scour analysis
162	Signing, Pavement Markings, Signalization (Permanent) 1. Signing 2. Pavement marking 3. Delineation 4. Isolated signals
163	Miscellaneous (Roadway) 1. Retaining walls and miscellaneous structures 2. Traffic control plan/detours/sequence of construction 3. Illumination 4. Miscellaneous and drafting standards 5. Compute and tabulate quantities 6. Special utility details (water, sanitary sewer, etc.,) 7. Miscellaneous structural details 8. Agreements (railroad, etc.), layouts 9. Storm Water Pollution Prevention Plan (SW3P) 10. Estimate 11. Specifications and general notes
164	Managing Contracted or donated PS & E PE Services (Includes both Highway Design and Survey Contracts. Includes Management by TxDOT Personnel or a Consultant.) Also includes all costs to acquire the Consultants Contract(s) and Services applicable to PS & E, Function Codes 160 - 190. PS & E PE are activities in function code 160 through 190.
165	Traffic Management Systems (Permanent) 1. Traffic Signal Systems 2. Freeway Control Systems 3. HOV Lane Control System 4. Intelligent Vehicle Highway Systems
166	Rework By TxDOT Of Completed Consultant Plans on PE & E projects. PS & E PE are activities in function codes 160 through 190. Rework Segment 76 FCs 160-190 for metric conversion. For reworking existing PS&E to metric units on projects already into plan preparation.
169	Donated Items or Services Estimated savings resulting from acceptance and use on a construction project of non-cash items or services which, if paid for by TxDOT would be charged to preliminary engineering function codes 160-190. (FIN use only)
170	Bridge Design 1. Preliminary studies and layouts 2. Foundation studies 3. Detailed design and drafting 4. Bridge inspection
180	District Design Review and Processing 1. Review 2. Prepare supporting documents 3. Printing 4. Coordination with Austin office
181	Austin Office Processing (State Prepared P.S. & E.) 1. Review 2. Investigation 3. Checking of design 4. Processing for Letting 5. Reproduction 6. Miscellaneous

Figure 45. List of Design-Related Function Codes in FIMS.

Table 17. Utility-Related Change Order Categories and Reason Codes.

Category	Code	Change Order Reason
2. Differing Site Conditions (Unforeseeable)	2G	Unadjusted utility (unforeseeable): This code should be used when unknown utilities impact the project.
6. Untimely Right-of-Way/ Utilities	6C	Utilities not clear: This code should be used for contractor impacts that are the result of known utilities not being adjusted or relocated on the date(s) specified in the plans.
	6D	Other: This code should be used for untimely right-of-way or utilities where other codes in this category are not appropriate.
7. Termination	7C	Contract termination or significant portion of project eliminated – Utilities: This code should be used when a project is terminated or a significant portion of a project is eliminated due to a major utility delay or impact. The utility impact could be the result of either a known or an unknown utility.

- **Reimbursable Utility Adjustment Data from the Utility Agreement Database (UAD).** This type of data included the following data elements:
  - U-number. This data element is the main ID for records in the UAD.
  - CSJ. The researchers used this data element to link the adjustment data with projects.
  - Utility agreement date.
  - Utility agreement amount.
  - Utility agreement amendment dates.
  - Proposed utility adjustment date.
  - Actual utility adjustment date.
  - Utility adjustment type, i.e., if the adjustment was an emergency work authorization (EWA).

The research team compiled all data elements into one master data sheet where each record represented one project.

REVISED METHODOLOGY

After data collection, the researchers had a better understanding of the information available for the analysis, so they made some revisions to the analysis methodology accordingly. Figure 46 shows which MOEs the researchers were able to calculate based on the available data and which were excluded from the analysis. Compared to the originally proposed methodology, the research team was not able to compare the total project costs, total project delivery time, percent of identified utility conflicts before design, and percent of identified utility conflicts during design. However, the research team was able to assess the number of reimbursable emergency work authorization utility adjustments.

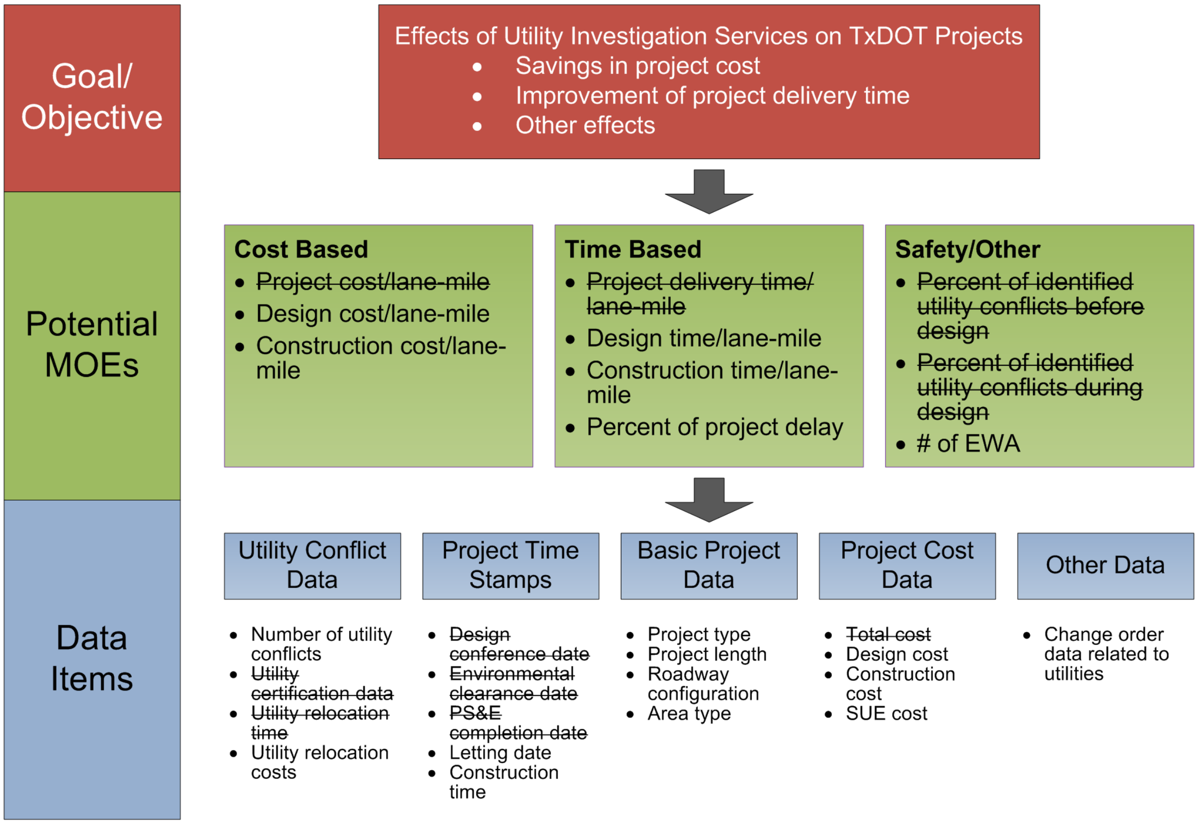


Figure 46. Refined SUE Cost-Effectiveness Methodology.

Based on available data, the researchers were unable to separate SUE projects into projects within SUE during design and projects with SUE during construction. As such, the research team only compared projects that used SUE at some point during the project development process with those that did not use SUE at all. In addition, the categories within each group of projects were made based on primarily three basic project characteristics: area type, project class groups, and design standard. Table 18 shows the sets of MOEs that the research team calculated for each combination of project category and project group.

The research team used SAS® to conduct both the comparison analysis and a two-sample t-test during this research. The t-test is designed to compare two means of the same variable between two populations (*58*). Depending on whether the variances for both populations are the same or not, the standard error of the mean of the difference between the groups and the degree of freedom are computed differently. As a result, SAS outputs two different t-statistics and two different p-values. When using the t-test for comparing independent groups, it is necessary to test the hypothesis on equal variance first. SAS uses two methods for computing the standard error of the difference of the means based on the assumption regarding the equity of the variances of the two groups. If the two populations have the same variance, SAS uses a pooled variance estimator; otherwise, SAS uses Satterthwaite's method.

Table 18. Conceptual Design of the Proposed Comparison Analysis.

Project Characteristic	Project Categories	Projects with SUE	Control Group (Projects without SUE)
Area Type	Rural Area	[$MOE_{1,1}$]	[$MOE_{1,2}$]
	Urban Area	[$MOE_{2,1}$]	[$MOE_{2,2}$]
Project Class	Bridge	[$MOE_{3,1}$]	[$MOE_{3,2}$]
	New Location	[$MOE_{4,1}$]	[$MOE_{4,2}$]
	Rehab	[$MOE_{5,1}$]	[$MOE_{5,2}$]
	Upgrade	[$MOE_{6,1}$]	[$MOE_{6,2}$]
	Other	[$MOE_{7,1}$]	[$MOE_{7,2}$]
Design Standard	2R	[$MOE_{8,1}$]	[$MOE_{8,2}$]
	3R	[$MOE_{9,1}$]	[$MOE_{9,2}$]
	4R	[$MOE_{10,1}$]	[$MOE_{10,2}$]
	Other	[$MOE_{11,1}$]	[$MOE_{11,2}$]

Note: For each project group and category, multiple MOEs are calculated, e.g.,$[\text{MOE}_{1,1}] = \begin{bmatrix} \text{MOE 1} \\ \text{MOE 2} \\ \cdots \end{bmatrix}$

The pooled estimator of variance is a weighted average of the two sample variances, with more weight given to the larger sample and is defined to be:

$$s^2 = \frac{\left(s_1(n_1 - 1) + s_2(n_2 - 1)\right)}{(n_1 + n_2 - 2)}$$

where s_1 and s_2 are the sample variances and n_1 and n_2 are the sample sizes for the two groups, and s^2 is the pooled variance. The standard error of the mean of the difference is the pooled variance adjusted by the sample sizes. It is defined as:

$$SE = \sqrt{s^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

Satterthwaite's method is an alternative to the pooled-variance t-test and is used when the assumption that the two populations have equal variances seems unreasonable. It provides a t-statistic that asymptotically (that is, as the sample sizes become large) approaches a t-distribution, allowing for an approximate t-test to be calculated when the population variances are not equal.

DATA ANALYSIS RESULTS

This section summarizes the results of comparing the SUE projects and control projects in an effort to examine SUE effectiveness on:

- Project design cost.
- Project design effort.
- Project construction cost increase.
- Project construction duration.
- Additional project construction days.
- Utility-related change order cost.
- Project utility agreements.
- Project emergency work authorizations.

Appendix D shows figures of the data and tables related to the statistical analysis.

SUE and Project Design Cost

Table 19 compares the mean project design cost and the mean project design cost per-lane-mile between SUE and control projects. As shown, SUE projects in general had much higher total design costs than control projects. However, when comparing the design costs on a lane-mile basis, SUE projects on average had a smaller per-lane-mile design cost than control projects. This is particularly the case for bridge and 4R projects. T-test results suggested that the differences for the mean project design costs are significant for all projects, and for the project classes urban projects, upgrade projects, and other projects. Differences of the mean design costs are also significant for the design standard category 4R projects. Statistically different values are highlighted with dark background in Table 19. T-tests did not find any statistically significant differences in means for design costs per-lane-mile. In Appendix D, Figure 50 through Figure 55 provide illustrations of the design cost by project category, and Table 80 and Table 81 provide the results of the t-test analysis.

Table 19. Mean Project Design Cost and Mean Project Design Cost per Lane-Mile (2011 Dollars).

Project Type	SUE Projects			Control Projects		
	Count	Total Design Cost	Design Cost/ Lane-Mile	Count	Total Design Cost	Design Cost/ Lane-Mile
All Projects	26	$2,144,614	$229,536	817	$203,704	$290,155
Area Type						
Rural	3	$513,283	$63,587	219	$145,668	$308,110
Urban	23	$2,308,400	$239,908	345	$358,039	$278,966
Project Class						
Bridge	7	$2,669,903	$274,252	110	$407,799	$710,368
New Location	2	$3,490,188	$170,125	26	$490,734	$99,943
Upgrade	8	$3,225,237	$181,603	93	$640,762	$104,925
Other	8	$427,546	$269,354	84	$117,436	$40,382
Design Standard						
3R	4	$605,352	$133,820	194	$220,696	$110,697
4R	19	$2,626,878	$258,987	235	$469,106	$408,637
Other	3	$1,142,627	-	367	$29,820	$98,019

Note: Highlighted values are statistically significantly different.

SUE and Project Design Effort

Table 20 compares mean design man-hours per project and mean design man-hours per project lane-miles between the SUE and control projects. Results were similar to those of the design costs analysis. On average, SUE projects had significantly *more* design man-hours than control projects, which may indicate that SUE was used for projects that required more significant design efforts. This fact was observed for all projects as a whole, and for the project categories urban, new location, upgrade, 4R projects, and other design standard projects. When comparing the design man-hours on a lane-mile basis, differences were not statistically different, except for 4R projects, which showed that SUE projects overall needed *fewer* man-hours per lane-mile to design. In Appendix D, Figure 56 through Figure 61 provide illustrations of the mean design time by project category, and Table 82 and Table 83 provide the results of the t-test analysis.

Table 20. Mean Total Design Man-Hours and Mean Design Man-Hours per Lane-Mile.

Project Group	SUE Projects			Control Projects		
	Count	Total Design Man-Hours	Design Man-Hours/ Lane-Mile	Count	Total Design Man-Hours	Design Man-Hours/ Lane-Mile
All Projects	26	13,520	1,527	813	2,133	2,238
Area Type						
Rural	3	1,401	1,297	217	1,511	2,103
Urban	23	15,101	1,542	343	3,514	2,173
Project Class						
Bridge	7	5,968	2,422	110	3,395	4,684
New location	2	13,869	2,551	26	3,327	1,164
Upgrade	8	30,323	1,343	93	6,968	1,271
Other	8	3,301	1,151	84	1,740	425
Design Standard						
3R	4	6,532	1,799	192	3,268	1,878
4R	19	16,538	1,444	235	3,978	2,800
Other	3	3,725	-	365	406	824

Note: Highlighted values are statistically significantly different.

SUE on Construction Cost Increases

Table 21 compares the percent construction cost increase and construction cost increase per-lane-mile between SUE projects and control projects. Construction increase was estimated as the difference between actual construction costs and the winning bid amount. Both projects that did and did not use SUE experienced mean cost increases of approximately ±5 percent. However, mean percent increases were only significantly different for rural projects, with a mean cost increase of 0.3 percent for SUE projects and 1.5 percent for control projects. In terms of per-lane-mile cost increase, differences between mean cost increases were only significantly different on a per lane-mile basis for urban and 4R projects. Here, urban SUE projects experienced a significantly *higher* cost increase than the control group, while 4R SUE projects experienced a significantly *lower* cost increase than the control group. In Appendix D, Figure 62 through Figure 67 provide illustrations of the mean construction cost increases by project category, and Table 84 and Table 85 provide the results of the t-test analysis.

Table 21. Mean Percent Construction Cost Increase and Mean per-Lane-Mile Construction Cost Increase.

Project Type	SUE Projects			Control Projects		
	Count	Construction Cost Increase %	Construction Cost Increase/ Lane-Mile	Count	Construction Cost Increase %	Construction Cost Increase/ Lane-Mile
All Projects	14	4.1%	$254,243	1174	3.0%	$71,114
Area Type						
Rural	3	0.3%	$54,629	443	1.5%	$74,928
Urban	11	5.1%	$334,089	420	4.2%	$70,407
Project Class						
Bridge	3	6.2%	$503,332	196	2.8%	$165,986
New location	0	-	-	20	–4.3%	-$97,441
Rehabilitate	3	3.4%	$20,257	99	–4.2%	-$74,763
Upgrade	4	3.5%	$356,134	86	2.9%	$97,145
Other	4	3.5%	-	335	5.3%	$13,301
Design Standard						
2R	0	-	-	61	2.6%	$3,303
3R	3	7.0%	$358,371	291	–4.3%	-$3,951
4R	7	2.3%	$41,758	318	2.7%	$125,319
Other	4	4.9%	$895,929	504	2.4%	$21,132

Note: Highlighted values are statistically significantly different.

SUE and Construction Duration

Table 22 shows the comparison analysis for mean project construction duration and mean project construction duration per lane-mile between SUE projects and control projects. The comparison suggested that mean construction duration for SUE projects was statistically significantly *higher* than the construction duration for the control projects. This was also found for the project categories urban projects and bridge projects. However, when comparing mean construction duration per lane-mile, the comparison study showed somewhat different results. In general, differences between SUE and control projects were not statistically significant, except for upgrade projects and 3R projects. These project categories showed a significantly *lower* mean construction duration on a per lane-mile basis for SUE projects. In Appendix D, Figure 68 through Figure 73 provide illustrations of the mean construction duration by project category, and Table 86 and Table 87 provide the results of the t-test analysis.

Table 22. Mean Project Construction Duration and Mean per-Lane-Mile Construction Duration.

Project Type	SUE Projects			Control Projects		
	Count	Construction Duration (Days)	Construction Duration/ Lane-Mile (Days)	Count	Construction Duration (Days)	Construction Duration/ Lane-Mile (Days)
All Projects	14	391	202	1174	184	294
Area Type						
Rural	3	344	388	443	177	337
Urban	11	405	127	420	231	230
Project Class						
Bridge	3	457	518	196	237	642
New location	0	-	-	20	408	166
Rehabilitate	3	264	98	99	198	87
Upgrade	4	660	41	86	404	136
Other	4	93	-	335	146	123
Design Standard						
2R	0	-	-	61	198	13
3R	3	468	42	291	195	159
4R	7	438	262	318	284	468
Other	4	205	279	504	114	48

Note: Highlighted values are statistically significantly different.

SUE and Additional Project Construction Days

Table 23 compares the mean percent of additional project construction days and the mean additional construction days per-lane-mile between SUE projects and control projects. Percent additional construction days were the difference of actual minus the planned number of construction days, divided by the number of planned construction days. The results suggested that in several project categories, SUE projects experienced a significantly *lower* percentage of additional construction days than the control projects. These project categories included all projects, rural, urban, upgrade, other project class, and 4R projects. The t-test results indicated that the differences in mean additional construction days per lane-mile were statistically significant for rural, bridge, upgrade, other project class, and 4R projects. For these categories, SUE projects on average showed significantly *fewer* additional construction days per lane-mile. In Appendix D, Figure 74 through Figure 79 provide illustrations of the mean number of additional project construction days by project category, and Table 88 and Table 89 provide the results of the t-test analysis.

Table 23. Mean Percent Additional Construction Days and Mean Per-Lane-Mile Additional Construction Days.

Project Type	SUE Projects			Control Projects		
	Count	Additional Days %	Additional Days/ Lane-Mile	Count	Additional Days %	Additional Days/ Lane-Mile
All Projects	14	11%	7.6	1174	16%	16.1
Area Type						
Rural	3	2%	0	443	14%	22.8
Urban	11	14%	9.3	420	21%	16.1
Project Class						
Bridge	3	18%	33.5	196	15%	62.2
New Location	0	-	-	20	23%	11.4
Rehabilitate	3	16%	4.4	99	23%	11.2
Upgrade	4	12%	1.0	86	18%	15.5
Other	4	2%	0	335	17%	2.5
Design Standard						
2R	0	-	-	61	21%	0.5
3R	3	16%	4.4	291	16%	9.0
4R	7	9%	0.8	318	19%	45.2
Other	4	12%	16.8	504	14%	1.2

Note: Highlighted values are statistically significantly different.

SUE and Utility-Related Change Orders

Table 24 makes a comparison of SUE projects and control projects in terms of the mean sum of utility-related change order amounts per project, the mean sum of utility-related change order amounts per lane-mile, and the mean percent of change orders amounts per project construction cost. Mean utility-related change order amounts showed no significant difference except for bridge projects, where SUE projects showed a significantly *lower* mean cost. In terms of utility-related change order amounts per-lane-mile, costs were significantly different for all projects, and rural, bridge, and 4R projects. For these project categories, SUE projects showed significantly *lower* costs. Overall, the percent of utility-related change order amounts were low, ranging between 0.01 to 0.12 percent of the total construction cost, for both SUE and control projects. Differences between the mean percentages were not significant except for bridge projects, where SUE projects showed a significantly *lower* percentage of the total construction cost.

In Appendix D, Figure 80 through Figure 88 provide illustrations of the mean cost of utility related change orders by project category. Table 90 through Table 92 provide the results of the t-test analysis for the comparisons of utility-related change order data.

Table 24. Mean of Utility Related Change Order Amount per Project, per-Lane-Mile, and Percent of Utility-Related Change Orders.

Project Type	SUE Projects				Control Projects			
	Count	CO* Amount	CO* Amount/ Lane-Mile	CO* Percent	Count	CO* Amount	CO* Amount/ Lane-Mile	CO* Percent
All Projects	14	$5,091	$163	0.04%	1174	$3,324	$2,917	0.10%
Area Type								
Rural	3	$547	$69	0.01%	443	$1,799	$756	0.02%
Urban	11	$6,331	$201	0.05%	420	$5,965	$4,234	0.12%
Project Class								
Bridge	3	$0	$0	0.00%	196	$5,481	$3,283	0.07%
New location	0	-	-	-	20	$4,574	$188	0.08%
Rehabilitate	3	$3,762	$381	0.10%	99	$3,972	$2,908	0.10%
Upgrade	4	$14,998	$0	0.07%	86	$19,530	$3,744	0.16%
Other	4	$0		0.00%	335	$1,176	$12,159	0.18%
Design Standard								
2R	0	-	-	-	61	$2,703	$324	0.10%
3R	3	$3,215	$503	0.09%	291	$456	$4,960	0.10%
4R	7	$8,805	$34	0.04%	318	$10,332	$3,265	0.11%
Other	4	$0	$0	0.00%	504	$639	$735	0.09%

*CO = Change Order

Note: Highlighted values are statistically significantly different.

SUE and Utility Agreement Amount

Table 25 compares the mean reimbursable utility agreement amounts per project and the mean reimbursable utility agreement amounts per project lane-mile. The study found that, in general, differences between mean agreement amounts are statistically significant for all projects, and urban, bridge, and 4R projects. For these types of projects, mean agreement amounts for SUE projects were significantly *higher*. Mean agreement amounts on a per-lane-mile basis were not significantly different, except for 3R projects. In this case, SUE projects had significantly *lower* agreements costs. In Appendix D, Figure 89 through Figure 94 provide illustrations of the mean utility agreement amount by project category, and Table 93 and Table 94 provide the results of the t-test analysis.

Table 25. Mean Reimbursable Utility Agreement Amount per Project and per Project Lane-Mile.

Project Type	SUE Projects			Control Projects		
	Count	Agreement Amount/ Project	Agreement Amount/ Lane-Mile	Count	Agreement Amount/ Project	Agreement Amount/ Lane-Mile
All Projects	31	$1,013,215	$97,560	1969	$19,313	$7,742
Area Type						
Rural	4	$346,174	$1,736	507	$20,888	$9,607
Urban	27	$1,112,036	$114,470	650	$34,096	$6,435
Project Class						
Bridge	7	$2,034,249	$441,042	211	$40,732	$12,505
New location	2	$1,148,455	$54,853	39	$254,927	$4,382
Rehabilitate	6	$229,102	$868	118	$12,095	$2,346
Upgrade	12	$1,124,868	$9,015	136	$114,815	$12,676
Other	4	$0	-	628	$959	$0
Design Standard						
3R	5	$4,500	$174	450	$26,183	$2,030
4R	18	$1,009,876	$153,493	365	$34,306	$13,092
Other	8	$1,651,177	$27,148	1101	$12,464	$1,872

Note: Highlighted values are statistically significantly different.

SUE and Utility Agreements

Table 26 compares SUE projects with control projects in terms of mean number of reimbursable utility agreements per project, mean number of utility agreements per-lane-mile, and mean percent of agreements not needed. Agreements not needed were those agreements in the UAD that were entered into the database but not executed. Reasons for entering agreements into the database but not executing them could be that the utility did not need to adjust (the utility conflict was resolved) or it was found that the utility is not reimbursable. The researchers calculated percent of agreements not needed by dividing the number of agreements not needed for a project by the total number of agreements for a project. Utility agreements included all agreement records in the UAD, including EWA utility agreements.

The number of agreements per project was significantly different for all projects, and urban, bridge, other project class, 4R, and other design standard projects. For these project categories, SUE projects generally had *more* reimbursable utility adjustments, except for the other project class category, where the control group had marginally more utility agreements. The mean number of utility agreements per lane-mile was not significantly different for SUE projects and the control group, except for rural projects, where the control group showed a marginally *higher* number of utility agreements per lane-mile.

The mean percent of utility agreements not needed was significant for a number of project categories, including all projects, and urban, upgrade, and 4R projects. Percent utility agreements not needed were roughly *twice as high* for SUE projects as compared to the control group. In Appendix D, Figure 95 through Figure 103 provide illustrations of the mean number of utility agreements by project category, and Table 95 through Table 97 provide the results of the t-test analysis.

Table 26. Mean Number of Utility Agreements, Mean Number of Utility Agreements Per-Lane-Mile, and Percent Utility Agreements Not Needed.

Project Type	SUE Projects				Control Projects			
	Count	UAs* per Project	UAs* per Lane-Mile	% UAs* not Needed	Count	UAs* per Project	UAs* per Lane-Mile	% UAs* not Needed
All Projects	31	1.84	0.17	53.3%	1969	0.09	0.06	25.2%
Area Type								
Rural	4	1.50	0.01	75.0%	507	0.07	0.05	24.0%
Urban	27	1.89	0.20	50.0%	650	0.20	0.08	26.5%
Project Class								
Bridge	7	4.14	0.75	51.7%	211	0.15	0.08	16.5%
New location	2	5.50	0.15	20.0%	39	0.74	0.01	25.0%
Rehabilitate	6	0.67	0.00	50.0%	118	0.03	0.01	33.3%
Upgrade	12	1.08	0.02	66.7%	136	0.69	0.13	30.3%
Other	4	0.00	-	-	628	0.01	0.00	33.3%
Design Standard								
3R	5	0.20	0.01	0.0%	450	0.08	0.01	25.6%
4R	18	2.50	0.22	55.6%	365	0.27	0.11	24.2%
Other	8	1.38	0.20	60.0%	1101	0.04	0.01	27.2%

*UA= Utility Agreement

Note: Highlighted values are statistically significantly different.

SUE and Reimbursable EWA Utility Agreements

Table 27 compares the number of reimbursable EWA utility adjustments per project and the number of reimbursable EWA utility adjustments per lane-mile between SUE and control projects. Reimbursable EWAs are a subset of the agreements analyzed in the section above and were identified using a column code from the UAD.

The mean number of EWAs per project were significantly different for all projects, and urban, bridge, other project class, and 4R projects. Except for the other project class, the number of EWA utility agreements was significantly *higher* for SUE projects than for the control group. In the case of the other project class, EWA utility agreements were marginally higher for control projects.

T-tests did not show any significant difference between the two project groups in the mean number of EWA utility agreements per lane-mile. In Appendix D, Figure 104 through Figure 109 provide illustrations of the mean number of reimbursable EWAs by project category, and Table 98 and Table 99 provide the results of the t-test analysis.

Table 27. Mean Number of Reimbursable EWA Utility Agreements per Project and per Project Lane-Mile.

Project Type	SUE Projects			Control Projects		
	Count	No. of EWA	No. of EWA/ Lane-Mile	Count	No. of EWA	No. of EWA/ Lane-Mile
All Projects	31	5.29	0.86	1969	0.25	0.17
Area Type						
Rural	4	5.00	1.68	507	0.29	0.15
Urban	27	5.33	0.72	650	0.52	0.21
Project Class						
Bridge	7	7.57	3.88	211	0.29	0.22
New location	2	15.50	0.19	39	1.51	0.07
Rehabilitate	6	3.33	0.10	118	0.31	0.03
Upgrade	12	5.00	0.10	136	2.13	0.33
Other	4	0.00		628	0.03	0.07
Design Standard						
3R	5	2.00	0.15	450	0.16	0.07
4R	18	6.22	1.32	365	0.85	0.27
Other	8	5.25	0.20	1101	0.09	0.06

Note: Highlighted values are statistically significantly different.

DISCUSSION AND CONCLUSIONS

To examine the effects of QLA and B SUE on project costs and delivery time, the researchers analyzed a large variety of project data at TxDOT by comparing projects that used SUE with a number of control projects. Compared with other SUE cost-effectiveness studies previously published, this analysis uniquely contributes to the current body of knowledge in the following aspects:

- Instead of estimating a SUE cost-benefit ratio, this study was intended to examine SUE effectiveness on project performance based on objective project data available at TxDOT data systems.

- Since the analysis was based on project data, findings are less subjective than previous studies based on personal opinions obtained through surveys or interviews.

- This study drew conclusions based on comparisons of a large variety of project performance measures between SUE projects and control projects.

- The study results are based on a relatively large number of TxDOT projects that used SUE mostly during design, including different project types in terms of location (i.e., rural and urban), project class, and design standard.

During the analysis, the research team undertook a significant effort in order to identify a sufficient number of SUE projects. The effort involved queries of TxDOT existing data systems, direct contacts to districts and DGN, and review of payment vouchers via FIN Imaging Service. At the end of the process, the research team was able to identify 32 SUE projects from several different districts representing multiple project classes and design standards. Those projects were then compared with a large group of control projects containing all TxDOT projects let between FY2005 and FY2009. To enable an in-depth and comprehensive assessment of SUE cost-effectiveness, the research team collected project performance data from a number of TxDOT data systems, including DCIS, FIMS, SiteManager, CIS, COD, and UAD.

The comparison of projects that used SUE to a control group of projects indicate that there is some evidence of a positive effect of SUE on several project MOEs. The findings of this analysis support anecdotal evidence from practitioners that almost uniformly described a positive impact of SUE on project performance. The major findings are summarized and discussed as follows:

- **Projects That Use SUE Services Tend to Be Larger Projects.** The analysis suggested that SUE projects in general were associated with projects that had a significantly higher design cost and involved more design man-hours. This observation was shown to be statistical significant for several difference project categories, such as urban, new location, upgrade, and 4R projects. In addition, results showed that projects involving SUE took longer to construct than control projects on average.

- **Projects That Use SUE Services Tend to Have a Lower Design Effort on a Per-Lane-Mile Basis.** The comparison of design man-hours per project and per project lane-mile between projects that did and did not use SUE showed that projects that use SUE involve more man-hours, but not significantly more man-hours per lane mile. Mean values for man-hours per lane-mile were smaller for all project categories, although the difference was only statistically significant in the case of 4R projects. Due to the limited sample size for most project categories, t-tests were not able to prove the differences were significantly different.

- **Differences in Mean Construction Cost Increases Did Not Show Consistent Trends.** Both projects that did and did not use SUE experienced mean cost increases of approximately ±5 percent. However, mean percent increases were only significantly different for rural projects, with a mean cost increase of 0.3 percent for SUE projects and 1.5 percent for control projects. In terms of per-lane-mile cost increase, differences between mean cost increases were only significantly different on a per lane-mile basis for urban and 4R projects. Here, urban SUE projects experienced a significantly *higher* cost increase than the control group, while 4R SUE projects experienced a significantly *lower* cost increase than the control group.

- **Projects That Used SUE Services Tended to Have a Longer Construction Duration, but a Shorter Construction Duration per Lane Mile.** Although SUE projects had a longer mean construction duration in some cases, many categories of SUE projects actually took shorter to construct on a per-lane-mile basis. In particular, t-tests suggested that the difference in mean construction duration per lane-miles was significantly lower for upgrade and 3R projects that used SUE services.

- **Projects That Used SUE Services Tended to Have Less Construction Delays.** When comparing construction delays, SUE projects had significantly less construction delays measured in both per-lane-mile additional construction days and percent of additional construction days for most project categories. T-tests suggested that the differences in construction delays between SUE projects measured by percent additional construction days were statistically significant for all projects, and rural, urban, upgrade, other project class, and 4R projects. Differences measured by additional days per lane-mile were significantly lower for SUE projects in the project categories rural, bridge, upgrade, other project class, and 4R projects.

- **Projects That Used SUE Services Tended to Have Lower Costs Related to Change Orders Associated with Utilities during the Construction Phase.** Although mean change order amounts were overall low for the group of projects that the research team analyzed, there were significant differences for projects that did and did not use SUE. Mean change order amounts were significantly lower for bridge projects. On a change order amount per lane-mile basis, t-tests showed that projects that used SUE had significantly lower change order amounts for all projects, and in the project categories rural, bridge, and 4R. T-tests also showed that bridge projects that used SUE had a significantly lower change order amount measured as a percentage of the project construction cost.

- **Projects That Used SUE Services Tended to Have Significantly More Utility Agreements, and Higher Utility Agreement Costs.** Several project categories had significantly more utility agreements for projects that used SUE than for projects that did not. These categories included all projects, urban, bridge, other project class, 4R, and other design standard. Utility agreements per lane-mile were not significantly different, except for the rural project category, where projects that did not use SUE had fewer projects than projects that did not use SUE. Mean cost of utility agreements per project were higher for projects that used SUE in the categories all projects, urban, bridge, and 4R. On an agreement amount per lane-mile basis, mean values were not significantly different, except in the project category 3R, where projects that used SUE had significantly lower mean agreement costs. This evidence could indicate that SUE services tend to be used for projects with complicated utility conditions.

- **Projects That Used SUE Services Tended to Have a Higher Number of Agreements That Were Not Executed.** This became evident during the analysis of UAD data. When compared with the control projects, projects that used SUE services generally had a larger percentage of utility agreements that were entered into the database but were not executed. The database did not provide the reason why agreements were not executed. However, a possible reason could be that the underlying utility conflict was resolved, and so the agreement was no longer needed. Another reason could be that TxDOT found that the utility was not reimbursable. The percent of utility agreements not executed per project was significantly higher for projects that used SUE in the project categories all projects, urban, upgrade, and 4R projects.

- **SUE Costs Constituted a Small Percentage of the Total Construction Costs.** Total cost of SUE services amounted to a mean of 1.85 percent of total construction costs. SUE costs were slightly higher for three types of projects: widen freeway, interchange, and new location freeway projects.

This analysis intended to assess SUE cost-effectiveness based on a comparison of a pool of SUE projects with control projects. Readers should notice that during the analysis the researchers were not able to control other factors that might have contributed to project performances. An example of the factors is the experience of the project manager and design engineers. Large projects tend to use more experienced project managers and design engineers, and therefore may result in more frequent use of SUE, better performances in relation to utilities, and/or better performances in project delivery.

During this analysis, the researchers intended to collect comprehensive project data for the calculation of project delivery time, costs, and other relevant MOEs. In the course of data collection, the researchers found that TxDOT was not tracking many needed data elements in the current data systems or had only recently started tracking these data items. For example, TxDOT has implemented Oracle Primavera P6 for tracking key milestones during the project development process. However, this system was implemented in 2009; during the time of this analysis, the districts did not fully implement and/or utilize the system. In addition, there is currently no database that stores data elements related to SUE contracts, work order, and payment information. As a result, most information lies with local staff and becomes lost over time and due to staff turnover. Therefore, it is necessary for TxDOT to develop strategies to retain the information either at the district level or in a central data system.

This research used 32 projects that availed of the SUE services. This was a relatively small sample size especially when comparing to the control group that contained a few thousand projects. If possible, future analyses should utilize more SUE projects. If data are available, it would be important to also compare projects with SUE services during design and those with SUE during construction.

CHAPTER 6: BEST PRACTICES FOR UTILITY INVESTIGATIONS

DEVELOPMENT OF BEST PRACTICES

An objective of this project was to develop best practices for utility investigations that can potentially benefit the TxDOT project development process. This development involved three major steps:

- Assemble draft best practices based on the findings of the review of utility investigation practices in other states and the online survey for TxDOT districts.
- Conduct stakeholder workshops to gather feedback on draft best practices and recommendations for additional improvements.
- Recommend final best practices based on stakeholder feedback.

As part of the review of best practices in other states, researchers identified trends and common practices among the states. The online survey attempted to extract information from practitioners at TxDOT about what has worked, what has not worked, and what elements of utility conflict management would be advisable to implement. This presentation of best practices can also serve as a decision-making framework for selecting and implementing practices that could benefit TxDOT with utility investigation activities. In this regard, it would be unreasonable to think that all recommendations and practices could be implemented immediately. However, it is possible to view the range of practices in context and narrow choices to implementable actions for the near future using the list presented here.

Categories of Best Practices for Utility Investigations

Chapter 3 highlighted current TxDOT utility investigation practices, while Chapter 4 provided a summary of innovative practices for utility investigations in several states. These practices were further examined and grouped into five general categories or approaches for how the practices are used, and how they might provide good examples for implementation at TxDOT. The five categories are:

- Policy and administrative approaches.
- Education and training.
- Procurement and contracting approaches.
- Project development processes (e.g., utility conflict matrix).
- Technology and information systems.

The best practices were also examined to identify possible trends, which the researchers sorted into these same general implementation categories. Additionally, best practices were evaluated based on the results of the TxDOT survey described in Chapter 3 that identified needs for strengthening utility investigation practices at TxDOT. For example, the wide variety of SUE QL practices reported in the survey results indicates a need for more standardized SUE policies across TxDOT agency-wide. Survey results also point to the need for education and training on

utility investigation (specifically in when and how to use SUE, and the benefits of SUE). The results from the questionnaire are used to justify and reinforce the recommendations.
The best practices and recommendation are also evaluated using three general criteria for the implementation, including the relative cost, its perceived benefits, and its relative complexity. The evaluation is based on the researchers' judgment in consideration of the results from the interviews and experiences reported in the literature. For example, a simple and short agency-wide policy could be issued to encourage SUE usage and its demonstrated benefits. This would be a relatively low cost, low complexity effort that would yield an immediate benefit. In contrast, developing a document management system for utility investigation reports is a high cost, high return, and highly complex implementation action (as VDOT's RUMS and PennDOT's UREDMS demonstrated).

Table 28 provides a summary of research recommendations followed by Table 29, which provides a summary of example practices in other states. Table 30 presents a summary of noteworthy practices that have been implemented by state DOTs within each of the five categories. Following the summary tables are detailed descriptions of each recommendation and a condensed version of example practices from various state DOTs. Note that TxDOT Research Project 0-6624 "Improving the Response and Participation by Utility Owners in the Project Development Process" was a parallel and complementary research effort. Not surprisingly, the recommendations resulting from both the 0-6631 and 0-6624 research projects share some common themes and content. The practices provided herein focus on utility investigation, but may overlap in some instances with 0-6624 emphasis on utility owner participation.

Table 28. Summary of Best Practice Recommendations by Implementation Category.

Implementation Category	Specific Implementation Action
Policy Approaches	
Multilevel committees	Statewide utility coordinating committee/working groups.
Agency-wide policy for SUE	Describe policy and requirements for SUE on all projects.
Agency outreach to stakeholders	Agency prepared educational briefing material (e.g., white paper) for legislators and stakeholders.
Standard operating procedures	Prepare SUE SOP for districts and divisions.
Education and Training	
Basic SUE training	Targets a broad audience, using a brief 1–2 hour format, focusing on SUE benefits and processes.
Advanced utility impact/utility conflict matrix training	Advanced SUE training for utility coordinators and designers involving utility conflict matrix.
Outreach/training for utility owners	Training for utility owners (similar to ODOT).
Procurement and Contracting	
Widespread availability	Any employee related to project can identify investigation need.
Widespread authority	Any project manager can approve SUE investigation.
Improved QA/QC	SUE provider qualifications, scope of services, quality control, minimum standards for submission, and review.
Project funding	Project budgets include SUE services and estimates.
Project Development Processes	
Utility impact/conflict analysis	SUE impact forms and conflict matrices for all projects.
Agency-wide uniform SUE criteria	Provide detailed guideline for agency-wide use of SUE.
Agency manual updates	Addenda and corrections to PDP, ROW, and Utility Manual.
Development of concurrence points	Utility conflict review at pre-determined stages in project development process.
Environmental review concurrency	Concurrent utility investigation and involvement with environmental reviews.
Quality Assurance	Develop SUE deliverables checklist.
Technology and Information Systems	
Utility project management systems	Develop software that provides utility project tracking scheduling and reporting.
Utility document management systems	Develop software to aid in the storage, retrieval, and utilization of utility investigation data.
Data archiving, sharing, uniformity, and asset management	Conduct pilot program for data archiving project.
Investigation of new SUE technology	Institute pilot project to investigate benefits of new and emerging utility investigation technologies.

Table 29. Recommended State DOT Best Practice Examples for Implementation Categories.

Implementation Category	State DOT
Policy Approaches	
Multitiered Committees	Florida
Policy on Utilities in ROW	Caltrans
Comprehensive SUE policy	Pennsylvania/Virginia
Multilevel MOUs	Ohio
Detailed SUE Manuals and Policies	North Carolina
Education and Training	
Training for Utility Companies	Ohio
Avoiding Utility Project Impacts Course	Georgia
Procurement and Contracting	
SUE Quality Control Requirements and Standards	Florida
Detailed SUE scope of services contracts with easy and early access to SUE services	Georgia
Design Concepts and Cost Estimating by SUE Providers	Maryland
Project Budgets include the cost of SUE services	North Carolina
SUE provider qualifications	Ohio
Project Development Process	
Utility Standards and Deliverables Checklists	Florida
Utility Impact Avoidance Process	Georgia
SUE concurrent with Environmental Review	North Carolina
Concurrence Points during PDP	Ohio
Utility Impact Form	Virginia
Technology and Information Systems	
VDOT Right-of-Way and Utilities Management System (RUMS)	Virginia
NCDOT SAP PMii program which provides utility coordination, and flowchart of production networks	North Carolina
UREDMS Web-based Document Management System	Pennsylvania

Table 30. Implemented Best Practices by State DOT and Implementation Category.

State DOT	Policy Approaches	Education & Training	Procurement & Contracting	Project Development Processes	Technology & Information Systems
Caltrans	X		X	X	
Florida	X		X	X	
Georgia	X	X	X	X	
Maryland	X			X	
North Carolina	X		X	X	X
Ohio	X	X	X	X	
Pennsylvania	X		X	X	X
Virginia	X		X	X	X

Policy Approaches

State DOTs use a range of policies and procedures to improve utility investigation and management. These types of policy best practices range from broad agency-wide policies requiring SUE to specific SUE procedures and SUE QL usage criteria. In general, states that have had SUE policies and practices in-place for many years have best practices in most of the categories mentioned above. Virginia, Pennsylvania, and North Carolina DOTs for example, have had SUE policies since the early 1990s. As a result these states have evolved not only policy mechanisms to advance SUE practices, but also have advanced, technology applications, project development processes, and SUE procurement and contracting requirements.

Policy Recommendations

Based on examples from other states, the following are policy approaches to improve utility investigations that TxDOT could implement:

- Policies to promote and standardize SUE practices internal to TxDOT, including:
    - Broad policies to establish minimum SUE investigation requirements at TxDOT.
    - Narrow targeted policies with specific changes and updates to SOPs and manuals (also applicable to project development process recommendations).
- Policies to improve coordination with utility owners and operators that are external to TxDOT, including:
    - Establishing coordinating committees and working groups between the TxDOT and utility companies in districts where these groups do not exist.
    - Establishing coordinating committees with oil and gas operators and pipeline owners

- Outreach to legislature and stakeholders external to TxDOT that educate about utility investigation issues:
    - Outreach to educate legislature on utility issues and challenges faced by state DOTs, municipalities, and utility companies.
    - Information and education to local development partners, such as cities, oil and gas, and utility owners.

Results of the agency-wide questionnaire conducted in Task 5 justified the recommended policy actions. Responses from the questionnaire indicate a general lack of awareness of SUE benefits. In particular, there were many responses of "don't know" when asked about expected return on investment for SUE. Additionally, low response rates to many questions may also indicate a lack of awareness or experience on the subject.

Table 31 summarizes the policy recommendations and also presents the researcher's evaluation of three criteria for implementing the recommendation, on a scale from low to high: relative cost, perceived benefits, and relative complexity. In general, policy actions are comparatively lower in cost and complexity but moderately beneficial. For example, a simple and short agency-wide policy could be issued to encourage SUE and its demonstrated benefits at comparatively little cost but with immediate benefit. Table 32 presents example policy approaches found at state DOTs, followed by a brief description of the cited example.

Table 31. Policy Implementation Recommendations.

Proposed Policy Recommendations	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity
Multilevel Committees	Statewide Utility Coordinating Committee/Working Group	Low	Low	Low
Agency-wide/ Statewide Policy for SUE	Agency-wide policy describing the benefits and minimum requirements for SUE	Low	Medium	Low
Agency Outreach to Legislators and Policy Makers	Agency prepared education briefing material for legislators and policy makers (e.g., white paper)	Low	Low	Medium
Standard Operating Procedures	Prepare SUE SOP for Districts and Divisions	Low	Medium	Low

Table 32. Summary of State Policy Approaches.

State DOT Example Policies	State DOT
Multitiered MOUs/Committees	Florida
Policy on Utilities in ROW	Caltrans
Multilevel MOUs	Ohio
Documented savings resulting from SUE practices	Pennsylvania

Florida Multitiered Committees

Multitiered committees in Florida, which combined with explicitly stated responsibilities for state DOT and utility owners, resulted in a dramatic reduction in utility-related claims. The multitiered committees included the following:

- Metropolitan utility coordinating groups. These committees operate at the local level to address conflicts among stakeholders, including utilities and governmental agencies.

- Florida Utilities Coordinating Committee. Established in 1932, FUCC is a state-level association of stakeholders that strives for better relations and a clearer understanding of plans and issues affecting those stakeholders. FUCC includes a number of subcommittees that advise the committee on items such as governmental procedures and operational methods, utility accommodation policies, utility easement dedications, and permit handling.

- District liaison committees. These committees are district-level committees that convene semiannually with the goal to facilitate utility adjustments that maximize safety to the public and workers in the field (both highway and utility); protect highway and utility facilities; accelerate project delivery; and minimize cost, inconvenience, and delays.

- AASHTO/IRWA Liaison Committee. This committee encourages mutual advance planning procedures (i.e., the focus is on advance planning, not design-level or reimbursement issues).

FDOT's responsibilities included the following:

- Furnish annually a five-year plan, including probable construction dates.
- During corridor studies, contact all utilities along the corridor.
- Notify utilities of all hearings along the corridor.
- After the corridor selection, send preliminary plans to the utilities.
- Consider changes recommended by the utilities to reduce utility costs whether or not such costs are reimbursable.
- Establish liaison committees in all districts and arrange for regular meetings among them.
- Include utilities in pre-construction meetings.

Utility owners' responsibilities included the following:

- Review plans for new utility construction and major changes.
- Provide area maps of their facilities.
- Provide data on utility structures and on prospective routes.
- Cooperate with the liaison committee.
- Review preliminary plans provided by the DOT.

Multilevel Memorandum of Understanding

ODOT is currently pursuing a new system of Memoranda of Understanding (MOUs) with utility companies. While state DOTs in the United States have used MOUs for some time, the ODOT example features a multilevel MOU initiative that identifies and recognizes the importance of good utility relocation practices to provide efficient and cost-effective highway project delivery for ODOT. This recognition begins at the highest levels of leadership of DOT and utility company, and ensures that utility work is performed in a manner that provides benefits to both utility company and ODOT. The MOU initiative provides an opportunity for each agency to understand one another's concerns and use the resolution of those concerns to save time, money, and resources for both parties.

The MOUs are created at various levels of operation between the parties. In the first level, leadership of both agencies signs and sets forth general principles and intent of parties to work together cooperatively. It also emphasizes identifying efforts that are created to address the needs of each party. In the second level MOU, middle management of both parties signs and defines the roles and responsibilities of each as well as standards, specifications and general procedures for conflict resolution. The third level MOU is project specific; project leaders from both parties sign. The content details specific provisions of the construction contract and utility relocation schedule. This overall effort fully integrates utility relocation activity into all aspects of operation for both the DOT and the utility company.

Caltrans High/Low Risk Policy

California has a policy that determines utility data requirements based on the risk to the public if an underground utility facility is accidentally damaged, sometimes called the "high/low risk policy" (*23*). This policy relates to Section 4216 of the California Government Code, which provides the requirement for statewide One-Call system and include definitions for high risk utilities (*24*). Examples of high risk utilities are:

- High-pressure natural gas pipelines.
- Petroleum pipelines.
- Pressurized sewer pipelines.
- High-voltage electric supply lines, conductors, or cables.
- Hazardous materials pipelines, e.g., pipelines transporting oxygen, chlorine, or toxic gases.

Low-risk utilities may be located using QLB. For example, Caltrans normally does not procure potholing services for culverts and cross-drains. However, a greater level of investigation may occur if the project engineer appeals to his or her supervisor. Exceptions to this policy that would result in a lower level of investigation are also possible, but occur very rarely, and the chief of the design division must sign.

This policy is applicable to the design phase of a project. For the construction phase, the contractor must follow applicable statutes, which require that all utilities be located and marked out on the ground by a regional notification center prior to any excavation (*59*).

Pennsylvania General Utility Practices

The Pennsylvania DOT (PennDOT) adopted SUE practices in the 1990s. Nearly all projects in the state undergo a minimum of QLD or QLC data collection. Beyond QLD and QLC, the need for SUE is determined based on the outcome of an impact analysis using a spreadsheet called the "SUE Utility Impact Form." In 2007, the Pennsylvania Transportation Institute of the Pennsylvania State University (PSU) developed this procedure based on an in-depth benefit-cost analysis of 10 SUE projects that PennDOT districts have executed (*40*). The PSU research shows that, compared with projects not utilizing SUE, the total cost savings of SUE projects may range from 10 percent to 15 percent on a typical project. The study found no relationship between SUE benefit and SUE cost and found further no relationship between utility complexity level and the total project cost. However, there appeared to be a strong relationship between SUE benefit-cost and utility complexity level. The benefits and cost of SUE increases as the utility complexity level of the project increases. The conclusion in the research is that QLA and QLB should be used based on the complexity of the buried utilities at the construction site to minimize risks and obtain maximum benefits. The PSU study estimated that an average of $22.21 is saved for every $1.00 spent on SUE. When the overall cost of the project is taken into consideration, the money spent on SUE is minor when compared to the cost savings of avoiding unexpected utility conflicts and unnecessary utility relocations.

Education and Training

This category for implementation reinforces other implementation efforts and offers the potential for a significant return on investment. Some DOTs have had success in developing and delivering training including Ohio and Georgia. Other states have recognized the need for training and even certification for DOT employees involved in utility investigation. For example, MDOT representatives thought a certification program should acknowledge the highly specialized skills that are required for utility coordination staff to conduct thorough utility investigations. Other specialized areas of the project development process such as right-of-way, construction, planning, and design already have some type of certification program at MDOT.

Education and training approaches used by state DOTs for utility investigation include:

- Overall staff and capacity development with a broad agency-wide focus.
- SUE and utility management and coordination with a narrow focus on utility coordinator and designers (similar to GDOT).
- Training and outreach targeting industry relationships (similar to the ODOT).

The justification for education and training is evident in the agency-wide questionnaire responses conducted in Task 5. This includes:

- Uncertainty from respondents on the authority to request SUE, and lack of knowledge on factors that influence SUE (see Questions 6–9).
- Uncertainty from respondents on the SUE procurement process, and indications that there are no procedures or criteria for SUE deliverables (see Question 26–27).
- A lack of knowledge and the response "don't know" when asked about expected return on investment for SUE (see Question 28).
- A need for training was also identified in 0-6624.

Table 33 shows the education and training examples presented earlier. The table provides a judgment on the three criteria for implementation including relative cost, perceived benefits, and relative complexity.

Table 33. Education and Training Recommendations.

Education and Training	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity
Basic SUE Training	Targets a broad audience, using a brief 1-2 hour format, focusing on SUE benefits and processes	Low	Medium	Low
Advanced Utility Impact Training	Advanced SUE Training for practitioners (similar to GDOT)	Medium	Medium	Low
Outreach Training to Utility Companies.	Training for utility designers (similar to ODOT)	Medium	Medium	Medium

Table 34 shows the education and training examples at state DOTs are presented followed by a brief description of the cited example. In general, there were fewer examples of education and training practices available from the review in Task 3. This same lack of education and training resources was noted in the SHRP2 Report "Encouraging Innovation in Locating and Characterizing Underground Utilities" (*3*).

Table 34. Summary of State Education and Training Practices.

Education and Training Example	State DOT
Training for Utility Companies	Ohio DOT
Avoiding Utility Project Impacts Course	GDOT

Ohio DOT Training for Utility Companies on Transportation Design

As part of improving the utility investigation process and utility owner participation during this process, ODOT conducts training sessions for utility company staff. The training sessions allow utility company staff to become more familiar with the ODOT design and construction plans and their interpretation. This improved familiarity with ODOT design plans helps utility companies to mark the locations of their utility facilities accurately on ODOT plans, which in turn are used during SUE investigations and construction activities. This training has been of significant benefit in coordinating both utility investigation and relocation efforts.

Georgia's Avoiding Utility Project Impacts

GDOT has developed a training course called "Avoiding Utility Project Impacts" that provides guidance on how to make effective use of the utility conflict matrix and how to perform a utility impact analysis. The training course shows how to weigh the cost of adjusting a major utility against a change in the roadway design and is now mandatory for all GDOT designers.

Procurement and Contracting

State DOTs typically have statewide or district-wide contracts for SUE providers. Best practices in procurement and contracting SUE services center on several issues including SUE provider qualifications requirements, quality control for SUE deliverables, having widespread availability, and SUE data management.

State DOTs use procurement and contracting approaches for utility investigation, including:

- Widespread availability of SUE services to ensure designers and project managers have ready access to SUE services.
- Widespread authority to use SUE in order to give access to SUE services and resources as soon as it is needed in the project development process and avoid delays caused by waiting for purchase authorities and approvals.
- Project budgets that includes funding for the cost of SUE investigations.
- Improved Quality and Quality Control of SUE contractor.

The justification for procurement and contracting improvements is evident in the agency-wide questionnaire described previously. This includes:

- Uncertainty indicated by respondents on the authority to request SUE, and lack of knowledge on factors that influence SUE use (see Questions 6–9).
- Uncertainty indicated by respondents on the SUE procurement process, and indications that there are no procedures or criteria for SUE deliverables (see Question 26–27).

Table 35 shows the procurement and contracting recommendations. The table also provides the relative cost, perceived benefits, and its relative complexity of the practice. Generally, the researchers observed that greater benefits were found in procurement practices that emphasized having easy access and availability of SUE services. Additionally, those states that emphasized strict pre-qualification standards for SUE providers and deliverables generally reported greater benefits.

Table 35. Procurement and Contracting Recommendations.

Procurement and Contracting	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity
Widespread availability	Any GDOT employee related to project can identify need	Low	Medium	Low
Widespread Authority	Project manager approval	Low	Medium	Low
Improved QA/QC	SUE Provider qualifications, scope of services, and quality control	Medium	Medium	Low
Project Funding for SUE	Project budgets include SUE services and estimates	Medium	High	Medium

Table 36 shows procurement and contracting examples at state DOTs with a brief description of the practice.

Table 36. Summary of State DOT Procurement and Contracting Practices.

Procurement and Contracting Examples	State DOT
SUE Quality control requirements and standards	Florida
Detailed SUE scope of services contracts with easy and early access to SUE services	Georgia
Design Concepts and Cost estimating by SUE Providers	Maryland
Project Budgets include the cost of SUE services	North Carolina
SUE provider qualifications	Ohio

Florida District-Wide SUE Scope of Services Quality Control

Utility investigations are procured through district-wide multiyear consultant contracts, a district General Engineering Contract (GEC), or through the individual stand-alone consultant design contracts. FDOT requires all consultants to follow the ASCE 38-02 guidelines for SUE work (*4*).

Each FDOT district has a SUE contract with multiple SUE providers. These contracts are specific to the district and the standards are also specified for that district. As part of their district-wide SUE scope of services, FDOT requires SUE consultants to have a stringent quality control process including the following elements (*27*):

- **Quality Reviews.** The consultant is required to make quality reviews to ensure the organization is in compliance with the requirements cited in the scope of services. The quality reviews must evaluate the adequacy of materials, documentation, processes, procedures, training, guidance, and staffing included in the execution of this contract.

- **Quality Assurance Plan.** The quality assurance (QA) plan details the procedures, evaluation criteria, and instruction to the organization to assure conformance with the contract. Significant changes to work requirements may require the consultant to revise the QA plan. The plan must include, among other things:

    - A description of the consultant's quality control organization and its financial relationship to the part of the organization performing the work under the contract.
    - The consultant's QA methods to monitor and assure compliance of the organization with the contract requirements for services and products.
    - The types of records that will be generated and maintained by the consultant during the execution of the QA program.
    - The methods used by the consultant to control the quality of the subcontractors and vendors.

- **Quality Records.** The consultant is required to maintain adequate records of the QA actions performed by the organization, (including subcontractors and vendors), in providing services and products under this contract. All records shall indicate the nature and number of observations made, the number and type of deficiencies found, and the corrective actions taken. All records are subject to audit review and are required to have a second level of peer review.

Georgia DOT Process to Request SUE

GDOT has formalized the process to request SUE services for a project. Any GDOT employee involved with a project may identify a candidate for SUE services. However, only a project manager, district utilities engineer, or state subsurface utilities engineer can actually submit a request for SUE services.

Requests can be made any time during the project development process, as soon as project enters the six-year Construction Work Program (CWP), i.e., during concept development, preliminary design, final design, or construction phase. Fill out the request form, including requested quality level, utility impact rating, and current project development phase, then submit it to the state subsurface utilities engineer. The latter has a two-week approval time frame to approve or deny the request.

Maryland DOT Multi-Year SUE contracts

The Maryland DOT has six SUE contracts with various SUE consultants that are valid for three years. The contracts have a value of $2 million each for the duration of the contract, or a total of $12 million. The multi-year, multi-company contracts allow the state to procure SUE work on short notice. The Maryland DOT ensures that the SUE consultants have the necessary qualifications, experience, and technology to meet the data collection standards defined in ASCE 38-02 (*4*).

The scope of services for SUE contracts is not limited to only utility investigations. For instance, SUE consultants are sometimes contracted to design preliminary utility relocations or "design concepts" for the DOT. In other cases, they are contracted to assist in developing preliminary cost estimates for utility relocations. These preliminary analyses help the SHA judge a project's potential for utility conflict impacts and the options for relocating utilities.

North Carolina DOT Project Budgeting for SUE

The NCDOT Utility Section has recognized the importance of including SUE activities early in the budgeting process so that funding for SUE is included on cost and budget for projects from the beginning, instead of being an add-on later in the project. By getting involved in programming and budgeting process for projects, the NCDOT Utility Section has helped ensure that SUE is available early in the projects. NCDOT also emphasizes the importance of early involvement with utility companies. In NCDOT's experience, using SUE early in the project development process enables making better and informed decisions earlier in the process.

Ohio DOT SUE Consultant Contracts and Requirements

Currently, ODOT has statewide contracts with four SUE providers, which are worth $1.5 million each for the duration of a biennium. The geographical locations of the SUE providers ensure that the entire state is easily accessible to the SUE consultants. A statewide contract is typically used when utilities are found during construction and a higher quality level SUE is immediately required. Every district is encouraged to use QLB and QLA data collection and has access to SUE providers for use in their project development process.

ODOT pays per foot to designate, per test hole to locate, and hourly labor and overheads. Basic deliverables for utility information are generally a CAD file, or a plan sheet that has utility information in plan view for QLA, QLB, QLC, and QLD, and in profile view for QLA. ODOT typically prefers to have the horizontal and vertical locations of mainline subsurface utilities and their associated attribute information collected and placed on construction plans to be utilized for design and utility coordination.

Ohio has strict pre-qualification requirements for all SUE consultants. They must demonstrate that they have the staff, equipment, experience, and resources to perform SUE services at all quality levels, as follows (*60*):

- The consultant must have at least one professional engineer and one professional surveyor both registered in Ohio that are employees of the firm, each with a minimum of two years' experience in subsurface utility engineering.
- A minimum of two additional full time staff, each with a minimum of two years' experience in successfully providing all quality levels of subsurface utility engineering using the equipment specified next.
- Equipment available to perform the full range of SUE services including one geophysical prospecting vehicle equipped with various electromagnetic/acoustical designating

equipment (QLB), one vacuum excavation non-destructive vehicle (QLA), and at least one GPR system.
- The consultant must provide a single project manager to represent the firm in a liaison capacity with the department.
- Capability of providing both electronic and certified hard copy deliverables in acceptable ODOT electronic and plan presentation format.
- Documented company plan for current quality assurance and quality control procedures.

Project Development Processes

State DOTs that have a long history of conducting SUE as a matter of practice have developed a wide range of project development processes including, detailed process manuals, checklists, impact/conflict criteria and matrices. The best practices that DOTs use in their project development processes also represent the greatest quantity of content and examples from which to choose. This section describes only a sampling of notable practices that characterize the wide range of project development processes involving SUE investigation at state DOTs.

Project development processes recommended for utility investigation include:

- Establishing uniform SUE criteria, impact forms, and conflict matrices.
- Standardizing SUE QL Criteria:
    - Early QLD-C by 30 percent on all projects.
    - QLB by 60 percent design.
    - QLA by 60–90 percent design.
- Providing detailed investigation procedures in PDP, Utility, and ROW manuals.
- Including funding for SUE in the project budgeting process.
- Including quality assurances and SUE concurrence points during the PDP.

The justification for procurement and contracting recommendations is evident in the agency-wide questionnaire described previously, including:

- Uncertainty of respondents on the authority to request SUE, and lack of knowledge on factors that influence SUE use (see Questions 6–9).
- Uncertainty of respondents on the SUE procurement process, and indications that there are no procedures or criteria for SUE deliverables (see Question 26–27).

Table 37 presents the project development process recommendations and includes a judgment on the recommendation's relative cost, benefits, and relative complexity. Based on several examples from the study of best practices in Task 3, the use of utility impact/ conflict analysis provides a relatively high benefit for relatively low cost and complexity.

Table 37. Project Development Process Recommendations.

Project Development Processes	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity
Utility Impact/ Conflict Analysis	SUE Impact forms and conflict matrices for all projects	Low	High	Low
Agency-wide uniform SUE Criteria	QLD-C by 30% on all projects QLB by 60% design QLA by 60%–90% design	Medium	High	Low
Detailed Manuals	Addenda and corrections to PDP, ROW and Utility Manual	Low	Medium	Medium
Concurrence Points	Utility review at pre-determined stages of project development	Medium	High	High
Environmental review concurrency	Concurrent involvement with environmental reviews and information	Low	Medium	Medium
Quality Assurance	SUE deliverables checklist	Low	Medium	Medium

Project development process examples from state DOTs, as mentioned previously, are abundant. Table 38 provides a sample of these practices by state DOT.

Table 38. Summary of State DOT Project Development Process Practices.

Project Development Process	State DOT
Utility standards and deliverables checklists	Florida
Utility impact avoidance process	Georgia
SUE concurrent with environmental process	North Carolina
Concurrence points during project development process to review utility conflicts	Ohio
Utility impact form	Virginia

Florida SUE Standards and Deliverables Checklist

FDOT's District 2 has developed detailed SUE standards (based on the ASCE 38-02 guidelines) and a deliverables checklist of key items that SUE consultants must provide in their services. The district requires QLB during the initial design phase up to 60 percent design to identify potential utility conflicts. QLA is performed only after 60 percent design. This reduces the cost that might be incurred when performing unnecessary QLA before conflict location can properly be identified during design.

The SUE standards also require SUE services and deliverables to be in accordance with the FDOT current procedures. It requires all field survey data to be gathered by using an electronic field book and in a Computer-Aided Civil Engineering (CAiCE) software readable format. The SUE consultant is responsible for depicting the subsurface utilities utilizing the ASCE standards that FDOT identified for a particular project (*26*).

FDOT requires all QLB data to be recorded on a "Designating Form" designed for that purpose. FDOT notifies the consultant of which form should be used on a project-by-project basis, based on FDOT needs for the particular project. In addition to the Designating Form, the SUE consultant provides a report detailing any discrepancies found between existing utility owner plans and what was designated in the field.

Georgia Utility Conflict Matrix

GDOT has been involved in the development of a utility conflict matrix concept since 2005 (*31*). The purpose of the utility conflict matrix is to provide designers sufficient information to develop design changes and avoid utility conflicts. GDOT uses the utility conflict matrix on all projects that involve QLB or QLA data collection. In practice, it has been a challenge to update the utility conflict matrix with information from the design group. GDOT is planning to make changes to the process to facilitate the tracking of changes to the utility conflict matrix that the design group made, which will also allow the determination of cost savings to the project due to the use of the utility conflict matrix.

NCDOT Procedure Manuals and Environmental Coordination

NCDOT has two manuals that provide information and practices about SUE: The *NCDOT Highway Design Branch Policy and Procedure Manual* and the *NCDOT Highway Design Branch Design Manual* (*33*, *34*). In addition, NCDOT provides a general guideline on SUE and the activities included in data collection at a particular quality level (*35*). These documents have been useful for project managers that are new to the SUE process and have helped to make information about best practice available to a wider audience within NCDOT.

NCDOT makes efforts to combine SUE data collection with environmental data collection. For example, Chapter 20 of the *NCDOT Highway Design Branch Policy and Procedure Manual* provides that the environmental planning document should discuss the magnitude and impact of utility conflicts (*33*). The inclusion of SUE data and identification of utility conflicts in the environmental planning document has been an accepted and useful practice in the past.

Ohio Concurrence Points and General Utility Practices

The Ohio Department of Transportation (ODOT) uses SUE extensively in its project development process. ODOT has placed a high priority on improving the communication with various stakeholders (including utility owners) during the project development process and stresses the importance of stakeholders' active participation in this process. As part of this effort, ODOT identified several key concurrence points, which are pre-defined stages of the project development process where the process is put on hold until stakeholders are consulted on key aspects of the project, including utility owners who are involved in this process. Various conflicts, concerns and issues, are discussed and resolved at these stages amid input from these stakeholders. The project is put on hold until all issues are resolved at these concurrence meetings. Concurrence points exist during the utility coordination process to identify and tackle any utility conflicts identified during the SUE process.

Within the larger project development process, ODOT has a well-defined utility investigation process in which highway plans are provided to utility owners along with a request to review and provide pertinent as-built or other existing QLD utility information. The next point of concurrence in the process is a face-to-face meeting and preliminary discussion of potential utility conflicts with utility coordinators who represent districts on all utility investigation issues. The goal of the meeting is to ensure that there is a clear understanding of the potential for utility impacts, resolve conflicts as possible, and discuss the need for SUE at better quality levels.

Pennsylvania Utility Impact Analysis

The SUE Utility Impact Rating Form is designed to recommend appropriate quality levels of SUE based on a utility impact score. The SUE Utility Impact Form was developed to address the legal requirements and comply with the state and federal laws (*41*). The SUE Utility Impact Form provides an analysis to determine if SUE use is "practicable," when SUE should be considered on a project, and what utility quality levels should be utilized based on an analysis of project criteria. The form is utilized to comply with the Pennsylvania "underground utility damage prevention law" (*42*). Utility impact rating refers to the utility complexity for a given project, section, or location.

The SUE Utility Impact Form involves three steps in which users answer a series of questions. Depending on the answers, a user might continue from one step to the next or might screen out of the process. If step 3 of the process is required, the form calculates a utility impact score (UIS) based on a series of so-called complexity factors that in combination provide an estimate of the project's complexity with regard to utilities. Answers can be provided on a range from 1 to 3 indicating the expected utility impact for that question (e.g., low to high, simple to complex, or good to fair.) Figure 34 in Chapter 4 provides an overview of the complexity factors and answer options that are used to calculate the utility impact score.

Technology and Information Systems

Technology and information system approaches can range from back-office technology such as document management systems, to field investigation techniques, utility databases and mapping software, ground penetrating radar, and utility tagging technologies. The range of technologies is quite broad. Many of these types of practices can be found in the literature, in particularly in SHRP 2 Report S2-R01-RW "Encouraging Innovation in Locating and Characterizing Underground Utilities" (*3*). For this task, the research team limited the presentation of technology and information systems to those that are state-of-the-practice versus state-of-the-art.

- Utility project management systems – Develop software that provides utility project tracking scheduling and reporting to improve investigation process efficiency.

- Develop utility document management systems (software) to aid in the storage, retrieval, and utilization of utility investigation data (similar to Penn DOT/VDOT). These systems have proven to save time and improve efficiency.
- Data archive technology and data sharing technologies. Improved data sharing between utility owners and DOTs has been cited in other states as problematic. VDOT provided utility owners and contractors with licenses for project CADD platforms. Additionally, a pilot program to establish a data archive for easier retrieval of as-built drawings and utility locations would improve future.
- Pilot projects for innovative and emerging utility investigation, detection, and mapping technologies such as 3-D mapping and visualization technologies.

The responses obtained in an agency-wide questionnaire conducted in Task 5 have reinforced the justification for technology and information system recommendations. This observation includes:

- On questions related to "issues associated with utility data quality," the response rate was very low. This may indicate that data quality is a low priority. However, data quality is generally a high priority in other states practices reviewed.
- Survey participants that were asked about the use of information management systems used CAD almost as much as spreadsheets to record data or manage utility information. There was a relatively high use of word processing, and 37 responses with 97 skipping the question. The low response rate may indicate a lack of interest in technology applications and/or low usage of information technology. It also may indicate there is little or no uniformity in data collection and archiving (Question 41).

Table 39 presents a summary of technology and information system recommendations listed above. The table includes a judgment on the recommendation's relative cost, perceived benefits, and relative complexity. It is apparent from the examples provided and study of best practices in Task 3, that technology and information systems generally provides a relatively high benefit for relatively high cost and complexity. Meanwhile, Table 40 lists the summary of technology and information practices.

Table 39. Technology and Information System Recommendations.

Technology and Information Systems	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity
Utility Project management systems	Develop software that provides utility project tracking scheduling and reporting.	High	High	High
Utility Document management systems	Develop software to aid in the storage, retrieval, and utilization of utility investigation data (similar to Penn DOT/VDOT).	High	High	High
Data archiving, sharing, uniformity, and asset management	Provide utility owners and contractors with licenses for project CADD platforms. Pilot program for data archiving.	Medium	Medium	Medium
Investigation new technology (e.g., GPR)	Institute pilot project to try new and emerging investigation technologies.	Medium	High	High

Table 40. Summary of Technology and Information Practices.

Technology and Information Systems	State DOT
NCDOT SAP PMii program that provides utility coordination, and a flowchart of production networks	North Carolina
UREDMS Web-based Document Management System	Pennsylvania
VDOT Right-of-Way and Utilities Management System (RUMS)	Virginia

North Carolina Scheduling, Tracking, and Reporting System

To improve utility coordination, NCDOT uses a project management system called Scheduling, Tracking, and Reporting System (STaRS) (*36*). The development of the system started in 2001, was implemented as "Project Management Improvement Initiative (PMii)" in 2004, and renamed to STaRS in 2007. STaRS is a centralized, integrated scheduling management tool that uses SAP R/3 software. This tool provides a flowchart of production networks with activities and activity elements that help with utility coordination activities. For example, the system specifies for each project when preliminary utility relocation plans are due, when NCDOT should review these plans, when these plans should be discussed with the utility owner, when utility relocation plans should be complete, and when utility permit drawings should be submitted.

Pennsylvania UREDMS

A notable practice at PennDOT is the use of a web-based electronic document management system called Utility Relocation Electronic Document Management System (UREDMS) (*43*). The system is designed to work with utility relocation documents using IBM® FileNet® software. UREDMS functions largely as an electronic filing cabinet. The UREDMS external web interface provides PennDOT's business partners with the ability to securely submit and view utility relocation documents using the Internet. A notable practice at PennDOT is the use of a web-based electronic document management system called Utility Relocation Electronic Document Management System (UREDMS) (*43*). The system is designed to work with utility relocation documents using IBM® FileNet® software. UREDMS functions largely as an electronic filing cabinet. The UREDMS external web interface provides PennDOT's business partners with the ability to securely submit and view utility relocation documents using the Internet.

Right of Way Utilities Management System

The VDOT Right of Way and Utilities Management System (RUMS) is a system that was implemented in 1999 and is based on proprietary software VDOT developed (*44*). RUMS provides up-to-the-minute highway project status reports through ad hoc queries served over a secure intranet. RUMS also enables forms processing and web-based reporting. VDOT also developed a web-enabled version of RUMS that has an intuitive user interface simple enough for a new user to quickly become familiar with the system and powerful enough for an advanced user to quickly navigate to specific information. Key functions of RUMS include the following (*44*):

- Providing metrics of current highway project status.
- Centralized management of appraisal forms, letters of correspondence, and other documentation, which allows right-of-way and utilities staff to generate, customize, store, and retrieve documents.
- Automated assignment and reassignment of work to division agents.
- Interfacing with VDOT's mission-critical project and program management system.

CONDUCT STAKEHOLDER WORKSHOPS

Overview of Workshops

The research team planned and conducted workshops in Dallas, Houston, Odessa, and San Antonio. Several weeks before each workshop, the research sent out an invitation to potential workshop participants. On the day of the workshop, the research team gave a brief overview of SUE technology and practices with the respect to the TxDOT project development process, followed by an overview and examples of several potential best practices for utility investigations. The research team provided a handout for each participant including an agenda (Figure 47), tables to record comments and feedback for each potential best practice, additional background documentation for some best practices, and presentation slides. In total, 71 participants attended the workshops, including 58 TxDOT personnel, five consultants, three utility company representatives, a representative from Texas 811, and four TTI personnel. TxDOT officials from 23 districts participated in the workshops (Figure 48).

Texas Transportation Institute

Texas Department of Transportation

Best Practices for Utility Investigations in the TxDOT Project Development Process – Stakeholder Workshop in Dallas

Dallas District Office, Dallas Room, December 9th, 2011, 9:00 AM – 12:00 PM

9:00-9:20	**Session 1** **Introductions**	Participant self-introductions Review workshop objectives	20 minutes
9:20-10:00	**Session 2** **Overview of SUE and PDP**	A brief overview of SUE and the PDP.	40 minutes
10:00-10:30	**Session 3 – Part 1** **Utility Investigation Practices**	Best practices implementation: What practices are right for TxDOT, what approaches are needed? • Policy and administrative • Education and training	30 minutes
10:30-10:45	**Break**		15 minutes
10:45-11:45	**Session 3 - Part 2** **Utility Investigation Practices**	Best practices implementation: What practices are right for TxDOT, what approaches are needed? • Procurement and contracting • PDP opportunities • Technology and information systems Activity #1- Participants will provide feedback using a moderated discussion and feedback forms.	60 minutes
11:45-Noon	**Session 4** **Workshop Review and Summary**	A capstone and summary of the workshop.	15 minutes

Figure 47. Sample Workshop Agenda (Dallas Workshop).

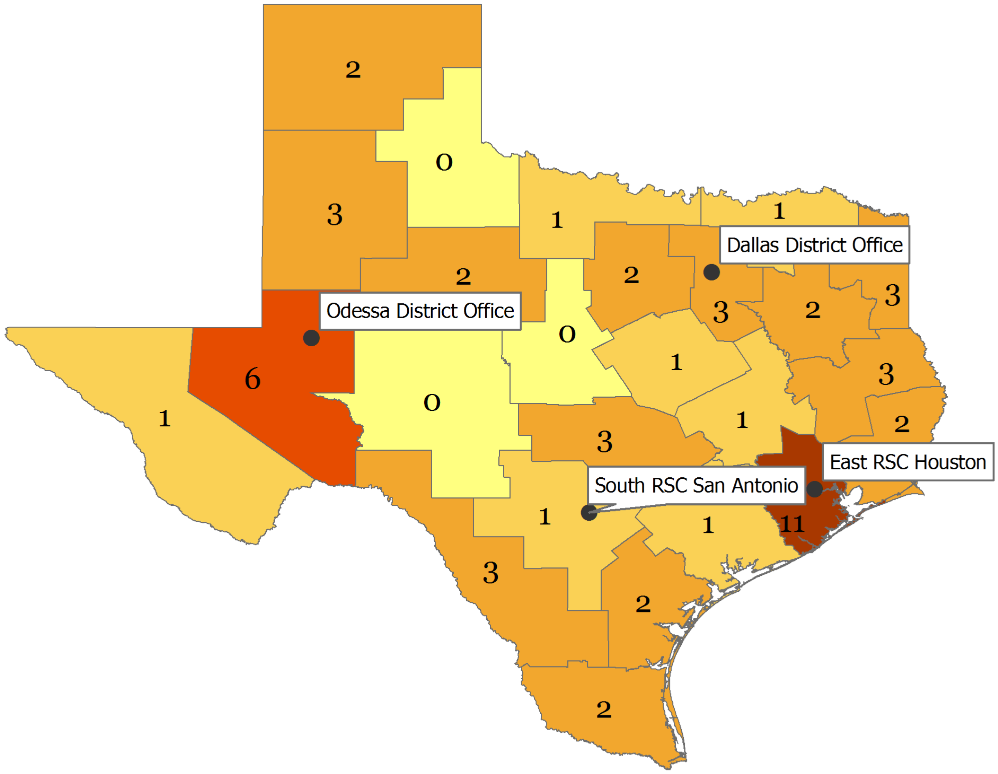


Figure 48. Number of TxDOT Officials Participating in Workshops by District.

The research team solicited comments from participants about the general use of utility investigation technology and SUE, the results of the TxDOT survey, and for each best practice outlined in the workshop documentation. After presentation of each best practice, workshop participants were asked to indicate if the best practice presented would be appropriate and useful for TxDOT or not. Possible answers were "yes," "not sure," or "no." In addition, workshop participants were asked to provide comments as appropriate for each best practice. The following presents a summary of comments received and a combined ranking of the best practices.

Comments on Utility Investigation Technology and SUE Technology

Participants at the four workshops focused on different aspects of the presentation. Some rural districts commented that they rely mostly on SUE data that utility owners provided, including test hole data, and only use a SUE provider if SUE data are not available from utility owners. Some participants highlighted that a phased approach is typical, where utility investigations start with less accurate information and additional, more accurate information is collected as needed as the project progresses.

Participants in East Texas noted that GPR SUE methods are often not effective due to soil conditions. Participants also commented that for longitudinal lines, approximate location data are typically sufficient. Crossings, however, typically require accurate location data, including depth. Exceptions are pipelines, which regardless of orientation have often caused significant issues during the construction phase in the past. Therefore, TxDOT should always determine the exact location of pipelines within project limits. Further, if TxDOT acquires new right-of-way for a project, it is critical to locate all utilities in the new right-of-way including depth information. Since these installations are outside the state right-of-way, utility accommodation rules did not apply at the time of installation, so they might be installed at a shallower depth than allowable under state rules.

There was consensus among participants that if done right, SUE is a fine investment that can provide a significant return on investment. There was less consensus on what return to expect, since there are many factors that affect that value, and it is difficult to quantify certain risks. For example, detailed location information can minimize the risk of damaging high-pressure pipes in addition to saving time and efforts and avoiding project delays. However, funding for utility investigation activities at QLB or QLA is often unavailable, which remains a frequent and widespread issue.

Comments Survey Results and General SUE/Project Development Process

Many districts commented that they do not currently have any guidelines for the use of SUE. Some districts are unfamiliar with the ASCE/CI standard 38-02 and therefore do not use it. Others were familiar with the standard but noted that it is not freely and readily available.

Some districts use checklists during the project development process, but most districts rely on the experience of the staff working in the utilities section. Frequently, district participants were unsure about how to transition from QLD and QLC data collection, which can be considered standard practice, to QLB and QLA data collection. Some districts avoid QLB data collection all together, for reasons related to funding, lack of experience, and lack of guidance.

All districts mentioned that compressed project timelines are the source of many project issues. Today, projects have much shorter timelines but project regulations and requirements, including utility coordination requirements, have been largely unchanged. As a result, projects get delayed more frequently.

Some districts reported that utility owners or contractors do not always follow permits, installing utilities at depths different from those specified in the permit. This is a major issue that happens quite frequently; as a result, utility installations require continuous tracking and inspections. However, districts typically lack the manpower to conduct these inspections, so many utility issues are not dealt with until they become a problem during the construction phase.

Possibly the biggest issue in the process of managing utility conflicts, according to some participants, is the uncertainty whether TxDOT projects move forward as planned, or are delayed, or even canceled. The funding reliability of TxDOT projects is a significant issue for utility companies. Projects that TxDOT delays for funding or other reasons can severely impact or even derail the budgeting plans of utility owners. The cancelation or indefinite delay of projects has increased in many areas of the state to a point where utility companies do not take an interest in a project until there is high certainty that a project will be funded, presumably very close to letting. However, at this time in the process it is too late to adjust utilities in a timely manner. Because projects are pulled from letting frequently, utility companies now wait for construction to start before they will spend money and commit resources to relocation. In other cases, TxDOT projects are designed years ahead to be shovel-ready once funding becomes available. In these cases it is unrealistic to ask utilities to get involved and start adjustments before a project is funded.

Best Practice Ranking Based on Worksheet Responses

Workshop participants were asked to provide input for each potential best practice, either "yes," "not sure," or "no," and add comments as desired. Based on the responses of the workshop participants, the researchers calculated a score and rank (1–16) for each best practice. To calculate the score, the team multiplied "yes" responses by 2, adding "unsure" responses, and dividing by the total responses. The score could thus range from 0 to 2. A score of 0 indicates rejection by all workshop participants, and a score of 2 indicates full support of all workshop participants for a best practice.

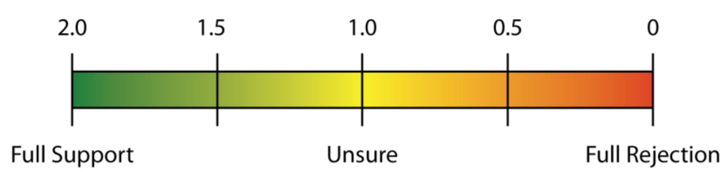
Table 41 shows a summary of the responses, score, and ranking for each best practice presented. The highest ranking best practices included: "advanced utility impact/utility conflict matrix training," "basic SUE training," "utility impact analysis," "outreach/training for utility owners," and "utility document management system." In total, the first 10 best practices received the uniform approval of workshop participants, evident in a score of 1.5 or higher.

The lowest ranking best practices were: "agency-wide policy for SUE" and "concurrent environmental and SUE review." However, even the lowest-ranked best practice received a score of 1.00, which indicates that workshop participants were overall unsure about this best practice. No best practice received a score of lower than 0.5, which would have indicated rejection of the best practice.

Table 41. Ranking of Best Practices (All Workshops).

Best Practice	Number of Responses				Score*	Rank
	Yes	Not Sure	No	Total		
Education and training: advanced utility impact/utility conflict matrix	46	0	0	46	2.00	1
Education and training: basic SUE training	44	0	0	44	2.00	1
Utility impact analysis	41	3	1	45	1.89	3
Outreach/training for utility owners	42	2	2	46	1.87	4
Utility document management systems	35	1	2	38	1.87	4
Project funding and budgeting for SUE services	30	5	0	35	1.86	6
Utility project management systems	33	4	1	38	1.84	7
Standard operating procedures	33	11	1	45	1.71	8
Improved QA/QC for SUE providers	24	12	3	39	1.54	9
Project development process concurrence points	23	20	1	44	1.50	10
Widespread availability and authority	18	24	1	43	1.40	11
Multilevel committees	18	23	3	44	1.34	12
Data archiving, sharing, uniformity, and asset management	14	27	1	42	1.31	13
Investigation of new SUE technology	13	21	3	37	1.27	14
Agency-wide policy for SUE	19	8	16	43	1.07	15
Concurrent environmental and SUE review	11	18	11	40	1.00	16

*Score is calculated as follows: ("Yes" responses × 2 + "Unsure" responses)/Total responses. Score ranges from 0 (all "No") to 2 (all "Yes").



Comments on Best Practices

This section provides a summary of comment received for best practices in the order of highest to lowest ranked best practice, based on the feedback from workshop participants.

Best Practices 4, 5, and 6: Education and Training

- There was a general consensus that training was critical in improving the use of SUE and the overall project development process. Participants should include TxDOT staff, utility company staff, and consultants.
- Training should vary depending on the audience, e.g., focus on process, technology, and applications for TxDOT staff, process for utility company staff, and consultants.
- Training is needed for new TxDOT staff and staff who do not deal with utility issues on a daily basis.
- Training is important because many business processes in the utilities area are undocumented, and TxDOT relies to a large degree on experienced staff.
- Training could provide TxDOT staff with a better understanding of the issues that utility companies have to deal with.
- Training should include coordination with larger cities and local partners for local projects because they have an impact on the TxDOT utility conflict management process. If all entities would use the conflict matrix for managing their conflicts, it would be a major improvement of coordination.

Best Practice 8: Utility Impact Analysis (UIA)

- All districts agreed that a utility impact analysis tool would be helpful. Some districts saw a potential for significant cost savings when using this tool.
- Some districts experimented with the utility impact tool prior to the workshop and found it to be very straightforward and helpful. Some districts suggested the utility impact analysis should be a required tool, while others indicated that it should be used as a guide and not a requirement.
- Utility impact analysis could give district utility staff an early estimate of what conflicts are likely to be encountered and their estimated impact.
- UIA could be used at the design concept meeting. This could even include a checklist for utilities at the time of work authorization as part of the request package.
- Asked to comment on the GDOT utility impact avoidance process, district representatives suggested that the decision of using SUE should be made at their (district) level.

Best Practice 12: Utility Document Management Systems

- All districts supported the idea of developing such a system. However, some participants were concerned about the time and effort requirements for populating such a system.
- Districts were concerned about having another stand-alone or stovepipe system. An effective utility document management system should be as much integrated with existing systems as possible.
- The system should address the need to include SUE and utility data in project records. Frequently, QLA data are not on design plans or any other project record systems.

- The system could be especially valuable if there was a feature for keeping track of the reimbursement eligibility of all utility relocations.
- Some participants suggested that such a system should have a GIS component for better functionality.

Best Practice 7: Project Funding and Budgeting for SUE Services

- Many participants suggested that, although it is possible to include SUE work in project budgets during the early stages of the project development process, it is frequently hard to identify the need and estimate the budget for SUE at that time. As a result, districts frequently do not include SUE as a line item in a project. A potential rule of thumb could be 1–2 percent of the budget for SUE.
- When working in a corridor, TxDOT could budget for QLB and QLA once the project is divided into sections (CSJs).
- Some districts suggested that TxDOT should consider including SUE as a line item for all non-system bridges.
- TxDOT should consider a rule to include all major utilities on the planimetrics, aerials, and schematics.

Best Practice 3: Standard Operating Procedures

- Workshop participants agreed that SUE should be a standard practice across all districts. There seemed to be a consensus from participants that this will be very helpful, particularly to new designers and other new employees involved in the project development process.
- There was no consensus on the level of detail that the standard operating procedures (SOPs) should provide. There should be a TxDOT-wide coordinated system, but not necessarily the same requirements for all districts.
- Districts supported the idea of standard procedures that sufficiently consider local situations. Some districts expressed concern about statewide standard operating procedures due to the fact that different districts conduct business differently.
- The conditions for different project sites vary substantially, so SOPs should include enough flexibility for procedures and/or equipment to take that into account.

Best Practice 6: Improved QA/QC for SUE Providers

- Districts agreed on the need for QA/QC of SUE providers, because pre-certifications alone are not sufficient to determine whether a SUE consultant is well-trained in how to acquire and use SUE.
- Some districts were concerned about how well SUE consultants defined their scope of work and the subsequent quality of the work provided.

- Several TxDOT participants supported the idea of guidelines for minimum standards for SUE providers and deliverables. For example, it is critically important to correlate information on the deliverables, e.g., utility facility location with owner and type, which may seem obvious but is not always delivered.
- In particular, participants indicated a SUE deliverable checklist for QLA would be a good idea. Frequently, when districts receive the SUE data from different service providers, they are not standardized in many ways and therefore cause difficulties when the district personnel try to understand and use them.

Best Practice 9: Concurrence Points in the Project Development Process

- Some districts suggested the Ohio DOT example involved too many concurrence points and this might be too ambitious for TxDOT to implement. Fewer concurrency points than suggested might be better and more useful.
- Concurrent points might be used as an information sharing point for all stakeholders in the project development process and not necessarily to request everyone's buy-in and concurrence for the project.
- To some degree, TxDOT is doing something similar, without having the stakeholders' actual "concurrence." There would be benefit in formalizing this process.
- It is probably unrealistic to expect that projects would be put on hold because of lack of concurrence with utilities.

The following best practices received an overall rating between 1 and 1.49, which indicates that participants did not reject the practice but were somewhat unsure about it.

Best Practice 5: Widespread Availability and Authority for SUE Services

- TxDOT staff commented that generally, if SUE providers are available through evergreen contracts, TxDOT district staff use them. The consultant procurement process is too lengthy and not feasible for a single project. The problem recently has been a lack of available SUE contracts due to budgetary constraints.
- SUE projects can be approved by districts on specific control section jobs (CSJs) and added as supplemental agreements to existing design contracts. The division approves evergreen (indefinite deliverable) contracts, and then districts can authorize task orders for SUE providers without further requiring the division's approval. However, if a supplemental contract is needed to request additional SUE data collection, it can become difficult to deal with.
- The cost of SUE can also be included in the project budget up front. However, it is difficult to estimate costs, including unit cost for SUE tasks. For example, the cost per test hole can vary significantly depending on the location and depth of the required hole.
- It is important that staff experienced with utilities and right-of-way issues are involved with the request for SUE services to avoid unnecessary costs and unnecessary data collection. Some participants suggested giving utility staff the authority to order SUE services because it would encourage designers to work more closely with utility staff.

- Participants highlighted the need to develop a method or process that standardizes SUE requests, so that SUE is based more on need and less on available funding. This would also help with districts' awareness of when and how to use SUE. In this regard, several districts liked how Georgia and Pennsylvania have formalized aspects of this process. If a similar process would be developed for TxDOT, participants emphasized that the process should consider neighboring districts that may have staff available to help with SUE investigations.

Best Practice 1: Multilevel Committees/Working Groups

- Overall, workshop participants provided mixed responses. Participants seemed to like the idea of memoranda of understanding (MOUs) at a high level for large, statewide-operating utility companies, but were more skeptical about MOUs at a lower level.
- Participants suggested it might be feasible to agree on some general principles, but neither party would likely be happy with very detailed agreements. In addition, it was unclear how MOUs would work given the fact that different districts have different practices and procedures when dealing with utility issues.
- There was some doubt that many utilities would see benefit and participate. There was also concern about the considerable turn-over, new utility companies, and change of ownership. A state statute to participate was seen as potentially helpful.
- There was some concern about the effort it would take to implement this at a project level, which would require a lot of communication from top to bottom, both within TxDOT and within utility companies. At a project level, this would probably create a lot of paper work: there could be potentially hundreds of agreements to develop and review. Currently, TxDOT districts do not appear to have the staff to perform this adequately. Some participants did not think these MOUs would carry a lot of weight in the field and may not be worth the effort.

Best Practice 14: Investigation of SUE Technologies

- Given recent developments in the area of SUE, most participants agreed that exploration of new technologies is a good idea. However, the cost for investigating new technologies is always a challenge that a research project may best bear.
- TxDOT officials managing utilities at the district level should be kept in the loop of new technology advancements.

Best Practice 2: Agency-Wide SUE Policy

- Overall, this best practice received a score of 1.07, with 19 "yes," 16 "no," and 8 "unsure" votes. However, the comments received on the feedback forms and during the discussion were much more positive. The main issue appeared to be a concern that an agency-wide SUE policy would not adequately take into account issues at the district level. As long as a policy would consider local issues, participants appeared to like this idea.

- Some districts had concerns that a state-wide SUE policy might result in projects with SUE used because of the policy but not actual needs. For SUE to be cost-effective, its use should depend on project conditions such as the complexity of utilities and confidence of existing utility data. From the design point of view, however, at least QLB data should be collected as much as possible to support and facilitate the design.
- There was some uncertainty about what should trigger additional SUE work. Local best professional judgment is important, but some utilities are inherently more risky than others (e.g., gas lines vs. water lines). There could also be specific, local triggers. There could be multiple criteria for using SUE that considers risk and site conditions.
- There was consensus that the high/low risk policy (Caltrans) was a good idea. This is a good method to guide the use of SUE. In many cases, there are limited funds that can be used for SUE. If utility-related risks can be correctly assessed, the limited funds then can be used for SUE on projects associated with high risks.
- An agency-wide policy could include a requirement to incorporate SUE information on design drawings, for example at the schematic design phase. A state-wide policy should also involve other agencies such as the Railroad Commission and the Public Utility Commission.

Best Practice 10: Concurrent Environmental and SUE Review

- Participants were somewhat skeptical about this practice because the two processes require very different sets of skills and expertise. Environmental process data collections are generally focused on database searching, whereas utility data collections require more on-site surveying.
- Some participants liked the idea when focusing not necessarily on combining tasks, but when coping with utility-related issues that affect both areas. In the past, certain utility impacts helped some projects to justify certain environmental issues.
- Other participants were concerned that this strategy could lead to further delay to the project delivery process because environmental and design process are often very disconnected. SUE data collected during the environmental process can become outdated when collected too far ahead of the design phase. In addition, it is difficult to forecast the need of SUE that early. In other cases, the environmental assessment is performed after design and is usually the last step prior to letting, especially if the assessment is produced in-house. In that case the SUE data would be collected too late.
- Some participants highlighted potential issues related to right of entry. If right of entry could be done once instead of twice, there could be significant benefits.

Conclusions and Recommendations

The workshops were well-attended and included TxDOT representation from 23 districts. None of the potential best practices were rejected outright, and the overall lowest ranked best practice ("Concurrent environmental and SUE review") received an average score of "unsure." The two highest ranked best practices received unanimous support from workshop participants: "Advanced utility impact/utility conflict matrix training," and "Basic SUE training."

Overall, workshop participants supported the top 10 ranked best practices, even though ranking of those practices varied among the workshops. For example, the best practice “Standard operating procedures” received full support from Dallas, Houston, and San Antonio Districts, but Odessa participants were unsure about the best practice. The best practice “Improved QA/QC for SUE providers” received full support at the San Antonio workshop, but was ranked fairly low at all other workshops. Similarly, San Antonio gave full support to the best practice “Agency-wide policy for SUE,” but Houston ranked it lower, and Odessa and Dallas ranked it in last place. This might point to the fact that different districts have had different experiences with SUE in the past, and therefore have different opinions about which best practices to pursue. Judging from the comments received, differences among workshop participants about certain best practices were also a result of how participants envisioned the implementation of a best practice.

Researchers noted that the following three issues seemed to be recurring at all district workshops:

- The need for resources and funding of SUE activities.
- The need to better integrate SUE services in the project development process.
- The need for SUE-related training.

Other relevant issues that participants felt strongly about were the need to raise awareness for SUE and the need to document TxDOT processes and experiences. Apart from the *Utility Manual*, there seems to be little documentation at TxDOT districts about utility investigation processes and procedures. It became apparent that most of the institutional knowledge on utility investigation lies with experienced TxDOT individuals who have acquired this knowledge through years of project experience.

Based on the feedback received at the workshops, the research team recommends advancing all of the best practices that received strong support from the workshop participants. Table 42 provides an overview of the best practices with a specific recommendation for advancing the practice toward implementation. According to these recommendations, the research team will prepare a range of materials, ranging from executive summary style descriptions to readily implementable training materials. In addition, the research team will prepare summaries and potential implementation options for those best practices that workshop participants did not fully support or were unsure about. These summaries can be used to help TxDOT administration determine the feasibility of future implementation.

Table 42. Implementation Strategies for Best Practices.

Best Practice	Rank	Stakeholder Feedback	Implementation Strategy
Education and training: advanced utility impact/ utility conflict matrix	1	Strong support	• TTI developed training materials for using utility conflict matrix as part of SHRP2. Provide recommendation to implement utility conflict matrix training.
Education and training: basic SUE training	1	Strong support	• Develop training module outlining basic SUE terminology, technologies, and techniques. • Include local limitations, pitfalls, and best practices.
Utility impact analysis	3	Strong support	• Modify and adopt existing utility impact tools for TxDOT business process. • Develop examples for using utility impact tool in TxDOT projects. • Develop training materials to use utility impact tool.
Outreach/training for utility owners	4	Strong support	• Determine which training topics would be appropriate subjects for utility owners (e.g., TxDOT processes, terminology, and policies; SUE technology and techniques) • Consider potential involvement and perspective of utility owners when developing training materials. • Coordinate with project 0-6624, which is focusing on strategies to improve utility owner participation in the project development process.
Utility document management system	4	Strong support	• Prepare executive summary of current systems inside and outside of Texas, research, potential value, and implementation options.
Project funding and budgeting for SUE services	6	Strong support	• Prepare summary of funding and budgeting strategies, advantages and disadvantages, and applications. • Develop training materials as needed to be used in basic and advanced courses. • Prepare executive summary as needed.
Utility project management systems	7	Strong support	• Prepare executive summary of current systems, research, potential value, and implementation options.
Standard operating procedures	8	Support	• Develop framework for SUE standard operating procedures. • Coordinate with project 0-6624, which involves a modernization of the TxDOT utility process.

Table 42. Implementation Strategies for Best Practices (Continued.)

Best Practice	Rank	Stakeholder Feedback	Implementation Strategy
Improved QA/QC for SUE providers	9	Support	• Prepare summary of existing requirements for SUE providers, including process to review deliverables. • Provide recommendations for improved QA/QC for SUE providers. • Develop training materials as needed to be used in basic and advanced courses. • Prepare executive summary as needed.
Project development process concurrence points	10	Support	• Prepare executive summary of strategy, including recommendations for integration into the TxDOT project development process. • Coordinate with project 0-6624 as needed.
Widespread availability and authority for SUE	11	Unsure	• Prepare summary of availability and authority for SUE services at districts. • Provide recommendations to improve availability and authority for SUE services.
Multilevel committees	12	Unsure	• TxDOT administration is reviewing strategy. • Prepare executive summary of comments and concerns received at workshops for TxDOT administration.
Data archiving, sharing, uniformity and asset management	13	Unsure	• Prepare executive summary of current systems inside and outside of Texas, research, potential value, and implementation options.
Investigation of new SUE technology	14	Unsure	• Prepare executive summary of comments and concerns received at workshops for TxDOT administration, including recent research developments.
Agency-wide policy for SUE	15	Unsure	• Review and summarize current TxDOT SUE policies. • Prepare executive summary with recommendations based on Task 6 technical memorandum and feedback from workshop participants. • Develop training materials as needed to be used in basic and advanced courses.
Concurrent environmental and SUE review	16	Unsure	• Prepare executive summary of comments and concerns received at workshops for TxDOT administration, including recent research developments.

REFINE BEST PRACTICES

Based on the feedback received in the workshops, the research team refined the best practices identified earlier to facilitate potential implementation of them at TxDOT.

Education and Training

Currently, many business processes in the utilities area are not well-documented in TxDOT manuals. Utility practices vary more or less in different districts and among different practitioners of the same districts. These factors result in a great need of training for all utility-related TxDOT employees as well as utility owners and consultants. Table 43 presents the education and training practices. The table provides the researchers' judgment about three implementation criteria including relative cost, perceived benefits, relative complexity, and rank based on workshop feedback. The following further describes the practices and recommended implementation actions:

- Basic SUE training. TxDOT should develop training modules outlining basic SUE terminology, technologies, and techniques. The training materials should include limitations, pitfalls, and best practices that are specific to different geographic areas due to the different soil conditions and possibly utility installation practices.

- Advanced utility impact training. TxDOT should implement existing utility impact analysis tools and provide training about its use to improve utility conflict analysis capacity agency-wide.

- Outreach training to utility owners. There are several utility-related topics that utility owners need to be familiar with. TxDOT may identify a list of training topics (e.g., TxDOT processes, terminology, and policies; SUE technology and techniques) and develop training materials. When developing the materials, it is important to consider utility owners' feedback to ensure maximized participation and benefits.

Table 43. Education and Training Recommendations.

Education and Training	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity	Rank
Basic SUE Training	Targets a broad audience, using a brief 1–2 hour format, focusing on SUE benefits and processes	Low	Medium	Low	1
Advanced Utility Impact Training	Advanced SUE Training for practitioners (similar to GDOT)	Medium	Medium	Low	1
Outreach Training to Utility Companies	Training for utility designers (similar to ODOT)	Medium	Medium	Medium	4

The training programs should be developed in such a manner that they meet the needs of different types (e.g., designers versus project managers) and levels (e.g., new versus experienced employees) of audiences. The training programs should also include coordination with larger cities and local partners for local projects because they have an impact on the TxDOT utility conflict management process.

TxDOT project 0-6624 devoted a significant effort to develop a training strategy for utility related topics. The strategy included a catalog of recommended courses, their contents, and their recommended durations. The outcome of that research complements the best practices described herein.

Technology and Information Systems

Technology and information system approaches can range from back-office technology such as document management systems, to field investigation techniques, utility databases and mapping software, ground penetrating radar, and utility tagging technologies. The range of technologies is quite broad. Many of these types of practices can be found in the literature, particularly in SHRP 2 Report S2-R01-RW "Encouraging Innovation in Locating and Characterizing Underground Utilities" (*3*). The following further describes the practices and recommended implementation actions:

- Utility document management system. TxDOT should develop utility document management systems to aid in the storage, retrieval, and utilization of utility investigation data, similar to systems in use at PennDOT and VDOT. These systems have proven to save time and improve efficiency.

- Utility project management systems. TxDOT should develop software that provides utility project tracking scheduling and reporting to improve utility investigation process efficiency.

- Data archive technology and data sharing technologies. Improved data sharing between utility owners and DOTs has been cited in other states as a critical issue. A pilot program to establish a data archive for easier retrieval of as-built drawings and utility locations would improve future data sharing.

- Investigation of new SUE technology. TxDOT should consider getting involved with pilot projects for innovative and emerging utility investigation, detection, and mapping technologies such as 3-D mapping and visualization technologies.

Table 44 presents a summary of technology and information system recommendations listed above. The researchers recommend that TxDOT should prepare executive summary of current systems inside and outside of Texas, research, potential value, and implementation options. Based on the summary, TxDOT could then identify opportunities to expand the functionality of certain existing data systems to fulfill the needs for utility document/project management and data archive. As needed, TxDOT could then assemble a team to allocate resources and develop new software tools for these purposes.

During the workshops, some participants raised concerns about the time and effort requirements for populating utility project/document management systems. In addition, participants had concerns about having another stand-alone system. To address these issues, TxDOT should implement utility data systems at multiple levels, with only the most pertinent staff responsible for populating and administrating the data system. Other users should only be responsible for a limited number of data elements that are in their function areas. In addition, such data systems should be integrated with other existing data systems to avoid redundant data input to the extent possible. Such a system should also have functions to store SUE and utility data, track reimbursement eligibility, and have a GIS component.

Table 44. Technology and Information System Recommendations.

Technology and Information Systems	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity	Rank
Utility Document management systems	Develop software to aid in the storage, retrieval, and utilization of utility investigation data (similar to PennDOT/VDOT).	High	High	High	4
Utility Project management systems	Develop software that provides utility project tracking scheduling, and reporting.	High	High	High	7
Data archiving, sharing, uniformity, and asset management	Provide utility owners and contractors with licenses for project CAD platforms. Pilot program for data archiving.	Medium	Medium	Medium	13
Investigation new technology (e.g., GPR)	Institute pilot project to try new and emerging investigation technologies.	Medium	High	High	14

Procurement and Contracting Best Practices

The research found that state DOTs typically have statewide or district-wide contracts for SUE providers. Best practices in procurement and contracting SUE services center on several issues including SUE provider qualifications requirements, quality control for SUE deliverables, having widespread availability, and SUE data management. The following are best practices for procurement and contracting approaches used by state DOTs for utility investigation, including recommendations for implementation:

- Project budgets that include funding for the cost of SUE investigations. This is a best practice that is already feasible but based on the data that the research team collected, is not a standard TxDOT practice. In order to improve the use of SUE, TxDOT should prepare a summary of funding and budgeting strategies, advantages and disadvantages, and applications. To facilitate the implementation, TxDOT should develop training materials for use in basic and advanced courses.

Notice that although it is possible to include SUE work in project budgets during early states of project development process, it is frequently hard to identify the need and estimate the budget for SUE at that time. A potential rule of thumb could be to include 1–2 percent of the budget during project development for SUE. TxDOT may consider including SUE as a line item for all on-system bridge projects. Moreover, TxDOT should consider a requirement to include all major utilities on the planimetrics, aerials, and schematics.

- Improved QA/QC of SUE contractors. Currently, many SUE providers are selected based on pre-certification, which sometimes do not necessarily ensure the quality and reliability of SUE deliverables. TxDOT should review existing QA/QC requirements for SUE providers, including the process to review deliverables. Based on the review, TxDOT should provide recommendations for improving QA/QC for SUE providers and develop training materials as needed for implementing the recommendations.

  A potential improvement to the current QA/QC process at TxDOT is to establish guidelines for minimum standards for SUE providers and deliverables. A SUE deliverable checklist for QLA and QLB SUE data would be also beneficial due to the different formats various SUE providers currently use.

- Widespread availability and authority of SUE services to ensure designers and project managers have ready access to SUE services and avoid delays caused by waiting for purchase authorities and approvals. For implementation, TxDOT should prepare summary of availability and authority for SUE services at districts and provide recommendations to improve availability of and authority for these services. TxDOT should also develop a SUE contracting mechanism such that SUE can be used based more on needs and less on available funding in project budgets. It is important to involve staff that is experienced with utilities and right-of-way issues to avoid unnecessary costs and data when requesting SUE services. TxDOT may consider giving utility staff the authority to order SUE due to their experience with utility issues. It would also encourage designers to work more closely with utility staff.

  Currently, districts have used indefinite deliverable or evergreen contracts for SUE services. Such contracts do not involve lengthy consultant selection processes and therefore are more flexible and efficient. Evergreen contracts need to be approved through the ROW division, making it time-consuming when districts need approval for supplemental contracts for additional SUE. The cost of SUE can be also included in the project budget up front or approved by districts on specific CSJs as supplemental agreements to existing design contracts. The former is less used due to the difficulty of estimating SUE costs in advance. The latter is less flexible, considering the processes of contracting and consultant selection.

Table 45 shows the procurement and contracting best practices, along with the relative cost, perceived benefits, and its relative complexity of the practice. Generally, the researchers observed that greater benefits were found in procurement practices that emphasized having easy access and availability of SUE services. Additionally, those states that emphasized strict pre-qualification standards for SUE providers and deliverables generally reported greater benefits.

Table 45. Procurement and Contracting Recommendations.

Procurement and Contracting	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity	Rank
Project Funding for SUE	Project budgets include SUE services and estimates	Medium	High	Medium	6
Improved QA/ QC	SUE provider qualifications, scope of services, and quality control	Medium	Medium	Low	9
Widespread availability and authority	Any employee related to the project can identify need for SUE	Low	Medium	Low	11

Project Development Process Best Practices

State DOTs that have a long history of conducting SUE as a matter of practice have developed a wide range of project development processes including detailed process manuals, checklists, impact/conflict criteria, and matrices. The best practices used by DOTs in their project development processes also represent the greatest quantity of content and examples from which to choose. This section describes only a sampling of notable practices that characterize the wide range of project development processes involving SUE investigation at state DOTs. Project development processes recommended for utility investigation include:

- Establishing uniform SUE criteria, impact forms, and conflict matrices. This would require TxDOT to:
    - Modify and adopt existing utility impact tools for TxDOT business process.
    - Develop examples for using these utility impact tools with TxDOT projects.
    - Develop training materials to use such utility impact tools.

  Utility impact analysis could give district utility staff an early estimate of what conflicts are likely to be encountered and their estimated impact. It could be used during design concept meetings as well. During the workshops, all district representatives agreed that a utility impact analysis tool would be helpful. Some districts saw a potential for significant cost savings when using this tool.

TTI has developed training materials for using the utility conflict matrix as part of SHRP2 (*22*). The training materials included modules and hands-on exercises that help different audiences to develop skills for utility impact analysis. As part of the same research, TTI also developed prototype utility conflict matrix tools that can be implemented with minimal effort. The project developed two prototype utility conflict matrices including one using the Excel platform and another using a DBMS. The research team coordinated recommendation for implementing the tools with Research Project 0-6624.

- Including quality assurances and SUE concurrence points during the PDP. Concurrent points can be used as information sharing points for all stakeholders in the project development process and not necessarily to request everyone's buy-in and concurrence for the project. To some degree, several districts have been doing something similar, without having actual concurrence from stakeholders. For implementation, TxDOT should prepare an executive summary of strategy, including recommendations for integration into the TxDOT project development process. Note that when implementing this practice, it is necessary to identify the most logical concurrence points without actually making the process overwhelmingly complex. It is unrealistic to expect that projects be put on hold because of lack of concurrence with utilities. Rather, it is a mechanism to ensure the timely collection of utility data.

  TxDOT Project 0-6624 has developed a modernized depiction of the TxDOT utility process, which includes an overview of the entire project development process with emphasis on utility-related activities including SUE data collection.

- Conduct concurrent environmental and SUE review. For implementation, TxDOT should prepare an executive summary of comments and concerns received at workshops for TxDOT administration, including recent research developments.

  Environmental process data collections are generally focused on database searching, whereas utility data collections require more on-site surveying. Stakeholders were concerned that SUE data collected during the environmental process could become outdated. Moreover, it is difficult to predict the need of SUE during that early stage. In other cases, the environmental assessment is performed after design and is usually the last step prior to letting, especially if the assessment is produced in-house. Thus, the SUE data would be collected too late. However when coping with utility issues that affect both areas, there are advantages for staff to work closely together. Results from Research Project 0-6065 indicated that there is potential merit to coordinate environmental and utility data collection (*61*).

Table 46 summarizes the best practices in the project development process category. The table also includes a judgment on the recommendation's relative cost, perceived benefits, and relative complexity.

Table 46. Project Development Process Recommendations.

Project Development Processes	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity	Rank
Utility Impact/ Conflict Analysis	SUE Impact forms and conflict matrices for all projects	Low	High	Low	3
Concurrence Points	Utility review at predetermined stages of project development	Medium	High	High	10
Environmental review concurrency	Concurrent involvement with environmental reviews and information	Low	Medium	Medium	16

Policy Approaches

The research identified several policy approaches that have a potential to improve TxDOT's utility investigations.

- Policies to promote and standardize SUE practices internal to TxDOT. These policies include:
    - Broad policies to establish minimum SUE investigation requirements at TxDOT.
    - Narrow targeted policies with specific changes and updates to SOPs and manuals (also applicable to project development process recommendations).

  For implementation, TxDOT should develop a framework for SUE standard operating procedures. SOPs should include some flexibility for different districts in terms of level of details and data requirements due to the different practices at districts. In addition, SOPs should take into consideration project site conditions. Different locations may have very different site conditions and therefore require different levels of SUE data. The implementation of this practice should also coordinate with Project 0-6624, which involves a modernization of the TxDOT utility process.

- Policies to improve coordination with utility owners and operators external to TxDOT. These policies include:
    - Establishing coordinating committees and working groups between the TxDOT and utility companies.
    - Establishing coordinating committees with oil and gas operators and pipeline owners.

  TxDOT administration has been reviewing this practice for potential implementation. An important component of this practice is multilevel memoranda of understanding (MOUs). Some workshop participants were concerned that implementation of a MOU at the project level would be difficult because it requires communications from top to bottom, both within TxDOT and within utility companies. In addition, this would result in numerous agreements to review by districts.

- Establish an agency-wide SUE Policy. TxDOT should review and summarize their current SUE policies, based on which TxDOT then prepares an executive summary with recommendations and develop training materials to be used in basic and advance courses.

  An agency-wide SUE policy should take into consideration factors such as local conditions and project needs for SUE data due to utility conditions and risks. Such a policy would promote the use of SUE based on needs instead of the existence of a policy. The SUE policy may also include a requirement to incorporate SUE information on design drawings, particularly at the schematic design phase. The policy may also involve other relevant state agencies such as RRC and PUCT. The high/low risk policy that Caltrans used can be an example for the TxDOT SUE policy.

Table 47 summarizes the policy recommendations and also presents an evaluation on the three criteria for implementing the policy including the relative cost, its perceived benefits, and its relative complexity. In general, policy actions are comparatively lower in cost and complexity but moderately beneficial. For example, a simple and short agency-wide policy, or SOP, could be issued to encourage SUE and its demonstrated benefits. This simple agency-wide policy would presumably cost very little, but would have an immediate benefit.

Table 47. Policy Implementation Recommendations.

Proposed Policy Recommendations	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity	Rank
Standard Operating Procedures	Prepare SUE SOP for Districts and Divisions	Low	Medium	Low	8
Multilevel Committees	Statewide Utility Coordinating Committee/Working group	Low	Low	Low	12
Agency-wide/ Statewide Policy for SUE	Agency-wide policy describing the benefits and minimum requirements for SUE	Low	Medium	Low	15

CHAPTER 7: DEVELOP AND TEST TRAINING MATERIALS

As part of this project, the research team developed training materials to disseminate the research findings and to improve the use of utility investigation services. The training materials are included in a separate product (0-6631-P1). This chapter summarizes the development and testing of the training materials.

BACKGROUND

Based on the research findings and with the concurrence of the project monitoring committee, the project team selected two best practices as focal points of the 4-hour workshop, basic SUE training and education, and utility impact analysis. As shown in Table 48, both best practices were ranked at the top by stakeholders during previous workshops.

Table 48. Overall Ranking and Implementation Strategies for Best Practices.

Best Practice	Rank	Stakeholder Feedback	Implementation Strategy
Education and Training: Basic SUE Training	1	Strong support	• Develop training module outlining basic SUE terminology, technologies, and techniques. • Include local limitations, pitfalls, and best practices.
Utility impact analysis	3	Strong support	• Modify and adopt existing utility impact tools for TxDOT business process. • Develop examples for using utility impact tool using TxDOT projects. • Develop training materials to use utility impact tool.

Basic SUE Training and Education

This best practice is included in the workshop by providing an overview of subsurface utility engineering, including terminology, practices, and technology used to determine the location of utility facilities. The workshop also provides an overview of utility investigation practices during the TxDOT project development process and the TxDOT utility cooperative management process. The workshop also includes a brief overview of contracting options and recommendations for utility investigation activities that are typically conducted by a consultant.

This content of this section is intended for the widest possible audience and would appropriately include engineers and non-engineers, including utility coordinators, planners, managers, and administrators. This section of the workshop is designed to raise awareness for the effects that utilities can have on TxDOT projects, and how SUE can be used to counteract the effects and keep projects within budget and on schedule.

Utility Impact Analysis

Utility impact analysis (UIA) is a proven technique for assessing a transportation project need for SUE at quality levels (QL) B or A, which are much costlier than QLD or C and typically involve the use of consultants. The analysis is used by several state DOTs to assess the need for more detailed utility data and usually involves the completion of a SUE utility impact form or table. These forms may provide a step-by-step process to determine if QLB or QLA SUE use is practicable, when SUE should be considered on a project, and what utility quality levels should be utilized based on an analysis of project criteria.

This section of the workshop is applicable to a very wide audience and it not necessarily focused on designers or utility practitioners, and is also useful for planners and managers. The UIA tool can be used as a screening tool to determine if the use of QLB or QLA on a project is warranted.

WORKSHOP DEVELOPMENT

Workshop Format

The research team developed training materials for a 4-hour workshop titled "Introduction to SUE and Utility Impact Analysis." The workshop is divided into four lessons, as follows:

- Lesson 1: Introductions and Workshop Overview (30 minutes).
- Lesson 2: Utility Investigation Concepts (90 minutes).
- Lesson 3: Utility Impact Analysis (90 minutes).
- Lesson 4: Wrap-Up (15 minutes).

The workshop is designed for a total of four hours of instruction, from 8:00 a.m. to 12:00 p.m. It includes 3:45 hours (225 minutes) of direct instructor contact and 0:15 hours (15 minutes) of breaks. The seminar provides ample opportunities for participant interaction and enables the instructor to adjust session and lesson start times and durations depending on the participants' discussion. Table 49 provides an overview of the workshop lesson plan, including lesson durations and instructional methods. Table 50 through Table 53 provide a detailed description of each lesson, including learning outcomes, topics covered by the lesson, activities conducted during the lesson, detailed time allocation for each portion of the lesson, plans for evaluating the effectiveness of the lesson, and references used during the lesson.

Table 49. Workshop Lesson Plan.

Lesson	Time	Lesson Title	Instructional Method
1	8:00 AM – 8:30 AM	Introductions and Seminar Overview	Instructor(s) welcomes participants, introduces him/herself, and leads participants through introductions. Participants introduce themselves and provide a brief description of their role and experience with utility investigation in the project development processes and their expectation for the workshop (15 minutes). Instructor provides an overview of the workshop objectives, outcomes, agenda, and reference materials (10 minutes). Instructor discusses ground rules, sign-in sheet, feedback forms, and other housekeeping items as needed (5 minutes).
2	8:30 AM – 10:00 AM	Utility Investigation Concepts	Instructor provides an overview of SUE Quality levels, technology and terminology, including limitations. Instructor provides an overview of TxDOT project development process, including utility cooperative management process (30 minutes). Instructor discusses best practices for utility investigations tied to the project development process (30 minutes). Instructor provides an overview of contracting options and recommendations for QLB and QLA SUE, including funding mechanisms and deliverables (20 minutes). Activity 1: Questions and answers "SUE Jeopardy" (10 minutes).
	10:00 AM – 10:15 AM	Break	
3	10:15 AM – 11:45 AM	Utility Impact Analysis	Instructor provides an introduction into Utility Impact Analysis (10 minutes) Activity 2: Instructor leads participants in completing the PennDOT utility impact form. This group exercise provides introduction for next activity (20 minutes). Activity 3: Participants are presented with an example project in a suburban setting and complete the GDOT UIA form. Participants share their results and the form is reviewed with the entire class (30 minutes). Activity 4: Participants are provided a much more complicated example section of Interstate through an urban setting. The class discusses challenges and issues with the example project. The purpose of the Interstate section is to share experiences and discuss strategies for SUE (20 minutes). Presentation of results and discussion (10 minutes).
4	11:45 AM – 12:00 PM	Wrap-Up	Activity 5: Instructor conducts a brief review of the workshop and assesses learning outcomes through question and answer session. Participants are given an opportunity to complete workshop/instructor evaluations (15 minutes).

Table 50. Lesson 1: Introductions and Seminar Overview.

Lesson Number:	**1**
Lesson Title:	**Introductions and Seminar Overview**
Learning Outcomes	At the end of lesson 1, the participant will be able to: Describe the workshop topics and agenda. Activity 1: The participant activities for this session include: • Each workshop participant will make self-introductions. The participant introduction should include their name, where they work, and what they do. • Each participant will also have an opportunity to express their expectations for the workshop.
Topics:	• Introductions (both instructor and participants). • Review of seminar objectives, outcomes, agenda, and reference materials. • Discussion of ground rules, sign-in-sheet, feedback forms, and other housekeeping items.
Instructional Method:	Interactive Lecture Instructor welcomes participants, introduces him/herself, and leads participants through introductions. Participants introduce themselves and provide a brief description of their role and experience with utility investigations, design, and other project development processes. Instructor provides an overview of the seminar learning objectives, agenda, and reference materials. Instructor discusses ground rules, sign-in sheet, feedback forms, and other housekeeping items as needed.
Instruction Day:	Day 1: 8:00 AM – 8:30 AM
Time Allocation:	• Participant Introductions 15 minutes • Workshop Review 10 minutes • Housekeeping 5 minutes • Total Lesson 1 30 minutes
Evaluation Plan:	• Instructor uses the instructor review form to take notes on the background, experience, and role of participants in utility investigations, design, or other project development processes.
References:	• Participant notebook. • Lesson 1 PowerPoint file and handouts. • TxDOT research project 0-6631 final report (online link).

Table 51. Lesson 2: Utility Investigations Concepts.

Lesson Number:	**2**
Lesson Title:	**Utility Investigation Concepts**
Learning Outcomes:	At the end of this lesson, the participants should be able to: • Describe SUE and SUE quality levels. • Identify when SUE occurs in the project development process. • Identify relevant contracting options for QLB and QLA SUE.
Instructional Method:	Instructor uses interactive lecture using question and answer methods with slides to introduce the following topics: • Utility investigation concepts and issues, including SUE technology and terminology, and limitations. • The typical TxDOT project development process. • A diagram describing when SUE occurs during the TxDOT project development process. • TxDOT contracting options for providing QLB and QLA SUE services. • Funding mechanisms for SUE services. Activity 1: Questions and answers: "SUE Jeopardy" • Instructor answers questions from participants. As needed, other participants participate in the discussion.
Instruction Day:	Day 1: 8:30 AM – 10:00 AM
Time Allocation:	• SUE technology and terminology 30 minutes • Utility investigations in the project development process 30 minutes • Best practices for contracting 20 minutes • Lesson Review/questions and answers 10 minutes • Total Lesson 2 90 minutes
Evaluation Plan:	• Instructor will assess responses by participants evaluate learning. • Instructor uses the instructor review form to summarize the type of questions and comments from participants.
References:	• Lesson 2 PowerPoint file (slides) and Participant notebook.

Table 52. Lesson 3: Utility Impact Analysis.

Lesson Number:	**3**
Lesson Title:	**Utility Impact Analysis**
Learning Outcomes:	At the end of the lesson the participant will be able to: • Perform utility impact analysis (UIA). • Complete a Utility Impact Analysis form. • Describe when to conduct QLB and QLA SUE on TxDOT projects.
Instructional Method:	The instructor uses a combination of interactive lecture to explain the utility impact analysis process and introduces an example case study. The instructor should walk-through the first UIA example with the participants. Upon completion of the first example, the instructor should introduce a second example for the participants to complete as a small group exercise with the instructor closely monitoring the groups. Groups should report back on their experience completing a UIA form. Prior to activities the instructor should: • Describe Utility Impact Analysis form in other states. • Describe a real-life example using Utility Impact Analysis. • Describe the sample documents that workshop participants will use for the hands-on activity to perform a Utility Impact Analysis. <u>Activity 2</u>: Instructor leads participants, as a group, in completing the PennDOT UIA form. This group exercise provides introduction for next activity (20 minutes). <u>Activity 3</u>: Participants are presented with an example project in a suburban setting (FM 546 in Collin County) and complete the GDOT UIA form. Participants share their results and the form is reviewed with the entire class (30 minutes). <u>Activity 4</u>: Participants are provided a much more complicated example section of Interstate through an urban setting. The class discusses challenges and issues with the example project. The purpose of the Interstate section is to share experiences and discuss strategies for SUE (20 minutes). • Perform a Utility Impact Analysis on a TxDOT project. • Discuss analysis results within the group, and select a group representative to present results. • Direct participants during exercise and answer questions as needed. • Share findings and experiences with the class. • Lead a discussion with participants about the use of the utility impact analysis tool.
Instruction Day:	Day 1: 10:15 AM – 11:45 AM

Table 52. Lesson 3: Utility Impact Analysis (Continued).

Time Allocation:	• Utility impact background and lecture — 20 minutes • Activity 1: Group UIA walk-through — 20 minutes • Activity 2: Complete Example UIA for Actual project — 30 minutes • Activity 3: Discuss example utility analysis urban section — 20 minutes • Total Lesson 3 — 90 minutes
Evaluation Plan:	• Instructor uses question and answer to assess learning outcomes. • Instructor reviews results of UIA activities to asses learning outcomes. • Participants use the participant feedback form to rate the effectiveness of the presentation.
References:	• Lesson 3 PowerPoint file and handouts. • Sample TxDOT project printouts and plan sheets. • Handouts that include blank UIA forms and example project information.

Table 53. Lesson 4: Wrap-Up.

Lesson Number:	**4**
Lesson Title:	**Wrap-Up**
Topics:	• Instructor provides summary and review of workshop. • Instructor reviews learning objectives. • Instructor collects feedback forms.
Instructional Method:	Interactive lecture. Activity 5: Instructor summarizes the activities of the seminar, addresses any final questions of seminar participants, and provides some closing remarks. Participants fill out the feedback forms. The instructor then collects the feedback forms provided by the seminar participants.
Instruction Day:	Day 1: 11:45 AM – 12:00 PM
Time Allocation:	• Activity 1: Final questions, closing remarks, and feedback — 15 minutes • Total Lesson 4 — 15 minutes
References:	• Participant feedback form.

Training Materials

The training materials consist of an instructor guide and a participant materials binder, which include the following items:

- Instructor Guide:
  - Workshop lesson plan.
  - Lesson descriptions.
    - Lesson 1: Introductions and Seminar Overview.
    - Lesson 2: Utility Investigations Concepts.
    - Lesson 3: Utility Impact Analysis.
    - Lesson 4: Wrap-Up.
  - Presenter Notes.

- Participant Materials:
  - Workshop overview.
  - Workshop agenda.
  - Participant notes.
  - Handout No. 1. PennDOT SUE utility impact form.
  - Handout No. 2. GDOT utility impact score form.
  - Appendix A. Sample data for workshop activities.
  - Appendix B. Texas Utilities Code: Underground Facility Damage and Safety (One Call Law).
  - Appendix C. Sample indefinite delivery contract.
  - Appendix D. Feedback form and sign-in sheet.

Workshop Testing and initial Delivery

The TTI research team conducted five workshops in July 2012. The workshop dates, locations, and attendance are summarized in Table 54. Several weeks before each workshop, the researchers sent invitations and reminders to potential workshop participants, using the same list of potentially interested parties that the research team developed for the survey conducted as part of Task 5 *Survey of TxDOT Organizational Units on Current Utility Investigation Practices*.

Table 54. Workshops Locations and Attendance.

Location	Date	Attending In-person	Attending Online	Total Attendance
Austin	Tuesday, July 3, 2012	11	n/a	11
Dallas	Wednesday, July 11, 2012	7	6	13
Waco	Monday, July 23, 2012	4	1	7
Houston	Thursday, July, 26, 2012	16	1	17
San Antonio	Friday, July 27, 2012	10	n/a	10
	Totals	48	8	56

During the workshop, the research team provided a draft participant notebook that includes an agenda, copies of slides, handouts for exercises, and evaluation forms to record feedback from workshop participants.

SUMMARY OF WORKSHOP FEEDBACK

Overview

The following is a description of the feedback that workshop participants provided anonymously in writing on feedback forms provided at the conclusion of each workshop. The research team collected feedback in terms of comments and ratings of presentation materials, handouts, and time allocation for each lesson. The research team collected lesson ratings using the following rating options: excellent, good, acceptable, needs some improvement, needs urgent improvement. This section provides a summary of comments received at all workshops for each lesson.

Comments for Lesson 1

Comments for lesson 1 were overall positive, although some comments appeared to relate to lesson 2. Due to the fact that this lesson provided an overview and introduction to the workshop there were not many comments from participants.

Ratings of Lesson 1

Participants at the workshops were asked to rate presentation materials, handouts, and time allocation for each lesson. Overall ratings from all workshops for Lesson 1 are provided in Table 55.

Table 55. Overall Ratings for Lesson 1 from Workshop Participants.

	Excellent	Good	Acceptable	Needs Some Improvement	Needs Urgent Improvement	Total
Presentation	27	20	0	1	0	48
Handouts	22	24	0	2	0	48
Time	19	24	3	2	0	48
Total	**68**	**68**	**3**	**5**	**0**	**144**
Presentation	56%	42%	0%	2%	0%	100%
Handouts	46%	50%	0%	4%	0%	100%
Time	40%	50%	6%	4%	0%	100%
Overall Rating	**47%**	**47%**	**2%**	**4%**	**0%**	**100%**

Ninety-eight percent of participants rated the presentation either excellent or good. Handouts received a similar rating, with 46 percent excellent and 50 percent good. Timing received a rating of 94 percent excellent or good. Researchers noted that the timing was slightly off target at some of the workshops. As workshops progressed, researchers were able to improve the timing.

Comments for Lesson 2

Participants' comments indicated that this section provided useful, even essential information for a broad variety of stakeholders in the TxDOT project development process. Participants also liked the discussion of SUE technology benefits and limitations and graphics used to highlight regional limitations. Several attendees appreciated the discussion on the relationship between cost savings and risk when conducting SUE.

Participants provided a number of comments to improve this section. Some attendees recommended a short overview of utility conflict analysis and utility conflict matrices, which are covered in detail in a separate TxDOT course. Others recommended to provide more examples and more detail on developing SUE technologies.

Ratings of Lesson 2

Participants at the workshops were asked to rate presentation materials, handouts, and time allocation for each lesson. Overall ratings from all workshops for Lesson 2 are provided in Table 56.

Ninety-seven percent of participants rated the presentation either excellent or good. Handouts received a similar rating, with 57 percent excellent and 39 percent good. Timing received a rating of 89 percent excellent or good. Researchers noted that especially at one workshop, there was so much discussion during this lesson that the timing was off by a significant amount. However, this discussion was very useful to gain insight into how the researchers could improve the workshop. During subsequent workshops, timing was much closer to the target time and should not be an issue during implementation of the deliverables.

Table 56. Overall Lesson Ratings for Lesson 2 from Workshop Participants.

	Excellent	Good	Acceptable	Needs Some Improvement	Needs Urgent Improvement	Total
Presentation	27	19	0	1	0	47
Handouts	26	18	1	1	0	46
Time	19	23	4	1	0	47
Total	**72**	**60**	**5**	**3**	**0**	**140**
Presentation	57%	40%	0%	2%	0%	100%
Handouts	57%	39%	2%	2%	0%	100%
Time	40%	49%	9%	2%	0%	100%
Overall Rating	**51%**	**43%**	**4%**	**2%**	**0%**	**100%**

Comments for Lesson 3

Participants liked the discussion and the hands-on activities and worksheets. Several participants found it very useful; some considered this lesson the best part of the workshop. Constructive comments for improving the workshop documents focused for the most part on the handouts, which should provide more detail and additional information to conduct the utility impact analysis. Following these comments, the research team improved the handouts for subsequent workshops. Some participants would have liked discussion of another example of how to use the UIA worksheets.

Ratings of Lesson 3

Participants at the workshops were asked to rate presentation materials, handouts, and time allocation for each lesson. Overall ratings from all workshops for Lesson 3 are provided in Table 57.

Table 57. Overall Lesson Ratings for Lesson 3 from Workshop Participants.

	Excellent	Good	Acceptable	Needs Some Improvement	Needs Urgent Improvement	Total
Presentation	26	16	1	1	1	45
Handouts	21	19	3	1	1	45
Time	19	18	5	2	1	45
Total	**66**	**53**	**9**	**4**	**3**	**135**
Presentation	58%	36%	2%	2%	2%	100%
Handouts	47%	42%	7%	2%	2%	100%
Time	42%	40%	11%	4%	2%	100%
Overall Rating	**49%**	**39%**	**7%**	**3%**	**2%**	**100%**

Ninety-six percent of participants rated the presentation either excellent or good. Handouts received a lower rating, with 47 percent excellent and 42 percent good. Four percent of participants indicated a need for improving the handouts. Timing received a rating of 82 percent excellent or good.

Comments for Lesson 4

In total, the research team received few comments for Lesson 4, possibly because Lesson 4 was relatively short and intended to give participants some time to provide feedback.

Ratings of Lesson 4

Participants at the workshops were asked to rate presentation materials, handouts, and time allocation for each lesson. Overall ratings from all workshops for Lesson 3 are provided in Table 58.

Table 58. Overall Lesson Ratings for Lesson 4 from Workshop Participants.

	Excellent	Good	Acceptable	Needs Some Improvement	Needs Urgent Improvement	Total
Presentation	22	18	1	1	0	42
Handouts	20	20	1	1	0	42
Time	16	21	4	1	0	42
Total	**58**	**59**	**6**	**3**	**0**	**126**
Presentation	52%	43%	2%	2%	0%	100%
Handouts	48%	48%	2%	2%	0%	100%
Time	38%	50%	10%	2%	0%	100%
Overall Rating	**46%**	**47%**	**5%**	**2%**	**0%**	**100%**

General Comments

General comments were overwhelmingly positive, generally noting that the information provided was useful and beneficial. One participant at one workshop did not like the utility impact analysis and handouts provided, but did not elaborate on the particular issue or provided a recommendation for improvement. Another participant noted that the workshop should spend more time on the subject of SUE QLA data collections.

A recurrent comment was that the mix of utility owners, consultants, and TxDOT officials attending the workshop seemed to be a good fit and beneficial for the discussion of issues. Some participants noted that starting the workshop at 8 a.m. makes it difficult for out of town participants to attend. Several participants suggested scheduling the workshop from 9 a.m. to 2 p.m., or 10 a.m. to 3 p.m. Several participants mentioned that a longer class with more background information and additional examples would be preferable. Another recommendation was to keep the current format and make it a one day class in combination with a utility conflict matrix workshop.

Participants also provided recommendations to extent the current format, aiming for a one-day class focusing on utility investigations only. For example, there was a request to devote one section to identifying utility appurtenances such as poles, risers, valves, in the field. This would be very helpful for new utility coordinators who often start with little utility background and knowledge about utility facilities, and often have to learn about utility facilities on the job.

Other requests included a section that focuses on advanced funding agreements and including utilities such as water and sewer facilities in the highway construction contract. There was also a request to provide some discussion on the decision process for changing the highway design to accommodate utilities versus adjusting the utility out of the way.

Webinar attendees provided some mixed responses on the usefulness of attending the workshop online. The research team felt that on the one hand, there were portions that could be reasonable attended via webinar, such as Lesson 2. On the other hand, there were portions such as Lesson 3 with the hands-on activities that were very difficult to follow online. The recommendation of the research team would be to offer the workshop only for attending in person and not via webinar.

Overall Workshop Ratings

Table 59 provides an overview of the overall workshop ratings by workshop participants, based on 545 ratings of presentation, handouts, and time allocation.

Table 59. Overall Lesson Ratings from Workshop Participants.

	Excellent	Good	Acceptable	Needs Some Improvement	Needs Urgent Improvement	Total
Total Responses	**264**	**240**	**23**	**15**	**3**	**545**
Presentation	56%	40%	1%	2%	1%	100%
Handouts	49%	45%	3%	3%	1%	100%
Time	40%	47%	9%	3%	1%	100%
Overall Rating	**48%**	**44%**	**4%**	**3%**	**1%**	**100%**

A large majority found the workshop to be either excellent (48 percent) or good (44 percent), while 8 percent found the workshop to be acceptable or in need of improvement. Presentation and handouts were rated excellent or good by 96 and 94 percent of participants, respectively, while timing were rated 92 percent excellent or good. Most of the recommended improvements to the workshop were either included in the final workshop materials that will be delivered as 0-6631-P1 or could be fairly easily included during an implementation of the research deliverables.

CHAPTER 8: CONCLUSION AND RECOMMENDATIONS

SUMMARY OF RESEARCH FINDINGS

Accurate information about underground utility facilities is critical for timely identification of utility conflicts during highway projects. Collecting accurate underground utility location information from utilities can be challenging. This is one of the reasons SUE has become a critical tool to help identify and locate utility installations within the right-of-way. The major objective of this project is to review the state of the practice in utility investigations and develop best practices for timing and use of utility investigation services in the TxDOT project development process. During the project, the research team:

- Reviewed current utility investigation techniques and technologies.
- Reviewed best practices and use of utility investigation practices in other states.
- Reviewed TxDOT project data to examine effects of utility investigation services.
- Surveyed TxDOT organizational units on current utility investigation practices.
- Developed draft best practices for utility investigations.
- Conducted workshops with practitioners.
- Reviewed and revised draft best practices for utility investigations.
- Developed and tested training materials.
- Developed draft content for inclusion in the *ROW Utility Manual*.

The following sections summarize the major findings of this project, followed by recommendations developed based on the findings. The chapter also includes a section on implementation-related issues aimed to facilitate the department when implementing the recommended strategies/best practices and/or the training materials developed during the project.

Utility Investigation Techniques

There is a wide range of geophysical survey techniques or methods that have been or could potentially be used for underground utility detection. Depending on a survey method's underlying technology, methods can be categorized into one of the following groups:

- Methods based on electromagnetic waves, such as GPR, pipe and cable locators, EMI, and electromagnetic terrain conductivity, and infrared thermography.
- Methods based on mechanical waves, such as detection methods based on acoustic waves, water waves, and seismic waves.
- Other Methods. These methods can be used for utility location and do not fall in the above groups, including electricity resistivity methods, magnetic methods, micro-gravitational methods, and chemical methods.

Among the various techniques, pipe and cable locators, GPR, and terrain conductivity are three geophysical methods that have been widely used.

- Pipe and cable locators. Pipe and cable locators are by far the most commonly used utility detection method. These locators utilize electromagnetic induction technology using antennas with coils to detect magnetic fields generated by buried utility facilities. Pipe and cable locators work in either passive or active mode. When in active mode, the method requires an AC to be induced onto a buried utility line through direct connection, clamping, or induction. Several factors, such as facility material and diameter, ground conductivity, and AC frequency, affect the accuracy and reliability of pipe and cable locators.

- GPR. A typical GPR detects underground facilities non-intrusively by capturing and analyzing the temporal variations of electromagnetic filed reflected by the facilities. The technology can theoretically detect utilities of a large range of materials and is suitable for buried utility facilities for which preliminary information is not available. The reliability of GPR in utility detection is affected by factors such as target size and shape, depth of cover, and site conditions. Many regions in Texas have soils with high levels of clay, caliche, and/or limestone, which can limit the usability of GPR.

- Terrain conductivity. Terrain conductivity is a non-intrusive geophysical method for detecting underground objects by measuring the conductivity of a cone-shaped volume of underground soil. The most important factors that affect terrain conductivity measurements include porosity of the subsurface material, degree of saturation, and concentration of dissolved electrolytes in the pore fluids.

The research team contacted several SUE providers actively providing SUE services in Texas to discuss utility investigation practices, techniques, and technologies. Most SUE providers interviewed indicated that they use ASCE/CI 38-02, Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data, as a guideline for SUE services. SUE providers suggested that QLB data should be collected as early as possible during the project development process and before the detailed design phase, which would allow design engineers to have sufficient information about utilities and avoid major utility relocations. QLA data collection, on the other hand, should be collected between the 30 percent and 60 percent stage of the detailed design phase so that unnecessary test holes can be avoided.

Utility Investigation Practices at TxDOT

To understand the current utility investigation practices at TxDOT, the research team conducted a comprehensive survey of several organizational units within TxDOT, including districts, regional support centers, and divisions, about the current process of using utility investigation practices. Out of 269 recipients of the survey invitation, 129 responded (48 percent) the survey and provided meaningful results. The researchers found that:

- There is considerable confusion about basic SUE terminology. Some participants were unfamiliar with the acronym SUE itself. Several others thought of SUE data collections as QLB or QLA data collections, but did not consider QLD or QLC data collection to be part of SUE as well. Other responses from participants displayed confusion about QLB or QLA data collections versus One Call services, which were occasionally thought of as data collection at QLB or QLA.

- Several respondents indicated a lack of knowledge about the different types of technologies that are in use for QLB or QLA data collections.

- Stakeholders had not sufficient knowledge or experience to determine the best use of a particular technology for QLB or QLA data collections. Some respondents asked SUE providers to determine the best technology and appeared frustrated with results. Another example is the use of QLA data collection during construction, which survey participants selected more often than any other phase of the project development process. During the construction phase however, QLA cannot be as effectively used to avoid project delays and cost increases as during earlier process phases.

- Use of QLB and QLA SUE technology is relatively infrequent. Some districts appear not to use certain SUE technologies at all. Since there are no detailed statewide guidelines on the use of SUE, this issue may be related to a lack of knowledge about the technology and its benefits.

- The use of SUE for TxDOT projects has significantly declined over the last few years. This is apparently due to significant reductions in funding for utility investigations.

- TxDOT officials are uncertain about benefits of QLB or QLA SUE, in particular final benefits in terms of return on investment. More than half of respondents were unable to quantify any return on investment, while about one third of respondents expected an average return on investment of 2 or higher. However, only 7 percent did not expect a positive return on investment by using QLB or QLA SUE.

- A lack of knowledge about SUE technology by many survey participants is evident, as is a lack of its best uses. Training and educational materials could close the gap between the options that TxDOT has at its disposal, and to make more effective use of project funds. Further, given that cost was the most frequently cited factor prohibiting more frequent use of QLB and QLA SUE, it appears that education about the benefits of SUE and expected return on investment could have a significant impact on the use of SUE by TxDOT officials.

Utility Investigation Practices at Other States

To identify best practices that are used in the United States to perform utility investigations, the research interviewed state department of transportation officials from California, Illinois, Florida, Georgia, Maryland, North Carolina, Ohio, Pennsylvania, and Virginia. During the interviews, the research team gathered information, sample documentation, and data related to utility investigation practices and evaluated potential strategies to implement utility investigation techniques into the TxDOT project development process.

All states interviewed collect some type of SUE data on all or most of their projects. The research team found that the use of the ASCE standard for collection and depiction of SUE data, including the use of four data quality levels (QLD, QLC, QLB, and QLA), is prevalent at most DOTs. However, there remains some confusion at state DOTs about these different types of SUE data. For example, during interviews with stakeholders the research team noted that frequently stakeholders think of SUE data as the equivalent of QLB or QLA data, but not QLD and QLC data. This may be attributable to the fact that in many cases, DOTs use in-house staff to collect QLD and QLC data, and use a SUE consultant to collect QLB and QLA data.

The research team confirmed that, in general, state DOTs start data collection at QLD during preliminary design, followed by QLC data collection that may be included in the activities to complete a right-of-way map for the project. An approved right-of-way map is typically a requirement to move a project from the preliminary design into the detailed design phase, so in many cases the QLC data collection efforts are complete at the end of the preliminary design phase.

While QLD and QLC data collections for utilities are often standard procedure, the use of QLB and QLA data collection varies greatly among the states interviewed for this research. The main factor that makes the use of QLB and QLA data less prevalent at state DOTs appears to be the fact that these data collection activities for the most part require the services of a consultant. This in turn requires monitoring of the consultant contract and contract deliverables, and thoughtful planning to determine locations where data collection at these quality levels will provide a reasonable return to the DOT on the funds invested in the consultant activities. The return on the investment, however, is directly related to the quality of utility conflict management and data collection that the DOT produced up to the point where the consultant is hired. For example, a QLB data collection may provide a higher payoff in an area of a project where the DOT has knowledge about the existence of utilities but not their location, as compared to an area without any utility installations. As a result, the research team found that DOTs appear to be more inclined to invest in QLB and QLA services if they have a detailed process in place that outlines utility investigation activities at all quality levels throughout the project development process.

Many states are using utility conflict matrices to manage utility data collected during the project development process. The structure of these matrices and content that state DOTs manage vary considerably, not just between states but also between districts of the same states. At the moment, use of these utility conflict matrices is mostly voluntary and often limited to internal use of the state DOT.

Effects of Utility Investigation Services on Transportation Projects

To examine the effects of QLA and B SUE on project costs and delivery time, the researchers analyzed a large variety of project data at TxDOT by comparing projects that used SUE with a number of control projects. Utilizing a variety of data sources, the research team was able to identify 32 SUE projects from several different districts representing multiple project classes and design standards. Those projects were than compared with a large group of control projects containing all TxDOT projects let between FY2005 and FY2009. To enable an in-depth and comprehensive assessment of SUE cost-effectiveness, the research team collected project performance data from a number of TxDOT data systems, including DCIS, FIMS, SiteManager, CIS, COD, and UAD.

The findings of this analysis support anecdotal evidence from practitioners that almost uniformly described a positive impact of SUE on project performance. The major findings are:

- Projects that use SUE services tend to be larger projects. The analysis suggested that SUE projects in general were associated with projects that had a significantly higher design cost and involved more design man-hours. This observation was shown to be statistical significant for several difference project categories, such as urban, new location, upgrade, and 4R projects. In addition, results showed that projects involving SUE took longer to construct than control projects on average.

- Projects that use SUE services tend to have a lower design effort on a per-lane-mile basis. The comparison of design man-hours per project and per project lane-mile between projects that did and did not use SUE found that projects that use SUE involve more man-hours, but not significantly more man-hours per lane mile. Mean values for man-hours per lane-mile were smaller for all project categories, although the difference was only statistically significant in the case of 4R projects. Due to the limited sample size for most project categories, t-tests were not able to prove the differences were significantly different.

- Differences in mean construction cost increases did not show consistent trends. Both projects that did and did not use SUE experienced mean cost increases of approximately ±5 percent. However, mean percent increases were only significantly different for rural projects, with a mean cost increase of 0.3 percent for SUE projects and 1.5 percent for control projects. In terms of per-lane-mile cost increase, differences between mean cost increases were only significantly different on a per lane-mile basis for urban and 4R projects. Here, urban SUE projects experienced a significantly *higher* cost increase than the control group, while 4R SUE projects experienced a significantly *lower* cost increase than the control group.

- Projects that used SUE services tended to have a longer construction duration, but a shorter construction duration per lane mile. Although SUE projects had a longer mean construction duration in some cases, many categories of SUE projects actually took shorter to construct on a per-lane-mile basis. In particular, t-tests suggested that the difference in mean construction duration per lane-miles was significantly lower for upgrade and 3R projects that used SUE services.

- Projects that used SUE services tended to have less construction delays. When comparing construction delays, SUE projects had significantly less construction delays measured in both per-lane-mile additional construction days and percent of additional construction days for most project categories. T-tests suggested that the differences in construction delays between SUE projects measured by percent additional construction days were statistically significant for all projects, and rural, urban, upgrade, other project class, and 4R projects. Differences measured by additional days per lane-mile were significantly lower for SUE projects in the project categories rural, bridge, upgrade, other project class, and 4R projects.

- Projects that used SUE services tended to have lower costs related to change orders associated with utilities during the construction phase. Although mean change order amounts were overall low for the group of projects that the research team analyzed, there were significant differences for projects that did and did not use SUE. Mean change order amounts were significantly lower for bridge projects. On a change order amount per lane-mile basis, t-tests showed that projects that used SUE had significantly lower change order amounts for all projects, and in the project categories rural, bridge, and 4R. T-tests also showed that bridge projects that used SUE had a significantly lower change order amount measured as a percentage of the project construction cost.

- Projects that used SUE services tended to have significantly more utility agreements, and higher utility agreement costs. Several project categories had significantly more utility agreements for projects that used SUE than for projects that did not. These categories included all projects, urban, bridge, other project class, 4R, and other design standard. Utility agreements per lane-mile were not significantly different, except for the rural project category, where projects that did not use SUE had fewer projects that projects that did not use SUE. Mean cost of utility agreements per project were higher for projects that used SUE in the categories all projects, urban, bridge, and 4R. On an agreement amount per lane-mile basis, mean values were not significantly different, except in the project category 3R, where projects that used SUE had significantly lower mean agreement costs. This evidence could indicate that SUE services tend to be used for projects with complicated utility conditions.

- Projects that used SUE services tended to have a higher number of agreements that were not executed. This became evident during the analysis of UAD data. When compared with the control projects, projects that used SUE services generally had a larger percentage of utility agreements that were entered into the database but were not executed. The reason for not having to execute was not provided by the database. However, potential reason could be that the underlying utility conflict was resolved, and as a result, the agreement was no longer needed. Another reason could be that TxDOT found that the utility was not reimbursable. The percent of utility agreements not executed per project was significantly higher for projects that used SUE in the project categories all projects, urban, upgrade, and 4R projects.

- SUE costs constituted a small percentage of the total construction costs. Total cost of SUE services amounted to a mean of 1.85 percent of total construction costs. SUE costs were slightly higher for three types of projects: widen freeway, interchange, and new location freeway projects.

This analysis intended to assess SUE cost-effectiveness based on comparison of a pool of SUE projects with control projects. Readers should notice that during the analysis the researchers were not able to control other factors that might have contributed to project performances. An example of the factors is the experience of project manager and design engineers. Large projects tend to use more experienced project manager and design engineers and therefore may result in more frequent use of SUE, better performances in relation to utilities, and/or better performances in project delivery.

This research used 32 projects that used SUE services. This was a relatively small sample size especially when comparing to the control group that contained a few thousands of projects. If possible, future analyses should utilize more SUE projects and if data available, it would be important to also compare projects with SUE services during design and those with SUE during construction.

Best Practices for Utility Investigation

As part of the review of best practices in other states, researchers identified trends and common practices among the states. The online survey questions attempted to extract information from practitioners at TxDOT about what has worked, what has not worked, and what elements of utility conflict management would be advisable to implement. Based on the findings, the research team identified and developed best practices that could benefit TxDOT in utility investigation. Those best practices were then further refined based on feedback gathered from several stakeholder workshops conducted across the state. The result of this process was a list of 16 best practices in five categories:

- Best practices in education and training. Currently, many business processes in the utilities area are not well documented in TxDOT manuals. Utility practices vary more or less in different districts and among different practitioners of the same districts. These factors result in a great need of training for all utility-related TxDOT employees as well as utility owners and consultants. The best practices in this category that were widely supported by stakeholders include:

    - Training on basic SUE terminology, technologies, and techniques, including limitations, pitfalls, and best practices that are specific to different geographic areas due to the different soil conditions and possibly utility installation practices.
    - Training on advanced utility impact analysis including the use of utility impact analysis tools.
    - Outreach training to utility owners on utility-related topics they need to be familiar with, such as TxDOT processes, terminology, and policies and SUE technology and techniques.

- Best practices pertaining to technology and information systems. The stakeholders supported that implementation of following best practices in this category:

    - Utility document management systems to aid in the storage, retrieval, and utilization of utility investigation data.
    - Utility project management systems that provide utility project tracking scheduling and reporting to improve utility investigation process efficiency.
    - Data archive technology and data sharing technologies to improve data management and sharing between utility owners and the department.

    - Investigation of new SUE technology that leads to innovative and emerging utility investigation, detection, and mapping technologies such as 3-D mapping and visualization technologies.

- Procurement and contracting best practices. These best practices center on several issues including SUE provider qualifications requirements, quality control for SUE deliverables, having widespread availability, and SUE data management:

    - Project budgets that include funding for the cost of SUE investigations. This is a best practice that is already feasible but based on the data collected by the research team, not a standard TxDOT practice.
    - Improved QA/QC of SUE contractors. Currently, many SUE providers are selected based on pre-certification, which sometimes do not necessarily ensure the quality and reliability of SUE deliverables.
    - Widespread availability and authority of SUE services to ensure designers and project managers have ready access to SUE services and avoid delays caused by waiting for purchase authorities and approvals.

- Project development process best practices. A sampling of notable practices that characterize the wide range of project development processes involving SUE investigation at other state DOTs include:

    - Establishing uniform SUE criteria, impact forms, and conflict matrices. This would require TxDOT to modify and adopt existing utility impact tools for TxDOT business process, develop example for using utility impact tool with TxDOT projects, and develop training materials to use utility impact tool.
    - Including quality assurances and SUE concurrence points during the PDP. Concurrent points can be used as information sharing points for all stakeholders in the project development process and not necessarily to request everyone's buy-in and concurrence for the project. To some degree, some districts have been doing something similar, without having actual concurrence from stakeholders.
    - Conduct concurrent environmental and SUE review. This practice has been used by NCDOT. Stakeholders' feedback suggested that environmental process data collections were generally focused on database searching, whereas utility data collections required more on-site surveying. Stakeholders were also concerned that SUE data collected during the environmental process could become outdated. In addition, it is difficult to predict the need of SUE during that early stage.

- Best practices pertaining to policy approaches. The research identified several policy approaches that have a potential to improve utility investigations by TxDOT:

    - Policies to promote and standardize SUE practices internal to TxDOT, such as broad policies to establish minimum SUE investigation requirements at TxDOT, and narrow targeted policies with specific changes and updates to SOPs and manuals (also applicable to project development process recommendations).

- Policies to improve coordination with utility owners and operators external to TxDOT, such as establishing coordinating committees and working groups between the TxDOT and utility companies, and establishing coordinating committees with oil and gas operators and pipeline owners.
- Establish an agency-wide SUE Policy to encourage the use of SUE throughout the state.

RECOMMENDATIONS

Based on the research findings of this project as well as the feedback from stakeholder workshops, the research team recommends:

- **Implement the best practices identified during this project to improve project development at TxDOT**. Table 60 summarizes the identified best practices, their anticipated implementation costs and benefits, and their ranks based on stakeholders' feedback. These practices have been used successfully in several other states. Some of the practices were highly supported by many stakeholders as evidenced during the two rounds of workshops conducted as part of this research.

  In the training materials developed as part of this project, the research team has included two best practices including basic SUE training and utility impact analysis training. A parallel project at TxDOT, project 0-6624 "Improving the Response and Participation by Utility Owners in the Project Development Process," has developed training materials that include a module on the use of utility conflict matrices.

Table 60. List of Best Practices, Implementation Cost, Benefit, Complexity, and Ranks.

Best Practice	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity	Rank*
Education and Training					
Basic SUE training	Targets a broad audience, using a brief 1-2 hour format, focusing on SUE benefits and processes.	Low	Medium	Low	1
Advanced utility impact training	Advanced SUE Training for practitioners (similar to GDOT).	Medium	Medium	Low	1
Outreach training to utility companies	Training for utility designers (similar to ODOT).	Medium	Medium	Medium	4
Technology and Information Systems					
Utility document management systems	Develop software to aid in the storage, retrieval, and utilization of utility investigation data (similar to Penn DOT/VDOT).	High	High	High	4
Utility project management systems	Develop software that provides utility project tracking scheduling and reporting.	High	High	High	7

Best Practice	Specific Implementation Action	Relative Cost	Perceived Benefit	Relative Complexity	Rank*
Data archiving, sharing, uniformity, and asset management	Provide utility owners and contractors with licenses for project CAD platforms. Pilot program for data archiving.	Medium	Medium	Medium	13
Investigation new technology (e.g., GPR)	Institute pilot project to try new and emerging investigation technologies.	Medium	High	High	14
Procurement and Contracting					
Project funding for SUE	Project budgets include SUE services and estimates.	Medium	High	Medium	6
Improved QA/QC	Sue Provider qualifications, scope of services, and quality control.	Medium	Medium	Low	9
Widespread availability and authority	Any employee related to project can identify need and project manager approval.	Low	Medium	Low	11
Project Development Processes					
Utility impact/ conflict analysis	SUE Impact forms and conflict matrices for all projects.	Low	High	Low	3
Concurrence points	Utility review at pre-determined stages project development.	Medium	High	High	10
Environmental review concurrency	Concurrent involvement with environmental reviews and information.	Low	Medium	Medium	16
Policy					
Standard operating procedures	Prepare SUE SOP for Districts and Divisions.	Low	Medium	Low	8
Multilevel committees	Statewide Utility Coordinating Committee/Working group.	Low	Low	Low	12
Agency-wide/ statewide policy for SUE	Agency-wide policy describing the benefits and minimum requirements for SUE.	Low	Medium	Low	15

*Rank is based on stakeholder's feedback.

- **Implement 0-6631-P1 (Best Practices in Utility Investigation Services – Training Materials) to improve the utility investigation practices at the department.** The survey of a large number of TxDOT employees suggested that SUE is not well utilized at many districts. In addition, many relevant TxDOT employees lack sufficient knowledge about SUE including the latest SUE techniques and the potential benefits of SUE. Describe training materials, modules, targets, best format to deliver, feedback, etc.

- **Maintain information about SUE contracts and services performed to enable SUE-related analysis and studies.** As part of this project, the research team conducted an in-depth analysis of the effects of SUE on project delivery time, costs, and efficiencies. During data collection, the researchers found that TxDOT was not tracking many needed data elements in the current data systems or had only recently started tracking these data items. For example, TxDOT has implemented Oracle Primavera P6 for tracking key milestones during the project development process. However, this system was implemented in 2009 and during the time of this analysis, the system was not fully implemented and/or utilized by districts. In addition, there is currently no database that stores data elements related to SUE contracts, work order, and payment information. As a result, most information lies with local staff and becomes lost over time and due to staff turnover. Therefore, it is necessary for TxDOT to develop strategies to retain the information either at the district level or in a central data system to enable future SUE-related studies including performance evaluation.

IMPLEMENTATION

Implementation Plan and Potential Impediments

The research resulted in a number of best practices pertaining to education and training, technology and information systems, procurement and contracting, project development process, to policies. The research also developed a set of training materials aimed to improve practitioners' awareness and knowledge about SUE for more effective and reliable utility investigation during highway projects. There are several possible avenues that TxDOT could consider for implementing the findings of this project:

- **Implement SUE Training Materials.** At a minimum, TxDOT should implement the training materials developed during this project. The implementation of the training materials would include the following actions:
    - Conduct SUE training courses at selected districts or regions. Plans for providing SUE training at districts and/or regions should be developed. Trainers who are selected for this task should have a thorough knowledge of SUE services, utility conflict management topics, and utility coordination, as well as how the interaction between utility activities and other project development process components.
    - Transition SUE training materials to long-term training mechanism. TxDOT should evaluate options to transition the SUE training materials to a long-term training mechanism within the department to ensure training is available to TxDOT employees, utility owner staff, contractors, and consultants. Ideally, the training course would become part of the regular catalog of courses offered at TxDOT.
- **Implement Training and Education Best Practices.** The need for training of staff involved in utility-related activities in the project development and delivery process was a common theme mentioned during the stakeholder workshops. Training needs are not limited to staff who normally interact with utility owners, e.g., utility coordinators and right-of-way agents, but extend to staff whose work is likely to be affected by utility issues, such as project managers, design engineers, and area engineers. The need for training also extends to highway and utility consultants and contractors. This implementation would involve basic SUE training, advanced utility impact training, and

outreach training to utility companies. The implementation would likely include the following activities:

- Implement the SUE training materials developed during this project.

- Schedule one-day training courses to disseminate the systematic use of UCMs in the project development process. The one-day UCM training course, which was developed as part of project SHRP 2 R15-B, is ready for deployment. The course content could be easily customized to suit TxDOT needs, as needed.

- Develop and pilot other utility-related training courses as needed following a systematic approach that includes conducting a survey of user needs and takes into consideration factors such as availability of existing courses that could be updated to address relevant utility issues and financial constraints. The researchers recommend that TxDOT do so in conjunction with the implementation of 0-6624 training courses.

- **Implement Education and Training Best Practices and Other Selected Best Practices.** Unlike the education and training best practices, implementing the best practices of other categories may require changes to current TxDOT businesses and therefore the implementation process may be more effort demanding. However, some of those practices may yield more significant benefits if implemented. It is not the researchers' intention to implement all recommended practices. TxDOT should identify and implement those practices that are most suitable for the department and will likely yield most benefits. TxDOT may implement one practice at a time or bundle multiple practices and implement them simultaneously. The following are the activities that such an implementation should include:

  - Assemble TxDOT implementation task force. TxDOT should assemble a task force to supervise and lead the implementation of the research products. The task force should include a delegate from ROW and officials from regional service centers and/or selected districts.

  - Conduct training session with task force. The researchers should provide a relatively brief presentation with the implementation task force to familiarize the team with the details of the best practices and aid the team with the determination of the best implementation plan.

  - Agree on implementation plan. Before implementation begins, the task force should agree on an implementation plan. This plan should define, as a minimum, which research products should be implemented and in what sequence, as well as what districts should be involved in pilot implementation. In addition, the plan should outline the strategy to provide associated training, including location, frequency, and participant groups.

- o Establish progress milestones, targets, responsibilities, and funding. The task force should establish major implementation milestones, target dates, responsibilities, and estimated needs for funding. In addition, the task force should get a commitment from TxDOT administration for the proposed plan, which might include one or more meetings and presentations of the plan with TxDOT administrators.

- o Update relevant manuals. The implementation team should play a strong role in updating the *ROW Utility Manual*, the *Project Development Process Manual*, and other relevant manuals if needed. At this point, the researchers do not foresee the need to make changes to statutes or Texas Administrative Code rules.

The researchers conducted a comprehensive analysis of impediments that might hinder the successful implementation of the recommended best practices and the developed SUE training materials. Potential impediments include:

- Technical challenges. Some best practices (e.g., technology and information systems and project development process best practices) require the use of information systems. Implementing such systems can be associated with additional efforts required for system maintenance, data collection and population, and system upgrades. Currently, TxDOT does not collect utility data systematically on all projects, which can be a challenge for some of the recommended best practices. In addition, different districts have different business practices and therefore may require customized designs and/or configurations of such systems.

- Economic challenges. For the training and education best practices, the researchers' perception is that there is a consensus at TxDOT for the training needs. In addition, implementing those best practices will generally require moderate resources. For some other best practices, their implementation may face the following impediments:

  - o TxDOT might not have the financial resources to implement some of the research findings. This is an important issue, particularly at a time when TxDOT is facing severe budgetary constraints. To overcome this challenge, TxDOT may implement the selected best practices gradually to reduce initial capital requirement. Instead of implementing an enterprise-level system statewide, TxDOT may develop low cost alternatives such as Excel- or Access- based tools and implements them at the district level first. However, the savings of implementing an enterprise-level system could be realized in the long term in terms of adaptability, scalability, avoidance of redundant data entry, data access, data sharing, and data security.

  - o TxDOT administration or districts might not perceive tangible economic benefits from implementing the selected best practices. This is an important issue, for which an obvious counter strategy is to document and disseminate lessons learned from study cases in which the selected best practices are used. Insufficient utility information and not managing utility data effectively increase the level of risk for a project owner, which in turn can have significant negative economic repercussions. For certain practices such as the use of UCM and other utility data management systems, strategies to address this issue include using them with control dates (to ensure the UCM or the other utility data systems are a living document), and start using them early in the project development process, i.e., at the beginning of the preliminary design phase.

- For some policy and project development process best practices, users might decide to ignore the updated policies/requirements in favor of existing practices they perceive to be more efficient or more cost-effective. The continuous and widespread training and outreach at different level can be an effective strategy for this challenge. In addition, users will typically increase their acceptability of the newly implemented policies/practices as they find that stakeholders increase their knowledge and understanding and project development and delivery efficiencies increase.

- TxDOT might not have the necessary tools to implement the best practices. Some of the best practices can be highly technical. Others require updates to several TxDOT manuals, a series of workshops throughout the state to disseminate the practices, and monitor the degree to which the practices implementation is successful.

Criteria or performance measure elements to evaluate the effectiveness of the implementation of the research products include the following:

- Number of TxDOT officials, by function category (e.g., utility coordination, preliminary design, design) who have attended the associated training courses.
- Reduction in the number of, and dollar amount associated with, unnecessary utility adjustments.
- Reduction in the number of, and dollar amount associated with, utility-related change orders or claims.

Required Changes to TxDOT Manuals

To facilitate potential implementation, the researchers reviewed several TxDOT manuals, including the *ROW Utility Manual* (*62*), the *Project Development Process Manual* (*21*), the *PS&E Preparation Manual* (*63*), and the *Roadway Design Manual* (*57*) to identify relevant sections that may benefit from findings of the research and propose updates to content and potential changes.

ROW Utility Manual

TxDOT *Right of Way (ROW) Utility Manual* is the main source of regulation and guidance for the accommodation of utilities on the state right-of-way in Texas. In its current version, the manual includes 12 chapters and one appendix.

TxDOT project 0-6624 “Strategies to Encourage and Facilitate Utility Owner Participation in Transportation Projects” developed a modernized depiction of the TxDOT utility process. The new depiction reorganized the activities associated with the utility process to better reflect desired or current utility practices at districts. The new depiction excluded several outdated or inaccurate activities in the current utility manual and updated other activities as needed. In particular, the new depiction includes a number of utility data collection and assessment activities that emphasized the use of SUE services and the importance of utility impact analysis. If implemented, the new depiction would result in major changes to Chapters 1, 2, 4, and 8, and relatively minor changes to other chapters.

In addition to the necessary changes resulting from 0-6624 recommendations, the following is a summary of recommended changes the 0-6631 research team identified. The recommended changes are mostly in Chapters 2, 4, and 5. The changes are based on the assumption that recommendations from 0-6624 will be mostly implemented while the current manual structure (i.e., major chapters, sections, and format) will be maintained.

- Chapter 1 – Introduction. This chapter includes an overview of the utility process at TxDOT, an overview of relevant fiscal and authorization issues, and a listing of available forms and templates. This research will not result in major changes to this chapter. However, the research team noted that on page 1-4, the manual provides a link to the Utility Accommodation Rules (UAR) in pdf. The link points to a file "uar.pdf" located at ftp://ftp.dot.state.tx.us/pub/txdot-info/row/. It appears that this file does not represent the latest version of the UAR and would need to be updated. Alternatively, the link could point to the online version of the UAR at http://info.sos.state.tx.us.

- Chapter 2 – TxDOT-Utility Cooperative Management Process and Subprocess. This chapter contains detailed descriptions in Sections 1 and 2 about required activities during the TxDOT utility cooperative management process and the right-of-way utility adjustment subprocess. The chapter also includes a section describing the process and issues relevant to the use of memorandums of understanding (MOUs). Recommended changes to Section 1, TxDOT Utility Cooperative Management Process, are as follows:

    - Activity "Exchange of Project Specific Information: Field Verification – Process Activity IV." The rewrite of the utility process will likely result in a split of this activity into several activities in the preliminary design phase and the detailed design phase. Notwithstanding the specific implementation of the new utility process, it is critical to stress a succession of increasingly detailed utility data collection efforts, starting with quality level (QL) D (existing records and oral recollections), and followed by QLC (aboveground survey), QLB (geophysical survey), and QLA (test holes).

      The narrative should also emphasize that QLD and QLC SUE data collection are typically performed by TxDOT staff. QLB SUE data collection is typically performed by a SUE provider, and QLA SUE data are either provided by the utility company or a SUE provider. Due to the high cost of QLA SUE data, it is important to emphasize the need of sufficient utility data collection prior to QLA SUE data collection/test holes to help identify critical locations for test holes. These locations should be determined by the TxDOT project designer with input by the TxDOT utility coordinator and utility owner.

The cost for test holes is typically a project expense, although utility owners sometimes agree to expose their facilities at their own cost, which can then be surveyed by a TxDOT surveyor at significantly lower cost. This requires some coordination with the utility company to ensure that utility locations are surveyed immediately after exposure of the facility. The activity should note that many projects require some detailed design definitions to make a determination for test hole locations, and a reference to activity VI that describes further SUE data collection activities.

The objectives of the activity could be modified as follows:

- Identify location and ownership of utility facilities within project limits using QLD and QLC SUE data collection activities.
- Consider the use of a SUE provider for QLB SUE data collection.
- Determine accurate horizontal and vertical locations in critical locations using TxDOT control datum.

- Activity "Design and Utility Construction Phase: Intermediate Design Meeting(s) – Process Activity VI." The rewrite of the utility process will likely result in a split of this activity into several activities in the detailed design phase, which will provide some information about SUE data collection. Notwithstanding the specific implementation of the new utility process, it is critical to stress that the activity should include recommendations for SUE data collection and requirements of SUE data collection deliverables, and a reference to SUE data collection in previous activities.

  In particular, the activity should include a reminder to consider QLB SUE data collection prior to 30 percent design so that data collection deliverables can be included in 30 percent design submittal. The activity should also include a recommendation that a need for test holes can arise at any time during the project development process, and that utility data collected should be included in the next round of design drawings. On many projects, the great majority of QLA SUE data should be collected following a review of the 60 percent design drawings, or as soon as the design of drainage and underground features is substantially complete. SUE QLA data should then be included in the 90 percent design submittal.

  A review of utility conflicts at this stage typically allows for a determination if the utility may remain in place or may need to move. However, some types of utility conflicts have the potential to create significant costs to utility owners and delays to the project. If there is any evidence of such conflicts, these utility conflicts should be reviewed as early as possible in the project development process to allow the designer to make changes to the design to avoid significant costs and delays. SUE deliverables should also be included in final plans, specifications, and estimates (PS&E) submittals.

- Recommended changes to Section 2, Right of Way Utility Adjustment Subprocess, are as follows:

    - Activity "Field Verification – Right of Way Subprocess Activity II." This activity describes the location verification and determination of utility ownership in the field during preliminary design prior to right-of-way release. To avoid confusion with activity "Exchange of Project Specific Information: Field Verification – Process Activity IV" of Section 1, the title of the activity could be changed to "Field Verification Prior to Right of Way Release – Right of Way Subprocess Activity II." Although the activity already includes some suggestions for use of SUE data collection, this should be expanded and clarified. Most SUE data collection during the preliminary design stage should be at QLD and QLC, which is typically performed by TxDOT staff. Typically, a SUE provider should be involved if there is a need for QLB or QLA data collection and only after QLD and QLC data have been collected by TxDOT and forwarded to the SUE provider.

  In addition to the above changes, TxDOT should consider adding a section in this chapter to specify requirements for the collection and storage of utility document and utility project data. The requirements should clearly identify data collection and management responsibilities, data items to be collected and stored, data collection timing, and potential data usage information.

- Chapter 3 – References for Utility Accommodation. This chapter reviews relevant federal and state codes, regulations, policies, and guidance. The research team does not anticipate major changes to the chapter.

- Chapter 4 – Preliminary Planning. This chapter provides information and guidance about utility-related preliminary planning activities, utility location investigations, preliminary utility adjustment funding determinations, initial exchange of design data and criterion, and requirements for LPAs. The implementation of TxDOT research 0-6624 recommendations will likely to result in significant changes throughout the chapter. Nevertheless, the recommended best practices of 0-6631 would result in changes mainly in Section 2 – Utility Location Investigations. Currently, this section includes very brief requirements on utility facility identification and use of SUE services.

  This section should be significantly expanded to describe the standard SUE data collection procedure, including the recommended SUE standards and referencing ASCE/CI standard 38/02 (*4*); required deliverables including standards, contents, and format; and required QA/QC procedures. The section should also provide a definition of SUE and quality levels, indicate which types of data collection are typically performed by TxDOT employees and which typically require a utility engineering contract, unless defined in an earlier section. This section should also include a brief overview of One Call data, how district may be able to acquire data effectively, and its uses and limitations.

- Chapter 5 – Utility Considerations During Highway Design. This chapter describes utility-related issues that need to be considered during highway design. Sections of this chapter contain information about SUE data collection, combined transportation utility construction, and intermediate design meetings, which need to be modified to ensure consistency. Specific changes that need to be made include:

  - Section 1 – Determination of Utility Impacts. This section should be expanded to include more information about utility impact analysis and the use of utility conflict matrices. The section should clearly identify the responsibilities, utility conflict identification and tracking activities, and the need for design solutions to avoid conflicts.

  - Section 3 – Utility Engineering Contracts. This section should be updated to include more recent research on estimated cost savings when using SUE QLB and A. This section could also include a summary of survey results that describes TxDOT staff estimates of cost savings when using SUE. This section should also expand on information about requirements or guidelines on the types, procedure, budgeting, and payment associated with SUE contracts. In addition, the section should include guidelines on project funding and budgeting for SUE services.

  - Section 8 – Intermediate Design Meetings. This section should be expanded to include recommendations for SUE deliverables during 30 percent, 60 percent, and/or 90 percent design milestones. Recommendations could be in form of concurrency points between SUE data collection and the project development process to ensure that SUE is effectively and timely utilized. Changes to this section should be coordinated with recommended changes for individual activities in Chapter 2.

- Chapter 6 – Utility Plans and Specifications. This chapter provides information and guidance on initial actions of the utility owners upon needed adjustments, utility plan preparation, and use of contractors on utility work. The researchers do not anticipate major changes to the chapter. However, based on comments from TxDOT staff in rural districts, it may be useful to add a section here that describes the benefits of coordinated test hole activities between TxDOT and utility owner. In some TxDOT districts, utility owners expose their facilities at their cost, and then notify TxDOT to survey the location of the facility. Utility owners that agree to this coordinated effort realize that there is a benefit if a utility may be allowed to remain in place if accurate information is available early in the project development process.

- Chapter 7 – Utility Cost Estimates. This chapter contains information about utility cost estimate requirements, estimate categories, and cost estimate issues pertaining to contract work and consultants. The researchers do not anticipate major changes to this chapter.

- Chapter 8 – Procedures for Utility Adjustments. This chapter includes general information and guidance on utility adjustment procedures, such as state, federal, local, and non-reimbursable utility adjustment procedures. The researchers do not anticipate major changes to this chapter.

- Chapter 9 – Forms and Agreements. This chapter describes the forms and agreements involved in the utility process. The researchers recommend that TxDOT add a section in the chapter to provide specifications and examples of SUE contract forms and requirements. The section should be developed in coordination with the changes previously recommended for Chapter 5 to avoid redundancy.

- Chapter 10 – Performing the Utility Adjustment. This chapter includes information about utility pre-construction activities, inspection activities, abandoned interests, and utility installation inspection. The researchers do not anticipate major changes to this chapter.

- Chapter 11 – Billing and Payments. This chapter provides general requirements and guidance on billing and payment related issues, such as invoicing and payment procedures, partial payments, final billings, reimbursement when LPA is responsible party, payments and final audit, and utility considerations in right-of-way project closeout. The proposed practices would not result in major changes to this chapter.

- Chapter 12 – Unique Conditions and Special Cases. This chapter pertains to the issues related to unique utility conditions and special cases. The proposed practices would not require major changes to this chapter.

- Appendix A – Reimbursement Guidelines and Billing Procedures for Utility Adjustments. The researchers do not anticipate major changes to this section.

Project Development Process Manual

The *Project Development Process Manual* is the main information source concerning the project development process at TxDOT. In its current version, the manual includes six chapters. The following is a summary of recommended changes the 0-6631 research team identified. The recommended changes are mostly in Chapters 2, 4, and 5, as follows:

- Chapter 1 – Planning and Programming. This chapter contains project development process activities during the transportation planning and programming phase. The activities are organized into several groups including needs identification, project authorization, compliance with planning requirements, study requirements determination, and construction funding identification. The recommended practices would not result in changes to these activities.

- Chapter 2 – Preliminary Design. This chapter describes the project development process activities during the preliminary design phase of transportation projects. The implementation of the recommended practices would require changes to several activities, as follows:

    - Task 2180, "Obtain information on existing utilities." This activity requires utility locations to be identified early during project development. The activity description currently includes a helpful suggestion to consider using SUE services (Task 4200.)

This task should be modified to avoid confusion about SUE activities at different quality levels. As is, several sub-tasks constitute SUE QLD activities. As such, the task should state that TxDOT staff should perform SUE QLD activities such as reviewing as-built plans and QLC (aboveground survey of utilities), and should consider using QLB and QLA data collection as performed by a SUE provider as described in Task 4200, depending on the specifics of the project. This task should also include information about performing a utility impact analysis using Excel spreadsheets that are used during the training workshop. Alternatively, performing a utility impact analysis could be included as a new, separate task.

- Task 2640, "Identify existing utilities on geometric schematic." This activity states that the design engineer should obtain information on existing utilities from utility owners and create a layout of the existing utilities on geometric schematic. To avoid confusion, sub-task two should state that information should be collected from utility owners unless it has already been collected as part of Task 2180. Similarly, a utility-layout should only be developed if it was not developed as part of Task 2180. The activity description also states that SUE can be considered for this purpose. Information about using SUE should be modified similarly to the recommendation provided for changes to Task 2180.

- Task 2650, "Identify potential utility conflicts." The manual requires the design engineer to determine potential utility conflicts based on the utility layout. The activity description also suggests that designers avoid utilities by revising alignments and project features. The description of this activity should be expanded to include information on utility conflict analysis including the use of utility conflict matrices and available utility project/document data sources.

- Chapter 3 – Environmental. This chapter includes project development process activities that take place during the environmental phase. The activities are organized into several groups including preliminary environmental issues, interagency coordination/permits, environmental documentation, public hearing, and environmental clearance. The recommendations of this research would not result in major changes to this chapter.

- Chapter 4 – Right of Way Utilities. This chapter describes project development process activities in relation to right-of-way and utilities. Section 1 of this chapter contains activities about right-of-way and utility data collection.

  - Task 4200, "Locate existing utilities." This task should be changed based on the recommended practices of this research. Currently, the description of this activity includes recommendations of using SUE. However, the activity does not include clear guidelines as to when SUE is used and how SUE contracts are procured. In addition, it does not provide any information on SUE standards, deliverables, use of utility conflict matrices, and utility document/project data sources. Information on these topics should be added to the manual. The task should also avoid confusion by defining SUE as non-destructive process of accurately locating utility facilities. Rather, it would be beneficial to define SUE in terms of data collection at different quality levels, as defined in ASCE/CI standard 38/02 and described later in this task. Helpful suggestions should be modified to state accurate levels of estimated project savings as documented in the research report. There could also be a helpful suggestion outlining estimated benefits by TxDOT staff, as documented in the TxDOT staff survey and described in the research report. All changes to this task should be coordinated with those recommended for the *ROW Utility Manual*, and cross-references should be added to both manuals. The section listing resource materials could include several important references, such as the ASCE/CI standard and two recent SHRP 2 studies (*3, 22*).

- The section "Information on Subsurface Utility Engineering (SUE)" should be reviewed and updated to align with the definitions for quality levels and other terminology provided by the ASCE standard 38/02.

- On page 4-2, paragraph four states that "This section includes the following tasks: (…) 2180. Obtain information on existing utilities. (…)" Task 2180 is not included in this section but rather chapter 2, and therefore this line should be removed.

- Chapter 5 – PS&E Development. This chapter describes project development process activities that pertain to the development of PS&E. The activities are organized in several groups including design conference, begin detailed design, final alignments/profiles, roadway design, operational design, bridge design, drainage design, retaining/noise walls and miscellaneous structures, traffic control plan, PS&E assembly/design review. The researchers recommend changes to the following activity descriptions:

  - Task 5120, "Review data collection needs." This activity is an opportunity during the detailed design phase for additional data collection to ensure data items needed during detailed design are up-to-date and accurate. TxDOT should add a recommendation in this activity for the review of utility data that have been collected up to this point in the project development process, and the need for additional QLB and QLA SUE data in order to obtain precise location information of conflicting utility facilities and develop design solutions to reduce project costs. Under the headline "Previous data collection may include (…)" the following additional tasks should be referenced:

    - Task 2180, "Obtain information on existing utilities."
    - Task 4200, "Locate existing utilities."

  - Task 5480, "Prepare preliminary bridge layouts." This task outlines the development of proposed features of bridge structures to be newly constructed, replaced, or modified. Under sub-tasks, the task outlines the need to obtain layouts of existing structures and utility facilities. This subtask should be expanded to include a recommendation to accurately locate utility facilities that may be in conflict with the proposed bridge structure.

- Task 5500, “Prepare bridge details.” This task describes the updating of bridge layouts developed under Task 5480. Under sub-tasks, the task mentions a need to obtain proposed utility plans from the roadway engineer. This subtask should be expanded to include a recommendation to accurately locate all exiting utility facilities in the vicinity of the bridge structure, to determine if any utilities are in conflict, and to ascertain if a design change can avoid the utility conflict.

- Section 7 – Drainage Design. This section discusses the design of drainage features, which often have a major impact on existing utility facilities. Either the introductory section or subsequent drainage design tasks should be expanded to discuss the need to evaluate impacts on utilities, and the opportunity to save costs and avoid substantial project delays during the construction phase. The task should emphasize the need to coordinate drainage design activities with the utility coordinator, the need to review existing utility data, and the opportunity to request additional utility data as necessary. There should also be a reference under this task to Task 4610, “Coordinate utility adjustment plans,” which requires that as soon as design of proposed underground features are substantially complete, construction plans should be sent to all utility owners. Plans must be forwarded to the utility coordinator so that they can be forwarded to utility owners.

- Task 5640, “Prepare retaining and/or noise wall layouts.” This task describes the activities to prepare layouts for planned retaining walls and/or noise walls. The task includes a sub-task that mentions the need to obtain plots of existing utilities to determine proposed wall locations. The sub-task should be expanded to emphasize the opportunity to avoid existing utilities by collecting accurate utility data in areas close to the potential location of such walls. The sub-task should also provide a warning for substantial delays during the construction phase if existing utilities are impacted. It would also be helpful to include references to previous tasks that may have collected utility data, including the following:

  - Task 2505, “Perform preliminary geotechnical surveys.”
  - Task 2240, “Perform other surveys.”
  - Task 2230, “Perform topographic surveys.”
  - Task 2180, “Obtain information on existing utilities.”
  - Task 4200, “Locate existing utilities.”

- Task 5830, “Prepare PS&E package.” This activity pertains to the assembly of the PS&E package for review by district. The current project development process manual includes a general list of documents that need to be included in the project development process assembly. This list could be expanded to include SUE deliverables such as utility plans, test hole reports, and other SUE documents.

- Chapter 6 – Letting. This chapter describes project development process activities during the final processing and letting phase. The research team does not anticipate changes to this chapter due to the recommended practices of this research.

PS&E Preparation Manual

The *TxDOT PS&E Preparation Manual* contains requirements and guidelines on the documents, records, forms, and other materials that are needed during the assembly of PS&E documents. The research team recommends changes to the following section in Chapter 2, "Plan Set Development:"

- Section 2, "Plan Set Preparation." This section contains requirements on the various plans that need to be included in PS&E assemblies. Under the header "Plan Sheet Sequence," the section contains brief information about plans pertaining to utilities, existing utilities, proposed utility (PS&E) layouts, and utility standards. These paragraphs may need to be revised to include requirements for SUE deliverables and to clearly specify the format/standard of the deliverables if they are to be included.

Roadway Design Manual

TxDOT *Roadway Design Manual* contains requirements and guidelines pertaining to roadway design topics such as geometrics, road side features, and road accessories. The recommended practices of this research will not result in changes to existing contents. However, it is preferable that TxDOT adds a separate chapter discussing design data collection including potential sources and data collection methods for each type of data needed for roadway design. One essential data component for roadway design would be the collection of utility data at different SUE quality levels. Alternatively, the Roadway Design Manual could reference sections in the ROW Utility Manual or the Project Development Process Manual that describes the data collection activities.

Utility Accommodation Rules

In addition to the manuals, the research team also examined the relevant rules included in the Utility Accommodation subchapter of the Texas Administrative Code (TAC) to identify needed changes (*7*). The researchers' assessment is that the recommended practices of this research are not likely to require changes to the current utility accommodation rules.

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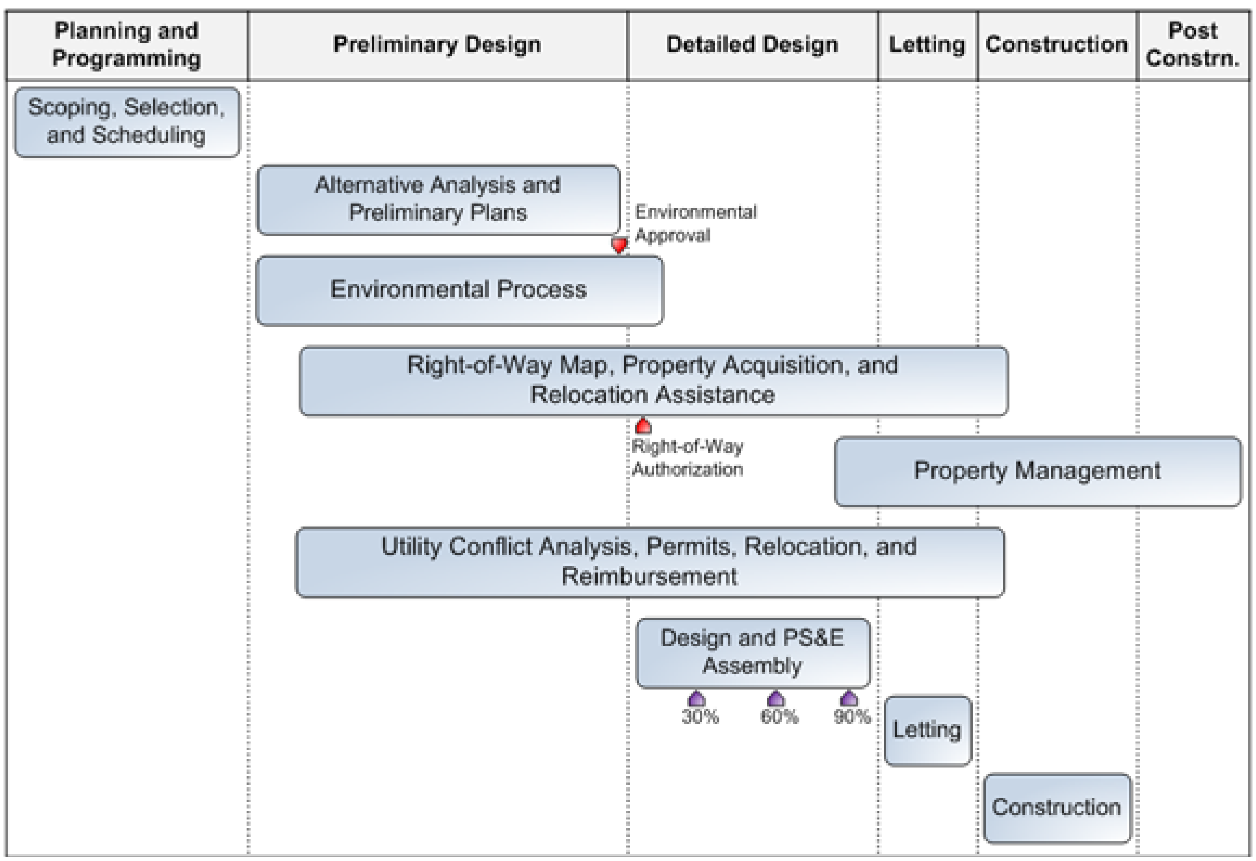
APPENDIX A. TXDOT SURVEY QUESTIONNAIRE

Page 1

1. In what phase(s) of the transportation project development process (see figure below) are you personally involved? (Check all that apply.)

☐ Planning and Programming
☐ Preliminary design
☐ Detailed Design (PS&E Development)
☐ Letting
☐ Construction
☐ Post-construction

Typical phases of the TxDOT project development process:



Page 2

2. Which utility investigation techniques has your district or region used in the past? (Check all that apply.)

☐ Existing records research (e.g., utility owner records)
☐ Surveying of surface utility appurtenances
☐ Pipe and cable locators
☐ Terrain conductivity
☐ Ground penetrating radar
☐ Ground penetrating radar arrays
☐ Magnetic methods
☐ Elastic wave methods (e.g., acoustic location)
☐ Vacuum excavation
☐ Infrared thermography
☐ Other

If Other please specify ______________________________

Page 3

Some of the following questions refer to quality levels (QL) for utility investigations, as defined in ASCE/CI standard 38-02. A quality level is a professional opinion of the quality and reliability of utility data, certified by a professional engineer or surveyor:

> QLD: Data collection from existing records or oral recollections.
> QLC: Surveying and plotting of visible utility appurtenances and making inferences about underground linear utility facilities that connect those appurtenances.
> QLB: Surface geophysical methods (e.g., ground penetrating radar) to determine the approximate horizontal position of subsurface utilities.
> QLA: Accurate horizontal and vertical utility locations through exposure of utility facilities at certain locations (e.g., test holes).

QLB data collection using pipe locator.

QLA data collection using vacuum excavation.

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3. Who can request the use of utility investigations on a project? (Check all that apply.)

	QLD	QLC	QLB	QLA
Planning and Programming	☐	☐	☐	☐
Preliminary Design	☐	☐	☐	☐
0–30% design	☐	☐	☐	☐
30–60% design	☐	☐	☐	☐
60–90% design	☐	☐	☐	☐
90–100% design	☐	☐	☐	☐
Construction	☐	☐	☐	☐

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4. Who can request the use of utility investigations on a project? (Check all that apply.)

	QLD	QLC	QLB	QLA
Project manager	☐	☐	☐	☐
Design team	☐	☐	☐	☐
District utility coordinator	☐	☐	☐	☐
District environmental coordinator	☐	☐	☐	☐
Utility engineer	☐	☐	☐	☐
SUE consultant	☐	☐	☐	☐
Utility company	☐	☐	☐	☐
Other	☐	☐	☐	☐

If Other please specify ______________________________

5. Who makes the final decision to use utility investigations? (Check all that apply.)

	QLD	QLC	QLB	QLA
Project manager	☐	☐	☐	☐
Design team	☐	☐	☐	☐
District utility coordinator	☐	☐	☐	☐
District environmental coordinator	☐	☐	☐	☐
Utility engineer	☐	☐	☐	☐
SUE consultant	☐	☐	☐	☐
Utility company	☐	☐	☐	☐
Other	☐	☐	☐	☐

If Other please specify ______________________________

Page 6

For the following quality levels, briefly describe the process to request and approve the data collection effort:

6. QLD data collection

____
____
____

7. QLC data collection

8. QLB data collection

9. QLA data collection

Page 7

Please select if procedures for utility investigations are different for the following:

10. Urban vs. rural projects?

- **Yes**
- **No**

Briefly explain why:

11. Projects on new right-of-way vs. projects entirely on existing right-of-way?

- **Yes**
- **No**

Briefly explain why:

12. Added capacity vs. non-added capacity projects?

- **Yes**
- **No**

Briefly explain why:

____
____
____

Page 8

13. What factors influence your decision to use or request QLB data collections for a project?

____
____
____

Page 9

14. How do the following factors influence your decision to use or request QLA data collection for a project:

	1 (No impact)	2 (Low impact)	3 (Medium impact)	4 (Medium to high impact)	5 (High impact)
Estimated density of underground utilities	○	○	○	○	○
Type of utilities (water, gas, oil, etc.)	○	○	○	○	○
Material of utilities (e.g., concrete, cast iron, PVC)	○	○	○	○	○
Ease of access to utilities	○	○	○	○	○
Estimated age of utilities	○	○	○	○	○
Estimated utility relocation costs	○	○	○	○	○
Estimated project traffic volume (e.g., ADT per lane)	○	○	○	○	○
Project urgency/schedule	○	○	○	○	○
Project area description (e.g., rural, suburban, urban)	○	○	○	○	○
Excavation depth on right-of-way					
Quality of known utility information (QLC and QLD)	○	○	○	○	○
Past performance and response of utility companies	○	○	○	○	○
Potential impact on businesses if utility is accidentally damaged	○	○	○	○	○
Potential environmental impact if utility is accidentally damaged	○	○	○	○	○
Potential safety impact if utility is accidentally damaged	○	○	○	○	○

15. What other factors influence your decision to use or request QLA data collections for a project?

____

____

____

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16. Do you use any type of checklist, flowchart, or other procedure to determine what type of utility investigation data to collect and when?

- **Yes** [go to question 17]
- **No** [go to question 18]

Page 11

17. Briefly describe the type of checklist, flowchart, or other procedure you use to determine what type of utility investigation data to collect and when:

____
____
____

Page 12

18. Which of the following utility investigation levels are typically performed in-house or outsourced to SUE consultants? (Check all that apply.)

	In-House	**SUE Consultant**
QLD	☐	☐
QLC	☐	☐
QLB	☐	☐
QLA	☐	☐

Briefly explain why:

____
____
____

Page 13

19. Have you been involved with the procurement of SUE consultant services?

- **Yes** [go to question 20]
- **No** [go to question 21]

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20. Please rate the overall effectiveness of the following types of procurement practices for SUE services:

	Least Effective	Somewhat Effective	Very Effective	N/A (Do not use)
Evergreen contract (one SUE consultant per district)	○	○	○	○
Evergreen contract (multiple SUE consultants per district)	○	○	○	○
Engineering services contract with SUE consultant (not evergreen)	○	○	○	○
Engineering services contract, SUE consultant included as subcontractor (not evergreen)	○	○	○	○
Other	○	○	○	○

If Other please specify ______________________________

Page 15

21. Have you been involved with the management of SUE contract task orders?

- **Yes** [go to question 22]
- **No** [go to question 23]

Page 16

22. Briefly describe challenges and recommendations for managing SUE contract task orders:

____
____
____

Page 17

23. Have you received QLB or QLA SUE deliverables in the past?

- **Yes** [go to question 24]
- **No** [go to question 26]

Page 18

24. Please rate your satisfaction with QLB data collection deliverables in the past:

	Excellent	Good	Average	Fair	Poor	No answer
Quality	○	○	○	○	○	○
Accuracy	○	○	○	○	○	○
Completeness	○	○	○	○	○	○
Reliability	○	○	○	○	○	○
Timely response to request for data collection	○	○	○	○	○	○
Timely product delivery	○	○	○	○	○	○
Value	○	○	○	○	○	○

25. Please rate your satisfaction with QLA data collection deliverables in the past:

	Excellent	Good	Average	Fair	Poor	No answer
Quality	○	○	○	○	○	○
Accuracy	○	○	○	○	○	○
Completeness	○	○	○	○	○	○
Reliability	○	○	○	○	○	○
Timely response to request for data collection	○	○	○	○	○	○
Timely product delivery	○	○	○	○	○	○
Value	○	○	○	○	○	○

Page 19

26. Do you have a formal process to review deliverables from SUE consultants?

- **Yes** [go to question 27]
- **No** [go to question 28]

Page 20.

27. Briefly describe the process you have in place for reviewing SUE deliverables:

____

____

____

Page 21

Research has shown that the use of QLB and QLA SUE can have significant benefits in terms of lower project cost. However, QLB and QLA SUE are not frequently used on TxDOT projects.

28. Can you give a reason why QLB and QLA SUE are not frequently used on TxDOT projects?

____
____
____

29. What is your expected return on investment when using SUE (project cost savings to SUE expenditures)? For example, a 10:1 ratio means expected project cost savings of $10 for every $1 spent on SUE.

	1:1 (no net savings)	**2:1**	**3:1**	**4:1**	**5:1**	**10:1**	**20:1 or more**	**Don't know**
Expected project savings	○	○	○	○	○	○	○	○

Page 22

30. For the following issues with utility data, indicate how frequently your district has experienced them.

	Frequently	**Sometimes**	**Rarely**	**Not an issue**
Utility data collection	○	○	○	○
Utility data liability	○	○	○	○
Utility data sharing within TxDOT	○	○	○	○
Utility data sharing outside TxDOT	○	○	○	○
Utility data updates	○	○	○	○
Utility data reliability	○	○	○	○
Other	○	○	○	○

If Other please specify ______________________________

Page 23

In other states, utility companies are increasingly concerned about sharing information about the location of their facilities with the general public and/or competitors.

31. To what degree is the management of confidentiality and/or security of utility data an issue in your district/region?

	High concern/priority	Medium concern/priority	Low concern/priority	Not an issue
Utility data security	○	○	○	○

Briefly explain why:

____
____
____

Page 24:

32. Can you share a best practice for utility investigations?

- **Yes** [go to question 33]
- **No** [go to question 34]

Page 25:

33. Briefly describe best practice(s) for utility investigations:

____
____
____

Page 26

34. Have you experienced any challenges with the use of utility investigations/SUE technology?

- **Yes** [go to question 35]
- **No** [go to question 36]

Page 27

35. Briefly describe what challenges you have experienced with the use of utility investigations/SUE technology, if any.

____
____
____

Page 28

36. Do you know of a current utility investigation practice in your district/region that could be improved or should be reviewed?

- **Yes** [go to question 37]
- **No** [go to question 38]

Page 29

37. Briefly describe current utility investigation practices in your district/region that could be improved.

____
____
____

Page 30

38. Are there any policies and/or regulations that constrain or obstruct the use of utility investigations in the project development process?

- **Yes** [go to question 39]
- **No** [go to question 40]

Page 31

39. Briefly describe the policy and/or regulations that constrain or obstruct the use of utility investigations in the project development process.

____
____
____

Page 32

40. Please select documents you use for utility investigations during the project development process. (Check all that apply.)

☐ Standard operating procedure (SOP)
☐ TxDOT Utility Manual
☐ SUE/utility investigations manual
☐ ASCE SUE standard (ASCE 38-02)
☐ Memorandum of understanding with utility companies
☐ Memorandum of understanding with SUE providers
☐ Field guide
☐ District policy or guide
☐ Other
If Other please specify ______________________________

41. What other information would help you decide when and how to use utility investigations or SUE technology in the project development process?

____
____
____

Page 33

42. What type of information management systems are used at your district/region to record, identify, and/or manage utility investigation data?

Data Management Platform	**Heavy Use**	**Moderate Use**	**Light Use**	**Do Not Use**
Spreadsheet (Excel, OpenOffice, other)	○	○	○	○
Word processor (Word, Word Perfect, other)	○	○	○	○
Desktop database (Access, other)	○	○	○	○
Server-based database (SQL Server, Oracle, MySQL, other)	○	○	○	○
CAD (AutoCAD, MicroStation, other)	○	○	○	○
Desktop/Server GIS (ArcGIS, TransCAD, Geomedia, other)	○	○	○	○
Other	○	○	○	○

If Other please specify ______________________________

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The following are questions for demographic purposes only that will not be related to survey responses in the final report.

43. What division, region, or district do you work in?

[Pull down menu of choices]

Design Division
Right of Way Division
Environmental Division
North Region
West Region
East Region
South Region
Abilene
Amarillo
Atlanta
Austin
Beaumont
Brownwood
Bryan
Childress
Corpus Christi
Dallas
El Paso
Fort Worth
Houston
Laredo
Lubbock
Lufkin
Odessa
Paris
Pharr
San Angelo
San Antonio
Tyler
Waco
Wichita Falls
Yoakum
Other
If Other please specify ______________________________

44. What section/field do you work in?

[Pull down menu of choices]

Design
Environmental
Right of Way
Utilities
Other
If Other please specify ______________________________

45. What is your position/title? (Select the option most closely matching your official title and functions).

[Pull down menu of choices]

Director/Head
Project Manager
Engineer
Staff/Support
Other
If Other please specify ______________________________

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46. Sometimes it is useful to follow up to clarify a response. May we contact you for further discussion?

- **Yes**
- **No**

47. Thank you for participating in this survey, we sincerely appreciate your help. If you have any further comments please enter them below or contact the project's principal investigator Edgar Kraus at e-kraus@tamu.edu.

____
____
____

Potential Follow-Up Interview

0-6631 Interview Notes

Interview conducted by: ____ Date: _________

Interview with: ____

Title: ____

TxDOT Division/Region/District: ____

Mailing address: ____

Phone number: ____

Email address: ____

Description of Innovative/Best Practice(s)

Recommendations for Implementation

Lessons learned

Other issues, recommendations, or comments

Sample Documentation Gathered

Additional Contact for Interview

APPENDIX B. RESPONSES TO TXDOT SURVEY ESSAY QUESTIONS

Question 6. For the following quality levels, briefly describe the process to request and approve the data collection effort: QLD Data Collection. (63 Responses, 66 Skipped.)

Table 61. Responses to Question 6.

Title	QLD Data Collection Process
Transportation Engineer Supervisor	The designer will discuss with Area Engineer and Maintenance Supervisor at PDC.
Transportation Engineer	Design personnel have to collect this information themselves.
Transportation Engineer	Project Manager, Design Team leader, determines need for utility locate
Design Engineer	Design team leader (project manager) and designer discuss the need and initiate the investigation.
Engineering Technician	Check district utility permit files, UIR permits, ROW maps, and old construction plans.
Transportation Engineer	Usually a visual inspection on the project and anything in previous plan sets by the Project Manager.
Design Engineer	Individual designer is assign all tasks associated with the design of a project, including utilities investigation. Designer obtains existing records, may conduct site survey.
Utility Coordinator	Project Manager may request & collect available data from area office records (design, maintenance, & SUE data, if available), then pass data along to others, incl. appropriate Projects Construction Utility Coordinator (PCUC) for evaluation & follow-up. PCUC ultimately responsible for acquiring final evaluation of “clear” or “in conflict.”
Transportation Specialist	If there's money in a contract it's requested thru the District Utility coordinator.
Engineering Specialist	Pull and review existing permits on file.
Project Manager	Compare and verify the existing utility plans to the preliminary construction plans.
Director of TPD	Request is made to our Survey Office to request SUE work through a professional services contract.
Engineer Supervisor	Request is submitted to whoever is managing the SUE contracts. A work authorization is drafted and approved by the Director of TP&D.
Head of Traffic	Utility Coordinator.
Design Engineer	Contact utility providers and request plans, drawings, maps of existing facilities in the area of the project. Or provide utility providers with project layouts to sketch in the approximate location of their facilities.

Title	QLD Data Collection Process
Utility Coordinator	We have records that we can check for every project. The request would be from the Design Team to the Utility Coordinator.
District Design Eng.	Designer contacts area office/maintenance office to obtain copies of any utility permits or utility maps that may be on file.
District Design Eng.	Data collection is part of the survey that is requested/performed.
Utility Coordinator	Review permit files.
Transportation Engineer Supervisor.	A discussion between the Project Manager and the District's Utility Coordinator to determine the level of the utilities needed for the complexity of the project. If there is lots of structures or excavation in a limited right-of-way and/or well developed urban area, one would request a higher level of data collection. You pick the level based on the type and location of the project. Same for all levels.
Design Technician	In our area office, we contact the affected utility companies for the approximate locations of their facilities. We determine the affected utilities by field verification and past experience of known service areas.
Advance Project Development Director	Coordinate project with local government staff and district utility office.
Utility Supervisor	As- built data.
Transportation Engineer	Design team can do utility location research in house. Team can request a SUE contractor be utilized, final decision is regional.
Transportation Engineer	Request plans from utility companies by letter. Transfer information to plans and have utility verify.
Plan Reviewer	On large projects, starts with project manager requesting to district utility manager. We do not do any levels on small projects.
Transportation Engineer Supervisor	PM initiate utility block map search and have utility owners provide layout at 30% utility meeting
Transportation Engineer	No need to request for approval. It is part of the required design process (data collection)
Design Project Supervisor	Look through old construction plans and permits.
Transportation Engineer	During early design (0–30%) the in-house design team or the consultant team starts collecting existing records. Usually, TxDOT personnel do not have internet access so the search is harder and more limited. The City of Houston has a lot of records electronically.
Utility Coordinator	We would give the project information to our surveyor group and start the work.
ROW Utility Coordinator	Design section call the Texas 811 call service for listing of utilities within the project limits and from the lists request records of utility maps/"As built" plans.
Engineering Specialist	Preliminary stage

Title	QLD Data Collection Process
Transportation Engineer	This information comes solely from existing utility records; also there is an initial meeting with the locals to help us in obtaining existing utility information from utility providers.
Area Engineer	Pull old utility permits.
Design Engineer	Tell designers to look it up and contact utility companies.
District Design Engineer	Designer looks up district utility permits on file and notifies companies of potential project by letter.
Transportation Engineering Supervisor	In pre-design conference and preliminary field trips to site, oral recollections and/or old plans are used to indicate existing utilities.
Area Engineer	Just go to the maintenance office and look at the existing records.
Staff Support	Utility coordinator.
Project Manager	Designer/design team conducts initial research on all applicable projects for general location and ID info (request/approval is implied by SOP); on major projects at request of project manager (PM) and approval of district review committee, more thorough research is conducted (detailed info, maps, etc.) early in preliminary design/alternatives development phase to be used with QLC & QLB data for plot plan of best available location info; PM is directly involved with data collection effort on major projects
District Utility Coordinator APPROVAL	Must talk with the local utility companies, permit mangers, maintenance foreman's and city officials to recall the placement. Also search utility files.
back-up utility coordinator	Utility meeting held early on in planning phase with utility companies whose responsibility it is to inform us of where there utilities are located in the proposed construction area.
District Utility Coordinator	Research property interests held by a utility in the court house, request utility As-built plans if available, conduct utility workshops to obtain utility information and introduce construction project and goals, visit with irrigation and drainage districts. Visit with local municipality.
District Design Engineer	The project manager or design team member will request utility maps (hard copies or electronic files) directly from the utility companies, and request utility permits from the TxDOT permit office.
Trans Engineer Supervisor	Letter sent to utility company.
Utility Coordinator	Request as needed based on exiting SUE contract.
Trans Engineer Supervisor	Research as-builts, use one call, research existing permits within ROW
Engineering Specialist	Starts with preliminary design.
Engineering Specialist	email sent to the Utility Coordinator
Design Engineer	TxDOT contacts/meets with the utilities and requests as-built utility plans.
Advanced Project Development	Utility coordinator will provide for in-house projects. Consultants provide for consultant projects.

Title	QLD Data Collection Process
Utility Coordinator	Review existing permit records, contact locate providers for list of registered utilities within the limits of the project, establish preliminary list of utilities
District Utility Coordinator	The Utility Coordinator (UC) discusses projects with the design team and survey team and determines if there could be potential utilities in the area
Bridge Engineer	Occurs through general discussion about project with adjacent land owners & local officials.
Director of Operations	Informal process.
Director /Head	Draft a scope of work for the region to execute a work authorization.
Supervisor, Design Utility Coordination Section	Design Engineer/Project Manager request SUE investigation through Design Utility Coordination section, and Region. Design Engineer/Project Manager may request block maps and utility documentation from utility during Preliminary Design phase.
Engineer	Designers could perform this level of data collection.
Director/Head	This collection is requested through district utility coordinator.
Utility Coordinator	This is expected - to do basic preliminary research.
Staff Support	Design reviews the project foot print area.

Question 7. For the following quality levels, briefly describe the process to request and approve the data collection effort: QLC Data Collection. (60 Responses, 69 Skipped.)

Table 62. Responses to Question 7.

Title	QLC Data Collection Process
Transportation Engineer Supervisor	The surveyor and designer will observe marked utilities when a site visit is made at start of project.
Transportation Engineer	Designers and surveyors have to collect this information ourselves. Sometimes the surveyor takes it upon himself to call Dig TESS and then surveys in all the paint markings on the ground.
Transportation Engineer	Project Manager, Design Team leader, determines need for utility locate
Design Engineer	Design team leader (project manager) and designer discuss the need and initiate the investigation.
Engineering Technician	Request survey crew to topography above ground appurtenances and comment on obvious signs.
Transportation Engineer	We survey all above ground utilities on projects that requires a survey.
Design Engineer	Individual designer may conduct survey work including utility investigations.
Utility Coordinator	Project Manager may use site visits to perform visual survey & record any apparent potential utility conflicts, then pass data along to others, incl. appropriate PCUC for evaluation & follow-up. PCUC ultimately responsible for acquiring final evaluation of “clear” or “in conflict.”
Transportation Specialist	If there's money in a contract it's requested thru the district utility coordinator.
Engineering Specialist	Utilize One Call.
Project Manager	Verify the construction plans with the existing utilities, at driveways, side streets, crossings, etc.
Director of TPD	Same as above (request is made to our survey office to request SUE work through a professional services contract).
Engineer Supervisor	Request is submitted to whoever is managing the SUE contracts. A work authorization is drafted and approved by the Director of TP&D.
Head of Traffic	Utility Coordinator.
Design Engineer	Contact utility providers to locate facilities on the ground at the project site via paint markings or flags and provide approx. depths. Schedule District survey crews to survey in utility locations once locates are complete.
Utility Coordinator	The survey request would be from the Design Team/Utility Coordinator to the Survey Crew.
District Design Eng.	Designer works through the District Advance Planning Engineer to request this information as part of the field survey for the project.
Utility Coordinator	Field survey.

Title	QLC Data Collection Process
Design Technician	We do in house field verification and call in locates from the affected utilities. This is done at the Area office level with in house personnel.
Advance Project Development Director	Coordinate project with local government staff, District Utility Office, and conduct project field trip.
Utility Supervisor	On the ground data
Transportation Engineer	Design team can survey utilities, or request assistance from district personnel. SUE contract must be requested and approved by Region.
Transportation Engineer	Field investigation and survey. Compare with record drawings. Have company verify findings.
Plan Reviewer	Same as above.
Transportation Engineer Supervisor	PM and project design team.
Transportation Engineer	No need to request for approval. It is part of the required design process (data collection).
Design Project Supervisor	Review survey notes with old construction plans and permits.
Transportation Engineer	District Survey Engineer orders a survey and provides basic data to the project manager.
Utility Coordinator	We would give the project information to our surveyor group and start the work.
ROW Utility Coordinator	Design section request field survey of utilities and generate utility plans for utility companies to verify the locations of the existing utilities.
Engineering Specialist	Preliminary stage.
Transportation Engineer	This information is usually collected during the preliminary phase of the project; all topographic surveys requested by the District identify utility facilities. This is initiated by design team.
Area Engineer	Surveyors pick up on topography surveying.
Design Engineer	Call Tx 1 call or Utility Co.
District Design Engineer	Designer request surveying for project design which the surveyor will obtain any visible utilities in the surveyed area
Transportation Engineering Supervisor	In general we use the One Call number to locate utilities for design and construction purposes. The designer makes the call and once the locates are marked goes out and gets measurements to include in the plans.
Area Engineer	Designer goes out to the project and looks when needed.
Staff Support	Utility Coordinator.
Project Manager	Typically, this process is combined with and immediately follows QLB investigation by utility companies as part of contracted surveying services; PM is responsible for request (approval by TP&D director) and coordinates data collection effort.

Title	QLC Data Collection Process
District Utility Coordinator Approval	Must call DIGTESS, usually responsible person is the surveyor or the designer in charge.
District Utility Coordinator	Windshield survey of project, surface locates for utility topography.
District Design Engineer	The project manager will work with the surveyor (TxDOT or consultant) to request that surface data for utilities be collected in the topographic survey.
Trans Engineer Supervisor	Letter sent to utility company.
Utility Coordinator	Request as needed based on exiting SUE contract.
Trans Engineer Supervisor	Research, find utility companies and request as-builts with horizontal and vertical information.
Engineering Specialist	Starts with preliminary design and detail design.
Engineering Specialist	Email sent to the utility coordinator.
Design Engineer	TxDOT contacts Texas One Call/Dig TESS/individual utilities and has lines located/marked. TxDOT then has marked utility lines surveyed.
Advanced Project Development	Utility coordinator will provide for in-house projects. Consultants provide for consultant projects.
Utility Coordinator	Perform site visit, request a meeting with utilities, request as-built records and ask them to mark up highway schematic/plans showing all known depths and locations, if available request survey staff to survey visible utility locations otherwise plot locations as they become available from utility's mark ups.
District Utility Coordinator	The UC will visit the site to look for utility appurtenances.
Bridge Engineer	Above ground utilities features are gathered as part of routine topographic surveying preformed during the initial design phase of most projects.
Supervising Design Engineer	Visit site and do One Call.
Director /Head	Draft a scope of work for the region to execute a work authorization.
Supervisor, Design Utility Coordination Section	Design Engineer/Project Manager may use appurtenances shown on the ROW maps to make inferences about UG utilities in the project limits. Design Engineer/Project Manager will also visit the project to visually determine OH utilities. QLC is also requested when we contract SUE services by an outside vendor.
Engineer	In recent times we are lacking in utility investigations during the design phase, but designers should use this level when needed.
Director/Head	This collection is requested through district utility coordinator.
Utility Coordinator	For congested urban areas, this level becomes an expectation.
Staff Support	Design request plans from utility companies for review.

Question 8. For the following quality levels, briefly describe the process to request and approve the data collection effort: QLB Data Collection. (54 Responses, 75 Skipped.)

Table 63. Responses to Question 8.

Title	QLB Data Collection Process
Transportation Engineer Supervisor	The surveyor or designer will place a call to 811, Texas one-call service, when a project begins.
Transportation Engineer	TxDOT has to contract this type of data collection out to a contractor. I think this type of data collection service is rarely used. Sometimes the surveyor takes it upon himself to call Dig TESS and then surveys in all the paint markings on the ground. Dig TESS does not provide depth information.
Transportation Engineer	Project Manager, Design Team leader, determines need for utility locate
Design Engineer	Design team leader (project manager) and designer discuss the need and initiate the investigation.
Engineering Technician	Project manager or survey crew submits online locate ticket.
Transportation Engineer	We contact DIGTESS/811 in conjunction with our survey to locate underground utilities; call is made by Design Team.
Utility Coordinator	Either Project Manager or PCUC will use GEO-REMOTE list request or formal "locate request" to acquire a list of utilities within project limits, then (appropriate) PCUC ultimately responsible for evaluating data and acquiring final evaluation of "CLEAR" or "IN CONFLICT."
Transportation Specialist	If there's money in a contract it's requested thru the District Utility coordinator.
Engineering Specialist	Request thru survey coordinator for consultant SUE work.
Project Manager	Contact one call dig test to locate existing utilities on a project prior to any excavation.
Director of TPD	Same as above.
Engineer Supervisor	Request is submitted to whoever is managing the SUE contracts. A work authorization is drafted and approved by the Director of TP&D.
Head of Traffic	Ask the TP&D Director.
Utility Coordinator	The request would be from the Design Team to the Design Engineer with help from the Utility Coordinator.
District Design Eng.	Designer contacts those utilities using the one-call method that may be affected by the proposed work and requests the utility locations be staked in the field using whatever methods (electronic or physical) are available.
Utility Coordinator	Use of pipe locator.
Design Technician	We do not have the equipment in house for QLB, and I've been informed that we have no money budgeted for SUE consultant contracts.

Title	QLB Data Collection Process
Advance Project Development Director	Hire qualified Subsurface Utility Engineer.
Utility Supervisor	Located data.
Transportation Engineer	Level B data would need to be requested through Region.
Transportation Engineer	Request Level B investigation from provider. Compare data collected with Level C & D information. Have company verify.
Plan Reviewer	Same as above.
Transportation Engineer Supervisor	PM request it through district utility coordinator, Region & Austin
Transportation Engineer	Designer will request this level of data collection through the Project Manager/Engineer and the District Utility Coordinator/Manager - Contract outsource at this level.
Design Project Supervisor	Request additional data collection from District Utility Coordinator.
Transportation Engineer	The Project Engineer (or consultant-if his scope includes utility investigations) asks that more data be collected through a SUE investigation. The SUE investigation is coordinated through our Survey Section or District Utility Section.
Utility Coordinator	We request type B investigation thru outside consultant.
ROW Utility Coordinator	Design section request field survey of utilities and generate utility plans for utility companies to verify the locations of the existing utilities.
Engineering Specialist	Review and approve level D, C than proceed to level B and level A.
Transportation Engineer	Sometimes the utility company may not have accurate records or some of their lines may be abandoned; at that time we would request the use of this level of data.
District Design Engineer	Never used.
Transportation Engineering Supervisor	I don't think we have used this very often, but I do think it has been done in the past.
Area Engineer	When more information is needed. PM calls utilities to locate.
Project Manager	Except when using SUE consultants, this service is provided by major utility companies upon request of TxDOT's PM for design purposes; requested and approved through design review process only for new location, added capacity and projects involving major drainage facility construction or other significant excavation activities; repeated or conducted initially for other applicable projects at beginning of construction by contractor request.
District Utility Coordinator APPROVAL	Not used but in contract.

Title	QLB Data Collection Process
District Utility Coordinator	Call in Dig-Tess to obtain surface locates electronically, call city or local water distribution company to locate facilities within project limits, (this usually happens early in design to explore design around options to minimize impact of utility infrastructure).
District Design Engineer	The project manager must request from the District Design Engineer to use the services of a SUE consultant to collect the data. The District Design Engineer must request from the Region if they can use consultant services for SUE work on a project. If approved the project manager works with the consultant to negotiate a work authorization or contract. The work authorization or contract must be approved by the region.
Utility Coordinator	Request as needed based on exiting SUE contract.
Trans Engineer Supervisor	Hire consultant to perform this work.
Engineering Specialist	Detail design phase.
Engineering Specialist	Email sent to the Utility Coordinator.
Design Engineer	Not used.
Advanced Project Development	Utility coordinator will provide for in-house projects. Consultants provide for consultant projects.
Utility Coordinator	Provide survey and/or mark ups from utilities to project manager for review, determine preliminary conflict locations that may require more research than reviewing the ex-records and mark ups, request QLB from utility if applicable however it is not the preferred level.
ROW Program Specialist	After contracting with SUE provider, request B, C, and D levels. Review results with project manager and identify potential conflict points. The decision to obtain additional data is made at that time.
District Utility Coordinator	The UC will call for locates using the Dig TESS system if the surveyors have not already done so.
Bridge Engineer	Normally performed by the Utility Company if they determine that the project may come into conflict with the utility.
Director /Head	Draft a scope of work for the region to execute a work authorization.
Supervisor, Design Utility Coordination Section	Design Engineer/Project Manager request SUE investigation through Design Utility Coordination section, and Region.
Engineer	This would need to be requested through the district utility coordinator during the design phase. In the construction phase this could be requested by contractor. Although at this phase it usually causes delays in construction.
Utility Coordinator	This level requires district funding and must be justified.
Staff Support	Project Manager determines the cost vs. need.

Question 9. For the following quality levels, briefly describe the process to request and approve the data collection effort: QLA Data Collection. (59 Responses, 70 Skipped.)

Table 64. Responses to Question 9.

Title	QLA Data Collection Process
Transportation Engineer Supervisor	Rarely used, lack of funds.
Transportation Engineer	TxDOT has to rely on the willingness of utility companies to provide this type of information, or obtain it through a TxDOT funded SUE contract. Designers/project managers can request this type of information from utility companies. Uncooperative utilities have to be referred to management.
Transportation Engineer	Data normally collected in urbanized areas. Approval needed to obtain SUE contract.
Design Engineer	Design team leader (project manager) and designer discuss the need and initiate the investigation. This level is not typically project wide, but is used at identified critical locations.
Engineering Technician	Project manager or survey crew contacts utility company about the need to more accurately locate some of their utilities. Survey crew and project manager or designer meet utility in the field to complete investigation using utility company's crew and equipment.
Transportation Engineer	If there is a potential conflict, the Project Manager tells the Utility Coordinator to contact and set up a meeting with the utility company. The PM and UC meet with the owners and discuss a plan. Then it is the utility company's option to do the test holes or move the line.
Design Engineer	Individual designer requests approval for outsourcing survey work. Project manager secures funding approval for outsourcing. Both designer and PM will perform utility coordination.
Utility Coordinator	Either PCUC, or rarely Project Manager, will request physical verification of a utility if there is a potential for conflict that cannot be verified by any other method. After location, if the utility does not agree there is a need to adjust the facility in apparent conflict, the PCUC consults the Project Manager and may thereafter request the utility to make the needed adjustment(s).
Transportation Specialist	If there's money in a contract it's requested thru the District Utility coordinator.
Engineering Specialist	Request thru survey coordinator for consultant SUE work.
Project Manager	Verify known conflicts of existing utilities with proposed construction.
Director of TPD	After info above, we coordinate with utility company to decide if pothole or other method needed.
Engineer Supervisor	Request is submitted to whoever is managing the SUE contracts. A work authorization is drafted and approved by the Director of TP&D.

Title	QLA Data Collection Process
Head of Traffic	Ask the TP&D Director.
Design Engineer	When conflicts are anticipated utility companies are asked to either pothole facility for an accurate location, or plan to adjust the facility. District survey crews are scheduled to collect pothole data.
Utility Coordinator	The request would be from the Design Team to the Design Engineer with help from the Utility Coordinator.
District Design Eng.	Designer contacts those utilities that appear to conflict with the proposed work and requests that accurate horizontal and vertical locations be provided. This information is used to either request the utility relocation or to redesign the work to avoid the utility.
District Design Eng.	If there is an apparent conflict with a utility, the district will have the utility cored to find its exact depth and location.
Design Technician	We do not have the equipment in house for QLA, and I've been informed that we have no money budgeted for SUE consultant contracts.
Advance Project Development Director	Hire qualified Subsurface Utility Engineer.
Utility Supervisor	Exposed data.
Transportation Engineer	Level A data would need to be requested through Region.
Transportation Engineer	Determine need and necessity for Level A investigation. Request work and compare data with current information. Provide to utility company to work on adjustments
Plan Reviewer	Same as above.
Transportation Engineer Supervisor	Same as GL B.
Transportation Engineer	Designer will request this level of data collection through the Project Manager/Engineer and the District Utility Coordinator/Manager - Contract outsource at this level.
Design Project Supervisor	Request additional data collection from District Utility Coordinator.
Transportation Engineer	The Project Engineer (or Consultant-if his scope includes utility investigations) asks that more data be collected through a SUE investigation. The SUE investigation is coordinated through our Survey Section or District Utility Section. QLA is not very frequently done.
Utility Coordinator	We request type A investigation thru outside consultant
ROW Utility Coordinator	Design section determine and request the location of test hole survey information of the utilities and generate utility test hole data sheet for utility companies to verify information.
Engineering Specialist	Review and approve Level D,C, B and review A

Title	QLA Data Collection Process
Transportation Engineer	Typically a mobility project in an urban area will require the use of SUE level A. We coordinate this with the region to allocate resources/funds to do this work.
Area Engineer	Once defined plan and known conflicts have utility tie down locations.
District Design Engineer	Never used
Transportation Engineering Supervisor	We have used SUE contracts where they potholed the utilities, but my knowledge of the use is over 10 years ago, not sure how often this happens now.
Area Engineer	We do not do this that I know of.
Staff Support	Utility Coordinator.
Project Manager	Upon design team request and PM approval, this level of investigation is conducted by utility company, TxDOT maintenance or contractor forces, only as needed to provide critical location data (higher quality level) or where other methods have been exhausted and quantity of data collected is inadequate
District Utility Coordinator APPROVAL	Work with the local utility companies to pothole when needed.
District Utility Coordinator	Request from utility physical exposures and obtain a positive tie on existing facilities within project limits, Survey and analyze all information obtained, have design team plot on utility plan sheets.
District Design Engineer	The project manager must request from the District Design Engineer to use the services of a SUE consultant to collect the data. The District Design Engineer must request from the Region if they can use consultant services for SUE work on a project. If approved the project manager works with the consultant to negotiate a work authorization or contract. The work authorization or contract must be approved by the region.
Trans Engineer Supervisor	If conflicts exist with current design, PM will request utility company verify the location X, Y, Z of their lines at these potential conflict locations.
Utility Coordinator	Request as needed based on exiting S.U.E. contract.
Trans Engineer Supervisor	Hire consultant to perform this work.
Engineering Specialist	Should be complete by Letting
Engineering Specialist	Email sent to the Utility Coordinator.
Design Engineer	TxDOT contacts utilities to have underground lines potholed/uncovered and then has lines surveyed.
Advanced Project Development	Approved by staff level for major freeway projects.

Title	QLA Data Collection Process
Utility Coordinator	Request utility assistance in completing QLA, ask utility to expose their facilities at certain locations and have district survey staff survey the pot hole locations to obtain the necessary elevations, if funding is available this could be accomplished by contracting with a utility engineering/sue provider, after pot hole information is obtained, confirm conflicts with utility and project manager.
ROW Program Specialist	Notify SUE provider about additional data needed and the locations of potential conflict points. Receive data and review with project manager.
District Utility Coordinator	The UC or AE will request the Utility excavate or expose their lines if other location techniques do not give accurate data.
Bridge Engineer	Is considered after a QLB survey identifies a possible conflict.
Director /Head	Draft a scope of work for the Region to execute a work authorization.
Supervisor, Design Utility Coordination Section	Design Engineer/Project Manager request SUE investigation through Design Utility Coordination section, and Region.
Engineer	District Utility Coordinator.
Utility Coordinator	This level requires District funding and must be justified, particularly in areas where the extent of conflicts is not well understood but is expected to be complex.
Staff Support	Project Manager determine amount of money to spend, Design engineer pick points to spend it on such as drainage areas.

Question 10. Please select if procedures for utility investigations are different for the following: Urban vs. rural projects? Briefly explain why.

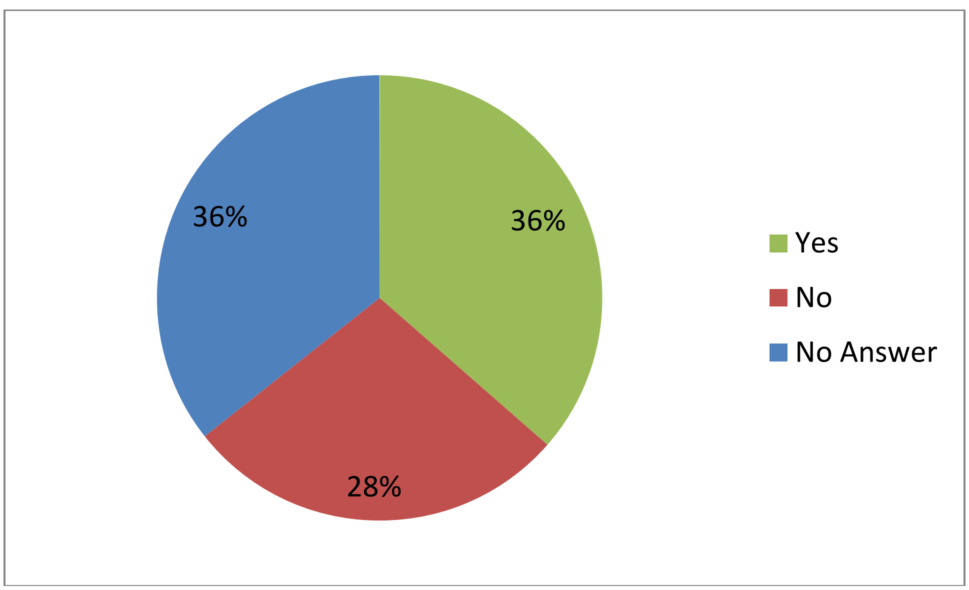

Figure 49. Responses to Question 10: Yes: 47, No: 36, No Answer: 46.

Table 65. Responses to Question 10.

Title	Urban vs. rural projects?
Transportation Engineer Supervisor	City utilities are coordinated with municipality and TxDOT utilities are commonly present and have to be located.
Transportation Engineer	Urban projects usually have more utility conflicts that need to be located and resolved.
Design Engineer	Urban projects are more likely to have underground storm sewer systems. This type of underground work requires a much greater understanding of potential conflicts within the entire length of the project.
Engineering Technician	Densification and limited room in ROW. Also usually fewer above ground appurtenances.
Transportation Engineer	More utilities, more investigation, limited ROW, limited options
Design Engineer	Typically, ROW is restrictive for urban project. Coordination with city is led by PM with designer and utility coordinator providing support. City utilities may be included into construction projects. Therefore City utility alignment assignments may be based on ease of construction.
Utility Coordinator	Potential for conflict increases proportionately with population and traffic densities. Consequently, QLB and QLA may be required more often and sooner in the process to allow more time for the often intricate coordination among several utilities needing to adjust.
Transportation Specialist	Urban usually more critical for underground as storm sewer usually employed in new road design.
Engineering Specialist	Urban more congested utilities. Need higher level investigation.
Project Manager	There are typically more utilities to be in conflict in the urban locations and less right-of-way to install the utilities or roadways.
Director of TPD	Rural typically only require C & D. Urban usually need B and then A. May have monthly coordination meetings in urban areas.
Engineer Supervisor	There are generally fewer utilities to contend with on the rural projects. Often times the rural utilities provide better information.
District Design Eng.	Utility density in urban areas is usually higher and more problematic than it is in rural areas. The chances for conflicts with the proposed work are greater.
District Design Eng.	Because there are always more utilities (water, sewer, gas) located within town sections than there are in rural areas.
Utility Coordinator	In urban projects have additional a more complex communication system, sanitary sewer systems, potable water systems, and natural gas systems.
Transportation Engineer Supervisor	Urban project tend to have more utilities, closely spaced in a small amount of right-of-way.

Title	Urban vs. rural projects?
Design Technician	In the past, when we had money for SUE contracts, we performed SUE on the large, complicated, urban projects. On the rural projects, they are usually less involved and are handled in house.
Transportation Engineer	Urban areas are more restricted and more crowded with utilities
Plan Reviewer	Complex projects with proposed storm sewers and many existing utilities can use SUE investigations.
Utility Coordinator	To look for monuments and Iron steel markers makes it difficult in the urban area.
Transportation Engineer	Urban areas are congested and require additional attention to utilities
Area Engineer	Differences in roadway designs.
Design Engineer	ROW is usually more crowded in urban.
Project Manager	Greater utility congestion in urban areas result in significant design constraints, plus scope of urban projects typically involve more complex design issues and hard roadside improvements, that increase potential for utility conflicts, e.g., multiple intersecting drives & roads, storm drain systems, retaining walls, curb & gutter, sidewalks, railings, luminaries.
District Utility Coordinator APPROVAL	Urban will be more impacted with utilities
District Utility Coordinator	Urban areas will generally be congested and traffic control requirements must be applied for an urban environment, sidewalks, driveways, congested utilities in row.
Transportation Eng. Supervisor	Municipalities do not participate in 811 "One Call" system. There are often fewer options available in urban projects if design features (concrete foundations, etc.) must be moved due to utilities.
District Design Engineer	There are more utilities within an urban area and the ROW is more constrained.
Trans Engineer Supervisor	Rural utility companies are easier to work with.
Utility Coordinator	Complexity of projects.
Advanced Project Development	On urban major freeway projects we go to a level A due to the amount of utilities expected to be in conflict.
Bridge Engineer	One-call or 811 contacts are made on all projects, but some of the smaller rural utilities are not part of the 811 system. These utilities must be contacted through local contacts.
Director /Head	More conflicts in the urban setting.
Supervisor, Design Utility Coordination Section	Less use of contract SUE work for rural projects. But the method to request SUE is the same.
Engineer	Usually more importance for utility relocations on urban projects.
Director/Head	Utility investigations are typically not needed for the preliminary design work on rural projects.

Title	Urban vs. rural projects?
Utility Coordinator	Utilities serve concentrations of people and this favors investigating urban settings. Rural areas have pipeline corridors, but they are well marked and easily investigated with bent-pipe data.

Question 11. Please select if procedures for utility investigations are different for the following: Projects on new right-of-way vs. projects entirely on existing right-of-way? Briefly explain why.

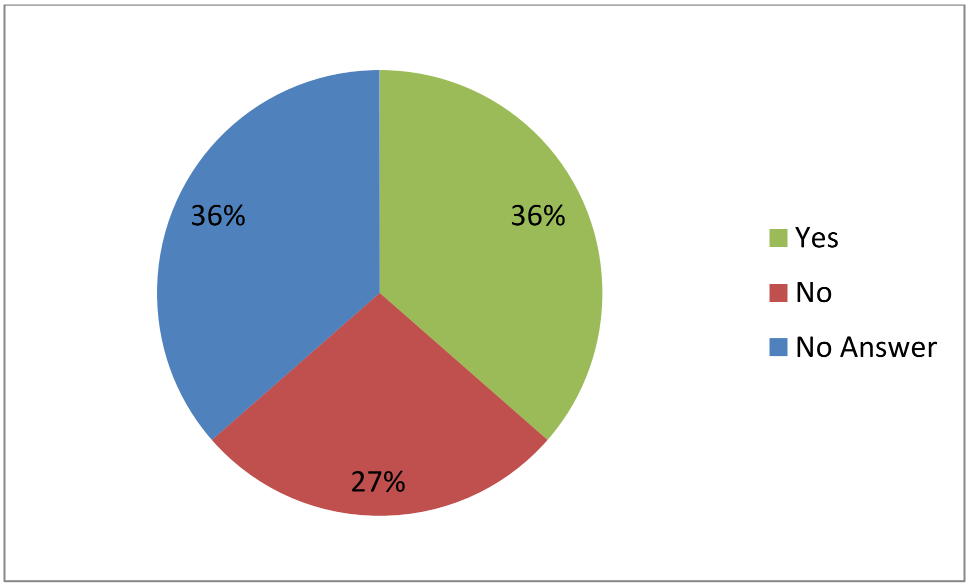

Figure 2. Responses to Question 11: Yes: 47, No: 35, No Answer: 47.

Table 66. Responses to Question 11.

Title	Projects on new right-of-way vs. projects entirely on existing right-of-way?
Transportation Engineer Supervisor	ROW personnel start the process of identifying utilities on new location projects.
Transportation Engineer	New ROW is more difficult because you have to get permission to be on property that has not been required yet.
Transportation Engineer	Projects requiring New ROW often contain utilities in the proposed ROW that need to be identified and relocated.
Utility Coordinator	New right-of-way will have nearly all compensable interests.
Design Engineer	TxDOT typically has a better knowledge of existing underground utilities on existing ROW. New ROW requires more project wide investigation.
Engineering Technician	District has no records of utilities on new ROW; but new ROW usually only has crossings which are less of a conflict.

Title	Projects on new right-of-way vs. projects entirely on existing right-of-way?
Transportation Engineer	New ROW project tends to have more because nobody planned for the road.
Design Engineer	New projects typically intersect existing utilities, such as pipelines. Parallel utilities are assigned alignments with limited tolerance for variation.
Utility Coordinator	Greater administrative paperwork involved if the condemnation process has to be used, and matched funding for adjusting utilities requires more lead time prior to letting.
Transportation Specialist	New ROW projects can get by with less in areas that you know will be under new road footprint and will need to be relocated regardless of exact position.
Engineering Specialist	Within existing right-of-way, usually have existing permits where new right-of-way does not.
Project Manager	With projects in new right-of-way the utilities can generally be relocated to accommodate the proposed construction in the new right-of-way, some crossings may remain in place. Whereas projects in existing right-of-way, the utilities could remain in place if not in conflict with the alignment of the new roadway, structures, or be relocated, or modified where in conflict with drainage structures, street crossings, the existing utilities may need to be relocated at drainage crossing, intersections, and adjusted to accommodate the new construction.
Engineer Supervisor	There are not usually utilities that are in conflict for projects on new right-of-way. If there are they are usually in easements and good data on location is available.
Utility Coordinator	Since our office does not have records of utilities outside of our ROW. We rely more on utility providers for their information.
District Design Eng.	Utility density in existing right-of-way is usually higher and more problematic than it is on projects built on new location. The chances for conflicts with the proposed work in the existing right-of-way are greater.
Director of TPD	Utility adjustments where utilities have a prior property right (i.e. easement) are eligible for reimbursement of their costs.
Utility Coordinator	There are no known records available to identify and help locate any and all utilities including abandoned oil/gas well production lines.
Transportation Engineer Supervisor.	There is more flexibility to design on new right-of-way. The designer can space structures to miss the utilities or purchase right-of-way that has minimal utilities. Also, utilities sometimes have an easier time to relocate utilities to a new facility on new right-of-way. Some times on there is no place to relocate utilities on projects entirely on existing right-of-way.
Design Technician	In the past, when we had money for SUE contracts, we would use SUE consultants on the larger, new location projects and the urban projects on existing facilities. We usually do the smaller projects in-house.

Title	Projects on new right-of-way vs. projects entirely on existing right-of-way?
Transportation Engineer	Utility owners tend to be more helpful when relocations are compensable with ROW acquisition.
Transportation Engineer	Yes. I once had a new location freeway that went through an old oil field that still had a few operating wells. There were over a hundred pipes buried underground going in various directions. Some were abandoned some were not and due to the age it was very difficult to tell which ones were active.
Plan Reviewer	Depends what major utilities a new location project crosses.
Director of Advance Project Development	More field work needed since we will not have records.
Utility Coordinator	Sometimes in the existing ROW is difficult due to other objects blocking the signs.
Transportation Engineer	When you expand a highway most of the time you are going to find utilities on easements that will trigger a different level of work.
Area Engineer	Existing ROW corridors may already be crowded with utilities.
Design Engineer	Existing easements are considered.
Project Manager	Reimbursable verse non-reimbursable.
Transportation Engineering Supervisor	I am not involved with this directly, but it only makes sense that a new location would require more investigation just due to lack of prior information.
District Utility Coordinator APPROVAL	Property owners are impacted which can slow up the relocation process.
District Utility Coordinator	For the most part on a new right-of-way project all existing utilizes on project have been encumbered and will require relocation. It is not cost efficient for a utility to obtain positive ties if all has to be relocated. They will generally design for relocations based on ROW acquisition and project scope.
Trans Engineer Supervisor	For projects on new ROW, determinations have to be made if the utility lines currently reside in easements, if so, then these adjustments would be reimbursable, etc.
Utility Coordinator	Usually no existing records on hand.
Trans Engineer Supervisor	Anything within new ROW is open to utilities that aren't mapped anywhere. If anything is within the ROW, there has to be record of them somewhere
Engineering Specialist	New ROW requires more detailed search because of oil/gas lines.
Engineer	Usually more importance is placed on new projects. Existing projects seemed to be passed on to the construction phase which in my opinion is not good practice.

Title	Projects on new right-of-way vs. projects entirely on existing right-of-way?
Director/Head	It is much more likely that utilities will need to be relocated when new right-of-way is needed.
Utility Coordinator	Utilities have to apply for permits to occupy existing state ROW, so data exists to determine the inventory of utilities. New ROW has no such repository of data that runs through official channels.

Question 12. Please select if procedures for utility investigations are different for the following: Added capacity vs. non-added capacity projects? Briefly explain why:

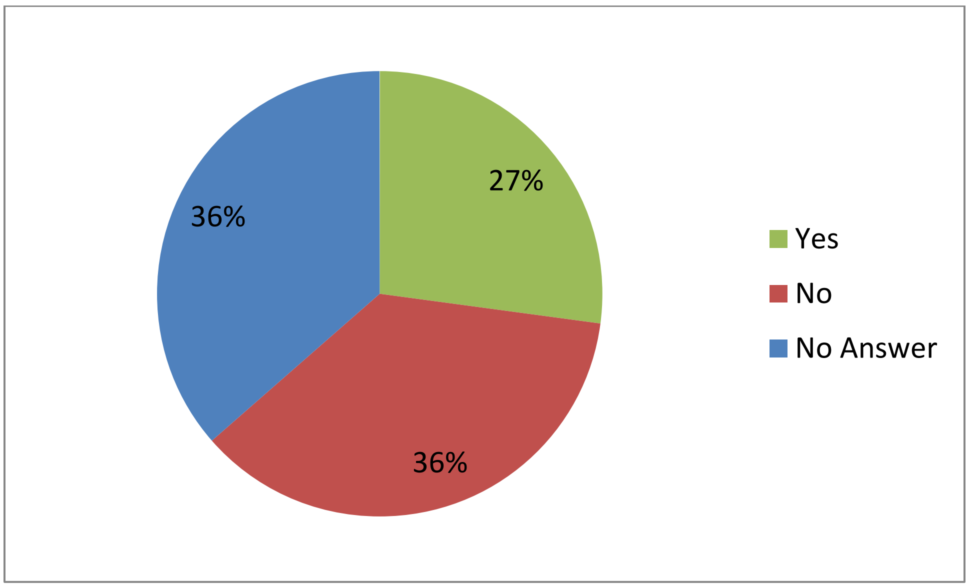

Figure 3. Responses to Question 12: Yes: 35, No: 47, No Answer: 47.

Table 67. Responses to Question 12.

Title	Added capacity vs. non-added capacity projects?
Design Engineer	Added capacity projects frequently encroach in established "utility corridors," so there is a greater chance of utility conflicts.
Design Engineer	Added capacity projects typically reduce the amount of available ROW. Therefore, stricter tolerances to assignments are needed. Non-added capacity projects typically have minimal conflicts.
Utility Coordinator	Potential for conflict increases proportionately with planned increase in traffic densities and the attendant "facility crowding." Consequently, QLB and QLA may be required more often and sooner in the process to allow more time for the often intricate coordination among several utilities needing to adjust.
Engineering Specialist	Added capacity is usually a larger job, affecting more land and utilities.

Title	Added capacity vs. non-added capacity projects?
Project Manager	Utilities are generally located near right-of-way.
Engineer Supervisor	Usually added capacity projects add pavement and create conflicts. Some non-added capacity can create conflicts as well.
District Design Engineer	Added capacity project normally require widening of the roadbed with the likelihood that adjacent parallel utilities will be impacted. Non-added capacity projects (rehabilitation, restoration, preventive maintenance) most often work inside the existing ditch line, which does impact the utilities along the back slope and right-of-way line.
Director of TPD	Same as previous if additional ROW required.
Utility Coordinator	It usually means the ditch flow line is moving closed to the right-of-way and in most cases the communication lines, water lines, sanitary sewer lines are in some cases below the existing flow line of the existing ditch which may have to be adjusted.
Transportation Engineer Supervisor	Add capacity projects, widened to the outside usually causes problems. Widened to the inside, usually little to no utility conflicts.
Design Technician	Once again, it depends on the type of project and the amount of utilities present. Usually, unless we are adding width to a facility, we don't encounter many conflicts.
Transportation Engineer	Non-added capacity projects may not acquire ROW and require relocation of utilities; therefore the actual location is not as important. Just knowing generally where a utility is may allow us to design around it.
Director of Advance Project Development	Roadway footprint changes.
Transportation Engineer	Projects of this nature will impact existing facilities and therefore need a higher level of study.
Area Engineer	Existing ROW may already have utilities.
Transportation Engineering Supervisor	Same as above, anything that is outside the current pavement structure could encounter new utilities, therefore requiring more investigation.
Project Manager	Added capacity projects usually involve widening, which impacts parallel utilities located near the existing right-of-way line. Adjacent property acquisition adds the right-of-entry process, reimbursable utility adjustment procedures and need for higher QL for utility data collection
District Utility Coordinator APPROVAL	Can impact the back slope and grade elevations more than just working what is there.
District Utility Coordinator	Added width vs. rehab.
District Design Engineer	Added capacity usually means reconstruction and widening, which may mean more conflicts with utilities if the vertical profile of the roadway changes, culverts are replaced or extended, storm drain is relocated or added, retaining walls are required, drill shafts for bridges are required, the pavement is widened, and any excavation for roadway construction.

Title	Added capacity vs. non-added capacity projects?
Utility Coordinator	Greater potential for impact to utilities on added capacity.
Engineering Specialist	Widenings affect utilities more.
Advanced Project Development	If not pavement widening or drainage work is done; no utility investigation is normally done.
Supervisor, Design Utility Coordination Section	Less use of contract SUE work for non-added capacity projects. But the method to request SUE is the same.
Director/Head	Non-added capacity project typically do not require utility relocation.
Utility Coordinator	Non-added capacity translates to 'no new ROW' which means utility involvement is negligible – generally.

Question 13. What factors influence your decision to use or request QLB data collections for a project? (68 Responded, 61 Skipped.)

Table 68. Responses to Question 13.

Title	Factors that Influence Decision to Use QLB
Transportation Engineering Supervisor	If excavation will take place, a call to 811 will be placed.
Transportation Engineer	I would say TxDOT does not itself collect this type of data. We rely on Dig Tess Markings and willingness of utility companies to pothole their lines. On large projects where funding is available, SUE contracts are set up. And I would think that our SUE contracts are somewhat standardized; contact the Lubbock regional ROW group for assistance.
Director of TP&D	All decisions are based on no prior knowledge and the type of work being performed.
Utility Coordinator	Unknown ownership, unknown type of utility, utility congestion, critical grade change and effect, costs to adjust.
Design Engineer	We identify the risk and determine the location and scope of the identification efforts that we will utilize.
Engineering Technician	Requested on all projects.
Transportation Engineer	Type of work planned. If we are surveying a project then we automatically call and get locates during the surveying process or if there is a potential conflict.
Design Engineer	Prefer not to use QLB data collection on a project due to tolerances. Prefer to pothole utilities to establish exact locations. Use Trimble equipment to gather data.
Utility Coordinator	Use of QLB for verification in the absence of any visible utility markers within project limits and refinement of data near cross-drainage structures, major cuts (and fills), and identification of older, unmarked utility roadway crossings.

Title	Factors that Influence Decision to Use QLB
Transportation Specialist	Level B usually gets used to identify specific conflict points between design elements and known utility to see if it can be designed around or will need relocation.
Engineering Specialist	Type of construction, amount of right-of-way and number of utilities within the project.
Project Manager	Location of existing utilities; when the existing utilities are in close proximity to the proposed construction or a potential conflict.
Director of TPD	Dependent upon information that comes from C & D surveys and where construction is occurring.
Engineer Supervisor	Likelihood of conflicts and availability of data from the utilities.
Head of Traffic	If there will be any construction activity in the area.
Design Engineer	Not previously used in this district.
Utility Coordinator	First and foremost is the scope of our design, then whether funds are available or not.
District Design Eng.	The information from the field survey (QLC) and the potential for conflicts with existing utilities and the proposed work.
Director of TPD	These methods are not available in-house. The decision to request a SUE contract would be based upon the complexity of utility installations and accommodations for the project indicated by QLD and C investigation.
Utility Coordinator	Safety of the construction crew, possible delays which means more cost for the project.
Transportation Engineer Supervisor.	Type of project, urban, limited right-of-way, large number of utilities.
Engineering Specialist	Within project proposed designs area/limit.
Transportation Engineer Supervisor.	When a utility is hard to relocate and should work around it.
Design Technician	The amount of utilities present on the project, the right-of-way width and whether we are acquiring new right-of-way, or squeezing a larger facility into an existing right-of-way. Also, if there is money for SUE.
Advance Project Development Director	Widening facility.
Utility Supervisor	The as-builts that the utilities have in their records. The size, time to adjust, the utilities. The amount of right-of-way left that the utilities may use.
Transportation Engineer	If initial investigations indicate a potential conflict, QLB becomes necessary to determine if relocation or design modifications are required.
Transportation Engineer	Incomplete records, location of new roadway facilities in relation to the existing utility.
Plan Reviewer	Complexity of proposed underground work and exiting utilities.

Title	Factors that Influence Decision to Use QLB
Transportation Engineer Supervisor	Complex utility from QLD and QLC.
Transportation Engineer	Costly (expensive to replace) existing utility in conflict with the design.
Design Project Supervisor	Larger number of utilities in the area.
Transportation Engineer	If we see potential conflicts, we ask for a QLB. We use a lot of storm sewers in Houston.
Utility Coordinator	It is critical to know the depth of all utilities and it makes our decision easy to request this type of information.
ROW Utility Coordinator	The factors that determine the use/request is the type of highway improvements.
Engineering Specialist	Accuracy of data provided by the utility entity, plans and field investigation might be different.
Transportation Engineer	Location type of project, availability of information.
Area Engineer	Number of lines type of lines.
Project Manager	Complexity of utilities on project.
Design Engineer	Utility location, conflict.
District Design Engineer	Don't use it.
Transportation Engineering Supervisor	I don't know.
Staff Support	Sorry, I can't remember what QLB stands for.
Project Manager	Primarily, when a potential for utility conflicts are anticipated based on project scope or route studies are performed and avoidance of conflicts is a design parameter.
Director of TPD	Amount of utilities, area of the project, impact of the project.
District Utility Coordinator Approval	We have only used when we have a SUE contract.
back-up utility coordinator	Usually the utility contractor's choice.
District Utility Coordinator	Project specific, all projects are different.
Transportation Engineer Supervisor	Time, cost, number of utilities, complexity of project.
District Design Engineer	The scope or complexity of the roadway project, the location of the project, and the amount of utilities.
Transportation Engineer Supervisor	The type of utility, and the proximity of the potential conflicts.
Utility Coordinator	Type and complexity of project.
Trans Engineer Supervisor	Knowing there are utilities there, but not having any record of depths and knowing you have potential conflicts.

Title	Factors that Influence Decision to Use QLB
Engineering Specialist	Any widening project, installing drainage features or a change in ditch flow line.
Engineering Specialist	Use whatever type collection that will get the job done.
Design Engineer	Not used.
Advanced Project Development	Need to know what utilities will be impacted by the project so coordination can take place.
Utility Coordinator	None, really do not prefer to use level B, it is not as accurate as going out and exposing, surveying and obtaining real data.
ROW Program Specialist	The need to know where the utilities are located.
District Utility Coordinator	We call for locates on every project. The utility responds and flags their facilities so that there is no doubt as to their location.
Bridge Engineer	During the design phase we request that the utility company mark their lines in the proposed work area. Generally they choose QLB methods. If we have a critical underground facility we discuss the project with the company and determine if a more accurate locate is necessary.
Director /Head	If it is a known, the utility will have to be relocated, and then the existing facility's QLB data is of little value.
Supervisor, Design Utility Coordination Section	Level of perceived utility complexity. Size of project - We typically use contract SUE providers on Interstate widening projects. New location projects. Proposed drill shafts. Proposed storm sewers/drainage facilities.
Engineer	Allocated time for completion of a project, urban vs. rural, new vs. existing ROW, time allowed for designers. The design phase seems to be rushed these days, therefore utility relocation are missed and passed on to be handled during construction.
Director/Head	Usually N/A during preliminary design stage.
Utility Coordinator	High probability of unknown utility companies, locations, and depth in a congested area - even after Levels C and D research.
Staff Support	None: it must be exposed and an elevation taken or it could be a change order during construction.

Question 15. What other factors influence your decision to use or request QLA data collections for a project? (34 Responded, 95 Skipped.)

Table 69. Responses to Question 15.

Title	Other Factors that Influence Decision to Use QLA
ROW Utility Coordinator	Potential of redesigning of highway improvements to clear utility conflicts.
Transportation Engineer Supervisor	None.

Title	Other Factors that Influence Decision to Use QLA
District Design Engineer	Potential for conflict with roadway construction. Risk for construction delay.
Project Manager	Safety to prevent incidents, determining the location of the utility.
District Design Engineer	Those listed in 14 are a good list of the factors.
Engineering Specialist	Culvert designs.
Design Engineer	Ability to get utility owner to conduct potholing operations.
District Utility Coordinator APPROVAL	Importance and time constraint.
Design Engineer	Utility provider's willingness to adjusting facility. Speed at which facility could be adjusted if conflict arises during construction and would conflict delay construction.
Design Engineer	Generally, utilities that cross under a roadway or culvert need the depths identified and are potholed/surveyed.
Transportation Engineer Supervisor	No money available for SUE contracts. Utility companies are normally responsible to clearing utilities. If they feel a line is questionable, they will uncover line to verify.
Director of TP&D	Conflict minimization.
Transportation Engineer	Design accuracy, minimize change orders.
Transportation Engineer	None.
Engineer	Time allowed for design phase.
Supervisor, Design Utility Coordination Section	Our decision to use QLA is mainly based on the type of construction to complete the project. We use QLA mostly when we are installing drill shafts and drainage facilities.
Utility Coordinator	Past experience from work in the same or nearby control sections. Do we have a handle on the usual suspects?
Director/Head	Usually QLA data is not needed for preliminary design work.
Utility Coordinator	Type of construction.
Trans Engineer Supervisor	Known conflicts.
Plan Reviewer	None.
Project Manager	When vertical location data impacts selection of design alternative or determination of construction cost (where alternative design is not available).
ROW Program Specialist	May be able to design around utility and not need to adjust.
Utility Coordinator	Scope of project: on bridge projects, whether items like a detour road or temporary provision for cross drainage are required.
Design Technician	Whether or not there is money available for SUE. If not, then it is a moot point.

Title	Other Factors that Influence Decision to Use QLA
Transportation Engineering Supervisor	Widening projects, bridge project super structure.
Utility Coordinator	Unknown depth/location.
District Utility Coordinator	Project scope.
Engineering Technician	When utilities are borderline between no conflict and conflict. When a possible design change may be able to avoid the cost of moving utilities.
Staff Support	I have been instructed to always use the same procedures.
Staff Support	The size of line and the type of line.
Design Project Supervisor	Size of the project and number of impacts.
Transportation Engineer	Time availability and schedule.

Question 17. Briefly describe the type of checklist, flowchart, or other procedure you use to determine what type of utility investigation data to collect and when. (12 Responses, 117 Skipped.)

Table 70. Responses to Question 17.

Title	Checklist, Flowchart, or Other Procedure Used to Determine Type of Utility Investigation
Design Engineer	District procedure for reimbursable vs. non-reimbursable utilities.
Utility Coordinator	District ROW has developed a procedures statement for all involved in the process. It is a checklist organized in step-by-step project chronology, with description and assignment of primary responsibility at each step.
Project Manager	From planning to preliminary design, design, and then construction of the project.
Engineering Specialist	Review plan and profile, drainage profile, signal foundation and locations especially on the widen projects.
Utility Supervisor	Notice of proposed construction letters.
Utility Coordinator	Type, depth, material.
Engineering Specialist	I resort to the FHWA website or other states.
Transportation Engineer	The TxDOT Utility Manual has an overview flowchart of the utility process. It includes a step to do utility investigation, however it does not provide information on what type of utility investigation is needed.
Director of TPD	Just use list of utilities and status.
District Utility Coordinator APPROVAL	We use a checklist that was developed in our district.
Transportation Engineer Supervisor	Project development process for TxDOT.

Title	Checklist, Flowchart, or Other Procedure Used to Determine Type of Utility Investigation
Staff Support	An overview is in the Design Manual but with limited schedules it's hard to follow any type of flowchart or procedures.

Question 22. Briefly describe challenges and recommendations for managing SUE contract task orders. (16 Responses, 113 Skipped.)

Table 71. Responses to Question 22.

Title	Challenges and Recommendations for Managing SUE Contract Task Orders
Director of TP&D	It all depends on how much you are willing to pay for the service. The more accurate, the more expense.
Transportation Engineer	SUE was a great tool for high-cost, limited-time projects. No challenges.
Design Technician	The SUE firm(s) should be vetted well to make sure they are capable of the work. They should also be evaluated accurately based on the quality and accuracy of work that we receive. Progress payments should only be made when a like percentage of work has been achieved.
Utility Supervisor	Same as project manager.
Transportation Engineer	Coordination with contractor (SUE) doing the work, assistance from local area offices in some cases, traffic control plans, coordination with utility companies when they do not have the resources to uncover their lines, guidance/oversight to SUE contractor when performing the work, and reporting of results.
Transportation Engineering Supervisor	It has been so long ago that I was involved with this, I am sure things have changed.
Director of TPD	SUE Consultant Project Manager keeps quitting, lots of turnover in the industry.
District Utility Coordinator APPROVAL	It has been a few years since managing a SUE contract and I believe the deliverables are different.
District Design Engineer	Negotiating hours and linear feet of utilities because of the unknowns. The time to get a SUE work authorization or contract approved by Division is too long.
Engineering Specialist	The effectiveness of the SUE contractor, the time it took to coordinate. I ended up doing most of the leg work. Most of the problems are caused by the utility companies not meeting there deadlines.
Utility Coordinator	Need to set defined scope of work activities and timelines for consultants, schedule monthly/weekly status report meetings to monitor progress and ensure that work is being accomplished on time, ensuring all activities are being met by the consultant, maintain good working relationship between all parties involved.

Title	Challenges and Recommendations for Managing SUE Contract Task Orders
ROW Program Specialist	Don't let the SUE provider dictate to you what they think you need. I will listen, but I do not let them make the final decision.
District Utility Coordinator	Making sure the contract outlines specific tasks the consultant is to perform but still having the ability to add to or amend the contract if something unforeseen comes up.
Director /Head	Verification of locating unknown utilities/use of sweeps and not just locating known or record lines. Holding SUE providers accountable for work as errors are normally discovered a year or several years later during construction after contract has expired.
Supervisor, Design Utility Coordination Section	Staying within time schedule and budget. Quality of the SUE survey varies from one provider to the next. Invoices usually need careful review.
Staff Support	The challenge is getting the most bang for the buck. Limited amounts of money make it hard to get all the information you need.

Question 27. Briefly describe the process you have in place for reviewing SUE deliverables. (13 Responses, 116 Skipped).

Table 72. Responses to Question 27.

Title	Process for Reviewing SUE Deliverables
Director of TP&D	Normal consultant review process.
Project Manager	Review and compare the vertical and horizontal data for potential conflicts.
Engineering Specialist	Look at each line and see where they are on each project. This info will then use to apply for special provision for 6 months delay.
Advance Project Development Director	It is included in our PS&E review process.
Utility Supervisor	TxDOT review, utility review.
Plan Reviewer	Review what is on scope of work.
Utility Coordinator	I am not in charge of this process. I know they advertise it in the newspaper for bid.
District Utility Coordinator APPROVAL	I was the only one reviewing. I would work with the designers and try to limit conflicts
Advanced Project Development	Check the deliverables against what is in the contract scope.
Utility Coordinator	Review and confirm deliverables between utility coordinator and project manager while also including utility company's input.

Title	Process for Reviewing SUE Deliverables
District Utility Coordinator	We compare the deliverables with what was outlined in the contract. We also assess the quality of the work and whether or not the consultant provided more than was asked. We also determine if the deliverables were timely, clearly presented, and organized.
Supervisor, Design Utility Coordination Section	The SUE survey is reviewed by the Design Engineer/Project Manager before the survey is accepted by District. If the Design Engineer/Project Manager is not satisfied with the survey, additional survey work may be requested from the SUE provider.
Utility Coordinator	We have a process (three-member team). I have not served on one of those teams.

Question 28. Can you give a reason why QLB and QLA SUE are not frequently used on TxDOT projects? (67 Responses, 62 Skipped.)

Table 73. Responses to Question 28.

Title	Reason Why QLB and QLA SUE Are Not Frequently Used on TxDOT Projects
Transportation Engineer Supervisor	Cost.
Transportation Engineer	Calling Dig TESS and requesting pothole depth from the utilities is cheaper than paying for a SUE contract. On large projects where manpower is low and funding is high, SUE contracts are more seriously considered. In our district, I do not like the way that utility location and adjustment issues are left to the project manager to handle.
Director of TP&D	Cost.
Utility Coordinator	Most rural projects we and Utility company are able to obtain good locates on utilities.
Engineering Technician	We use at least QLB on all projects. I'm not sure why others don't.
Transportation Engineer	We don't have the equipment. If we need it, then we call DigTESS or the utility companies to do it. QLA is done by the utility companies to determine if they have to move it. It is usually cheaper for them to spend some time locating their line than to move it.

Title	Reason Why QLB and QLA SUE Are Not Frequently Used on TxDOT Projects
Utility Coordinator	My personal assessment based on what I have seen of the services provided by SUE contractors is that there is a great deal of variability in the quality delivered, most generally on the poor side, reflected in my responses to question 22. Consequently, as conditions warrant, I depend more on the utilities themselves, or their selected location / adjustment contractors (for both QLB & QLA), for I have found them more reliable as they have an investment to protect. In contrast, I have used my responses to question 23 as the vehicle to indicate my evaluations for utilities' response where these two data sources are concerned. In addition, this is both a natural and logical response to law, in which there is an understanding of the right of utility ownership – a different sense of stewardship, in spite of the overused concept of eminent domain – compared to TxDOT's limited management of commonly held property.
Transportation Specialist	No. We use as we feel justified by the cost.
Engineering Specialist	High expense for SUE work, minimal to low accuracy.
Project Manager	QLA SUE is more costly. QLB is not as accurate to extent of within 2 feet left or right of location. May not fit design criteria.
Director of TPD	We use A and B where necessary so don't agree with that statement for our district. I assume cost might be an issue for some.
Engineer Supervisor	I believe that the cost deters some project managers even though it can actually lower project costs.
Head of Traffic	I think of no good reason TxDOT would want anything but A or B. The criteria should be Start with A then work down to B or C as the project specifics warrant.
Design Engineer	Cost. Primarily due to this work being considered a professional service and the lack of a competitive bidding process for these services.
Utility Coordinator	Funding.
District Design Engineer	A lack of an active contract with a SUE consultant or the lack of consultant funds to pay for this work.
Director of TPD	Shortage of resources, funds, and time.
Utility Coordinator	Current budget constraints and cost.
Transportation Engineer Supervisor	Cost.
Engineering Specialist	Budget.
Transportation Engineer Supervisor.	Possible cost.
Design Technician	I have been told that we currently don't have money budgeted for SUE. I'm also not sure if some project managers understand when it is useful and when it isn't. It isn't always a benefit, but sometimes is quite necessary.

Title	Reason Why QLB and QLA SUE Are Not Frequently Used on TxDOT Projects
Advance Project Development Director	Budgetary and schedule constraints.
Utility Supervisor	We use on all large projects.
Transportation Engineer	Additional funds are not available.
Transportation Engineer	Cost is the main reason and lack of in-house capability. Time is also a factor. It is difficult to meet PS&E deadlines while waiting on SUE data.
Plan Reviewer	The only explanation I have is that projects that use QLC and D may be rural projects. I think QLA and B should be used on all urban projects with cost over 5 Million.
Transportation Engineer Supervisor	Higher cost.
Director of Advance Project Development	Cost and time.
Design Project Supervisor	It is my experience that TxDOT only uses B and A for larger projects with major adjustment. Most of my projects are smaller with documented utilities.
Transportation Engineer	The upper management does not want to spend the money. However, it is the designers who are blamed when there are construction problems due to utility conflicts. Also, I learned that when the adjustments are done on a project, the final data is not sent to the original designers to recheck and this has caused some problems.
Utility Coordinator	I think due to the fact most pipelines in this level are no threat to the proposed project and also because they are deep in the earth.
ROW Utility Coordinator	Cost is the reason why QLB and QLA SUE are not used frequently.
Engineering Specialist	1) Special project not initially programmed 10% of the time. 2) Financial constrains 30% of the time. 3) Design plans not complete in time to allow additional investigation.
Transportation Engineer	Funding is mainly the main reason.
Area Engineer	SUE consultant cost.
Design Engineer	Expensive.
Design Engineer	Not needed.
District Design Engineer	Budget.
Transportation Engineering Supervisor	I would think they reason in this district is merely the types of projects we do. We do not get a lot of new location projects. Most of what we do is within the existing pavement bed and the depth does not change much, if at all.
Area Engineer	Extra cost, utility companies place the lines pretty much where the permit says.

Title	Reason Why QLB and QLA SUE Are Not Frequently Used on TxDOT Projects
Staff Support	I have been instructed to always use the same procedures.
Project Manager	Probabilistically they may lower cost, but if the need for an SUE on each project can be accurately determined in advance, then we have very few projects that justify this expenditure. Additionally, the value of this service is considered to be poor by many in-house designers and PMs; we can do a better job in-house if resources are available.
Director of TPD	Time frame to get the data collected often does not fit the work schedule.
District Utility Coordinator Approval	Not enough SUE contracts available. I also believe you do not always get the bang for the buck.
Back-Up Utility Coordinator	District decision.
District Utility Coordinator	No ($).
District Design Engineer	The use of consultants for QLB and QLA SUE is required because TxDOT does not have the expertise or equipment. The cost for QLB and QLA SUE is expensive. Sometimes there is not enough time in the project schedule to allow for QLB and QLA SUE.
Transportation Engineer Supervisor	Time and cost.
Utility Coordinator	Attempt to cut or hold down cost early in project development.
Transportation Engineer Supervisor	I don't know. I suspect the cost of hiring a consultant to do the work. I think QLB and QLA should be used on all TxDOT projects.
Engineering Specialist	Cost. SUE charges for their services. It doesn't cost anything but my time to call locates into Dig-Tess or the utility to get horizontal positions and I can also pick those up on the survey. I can call the utility company to expose the underground utility. Most of the time, there is a breakdown in communication between TxDOT designers and the SUE contractor. SUE contractors are not involved enough in the design phase to know what is expected from them.
Engineering Specialist	Money.
Design Engineer	Do not have current SUE contract. Have not used QLB (radar) method. QLA investigations are generally done with TxDOT forces or contracted surveyor.
Advanced Project Development	QLA may not be used normally due to lack of funding. QLB may not be used due to funding also.
Utility Coordinator	It is expensive and normally is not provided in a timely manner, it can be accomplished with in house staff and utility staff along as you have a good working relationship with both parties.
ROW Program Specialist	Not used.

Title	Reason Why QLB and QLA SUE Are Not Frequently Used on TxDOT Projects
District Utility Coordinator	Due to the type of projects our district has been involved within the last several years, we have not needed much B or A SUE.
Bridge Engineer	It may improve the survey if you explained SUE.
Supervising Design Engineer	Too expensive for projects in our district
Director/Head	Perceived belief the risk is minimal and the services needed can be performed by DOT staff.
Supervisor, Design Utility Coordination Section	As a whole I would say most TxDOT projects (includes maintenance) do not involve the potential to disturb a UG utility. Probably less than 25% of [district] projects require SUE survey.
Engineer	Lack of funds and lack of importance stressed.
Director/Head	This level of detail is typically not needed for preliminary design work.
Utility Coordinator	SUE use is not a staple of our past history. TxDOT engineers don't typically consider utilities or utility impacts to the degree that they should. The crux is that utility adjustments don't hit their bottom line whereas invoking SUE contracts does. Blame it on short-sightedness.
Staff Support	Lack of money or an accelerated time line for the project.

Question 31. To what degree is the management of confidentiality and/or security of utility data an issue in your district/region? (70 Response, 59 Skipped.)

Table 74. Responses to Question 31.

Title	Management of Confidentiality and/or Security of Utility Data	
Transportation Engineer Supervisor	Not an Issue	I do not give out utility information to the public. I cannot speak for others.
Transportation Engineer	Not an Issue	I don't understand the question. I don't think TxDOT is worried about confidentiality of utility data. Utility companies are paranoid about sharing their utility maps or GIS shape files.
Plan Reviewer	Not an Issue	We give them to utility companies.
Design Engineer	Not an Issue	Hasn't been as issue.
Engineering Technician	Low Concern	The utilities we work with haven't expressed concern about this.
Transportation Specialist	Low Concern	AT&T has been the only firm to try and claim security reasons. It's BS.
Advance Project Development Director	Low Concern	I have not seen this become a concern.

Title	Management of Confidentiality and/or Security of Utility Data	
ROW Utility Coordinator	Low Concern	Most of the utility data that are provided to the department do not have any confidentiality/security issue.
Transportation Engineer Supervisor	Low Concern	I wish utility companies would give us exact locations of their facilities. We never get clear or precise information. This makes it hard to design accurately. We never get full cooperation from utility companies.
Supervisor, Design Utility Coordination Section	Low Concern	The electrical utility (Center Point) does not usually share the exact location of their UG electrical transmission lines, due to national security issues. Not too much of a problem with other utilities.
Staff Support	Low Concern	I haven't seen any concern from utility companies. Lines may be out of compliance from UIR.
Utility Coordinator	Medium Concern	In our district and among area utilities in general, the threats of terrorism and industrial espionage are of low- to very low concern. However, I work with purpose to cultivate a high level of trust with all our utilities for the good of the Department and for effectiveness in coordination, always keeping in mind the potential for sensitivity to these issues. Since 9/11, the level of alert has subsided, but I believe TxDOT and public utilities should still regularly be reminded of the specific dangers of attack.
Project Manager	Medium Concern	The public should have the right to know what is within TxDOT right-of-way.
Head of Traffic	Medium Concern	Proprietary technologies.
Design Technician	Medium Concern	Some utility companies do ask us not to share the information they give to us for reasons of the information being proprietary and in some instances, a security issue. Some utilities are regulated by other governmental agencies for security reasons.
Transportation Engineer	Medium Concern	We must share data amongst all utilities involved in relocations; however, we only share location and type of facility which is of a general nature.
Design Project Supervisor	Medium Concern	I have not seen this.
Engineering Specialist	Medium Concern	Some communication lines (telephones).
District Design Engineer	Medium Concern	The communication utility business has become very competitive and they have been reluctant to share a lot of their information for this reason.

Title	Management of Confidentiality and/or Security of Utility Data	
Utility Coordinator	Medium Concern	Security/confidentiality is growing quickly, year by year.
District Utility Coordinator	High Concern	All utility information provided by utility companies is kept confidential.
Transportation Engineer Supervisor	High Concern	We are not given electronic files from the telecommunications companies, so the drawings we have are inaccurate.
Advanced Project Development	High Concern	TxDOT puts high priority on confidentiality of data.
Utility Coordinator	High Concern	Agree with the statement above.
ROW Program Specialist	High Concern	Utility companies are being more particular concerning this issue due to TxDOT's records being subject to open records request.

Question 33. Briefly describe best practice(s) for utility investigations. (27 Responded, 102 Skipped.)

Table 75. Responses to Question 33.

Title	Best Practice for Utility Investigations
Transportation Engineer	Be in contact with the utility companies from the very beginning.
Design Engineer	Do not accept the responsibility of the utility. Utilities have a right to be on the ROW. However, that does not mean that the state has to accept costs that are the responsibility of the utility. Pothole to determine exact locations to minimized liability.
Utility Coordinator	1) One suggestion I have made to address a need in our recently launched online UIR is to include CSJ numbers in the online form so utility adjustments necessitated by construction projects can be distinguished from utility-generated rehab and expansion projects, yet the records still maintained in the UIR system. 2) Though related only indirectly to data collection, one other suggestion I have made to reduce survey staking for utility reference during multi-utility adjustments is to use studded steel T-posts for ROW marking, rather than wood stakes or laths. On rural projects in particular (where new low-profile ROW monuments are hard to find in brush, tall grass, leaf cover, etc.), this is a more durable solution to marking where "cows and contractors" might otherwise take their toll on wood staking.
Transportation Specialist	Design your utility locate needs to the specific type project being developed. Don't just request the world when it may not be needed and the levels B and A are very expensive.
Project Manager	Probably One Call verification, communication, cooperation, and coordination.

Title	Best Practice for Utility Investigations
Head of Traffic	Level A.
Utility Coordinator	1) Search Local records. 2) Discuss with Local Utility Providers. 3) Survey potential conflicts. 4) Provide information with Local Utility Providers.
Engineering Specialist	SUE plans, and coordinate with all utilities within the project in the utility coordination meetings.
Design Technician	I perceive that there is a possible conflict of interest between reviewing and oversight of SUE contracts, due to the fact that some people tend to review SUE consultants leniently whether we receive the desired result or not, so as not to burn a possible bridge to future employment.
Advance Project Development Director	In preliminary design, coordinate utility locations with local government staff and avoid any major utility when possible.
Utility Supervisor	Get a SUE done.
Utility Coordinator	Work with utilities to locate their exact location and depth of cover.
ROW Utility Coordinator	My best practices are to have a point of contact among utility representatives in establishing a good working relationship that provides the exchange of ideas and concerns.
Engineering Specialist	Follow the guide lines provided by FHWA.
Area Engineer	Go out to the project and actually plot what you see and not rely on utility company's giving you the information. The designer needs to do the work himself. He is putting his name on it.
Project Manager	1) Conduct QLD on all applicable projects. 2) Based on initial findings and other preliminary design info, determine need for further investigation. 3) Plan services needed from surveying consultant; prepare records research data for consultant use including plot plan of utilities and highway improvements, if appropriate. 4) Coordinate QLB and QLC data collection with surveyor; review deliverables and request supplemental information, including QLA data, if needed.
District Utility Coordinator Approval	We work with all parties as early as possible but sometimes due to letting schedules we do not get enough done before construction begins and this impacts the construction schedule.
District Utility Coordinator	Communication, cooperation, coordination.
Transportation Engineer Supervisor	100% cooperation on both sides. TxDOT frequently requests information from utility companies. Utility companies are not good with responding and giving good information. They make it hard for TxDOT to do their job well. TxDOT has no jurisdiction over utility companies, so we never get full cooperation from them. This leads to a bad product on our end and bad relationships as well.
Design Engineer	Start investigation early and try to design around possible conflicts. If conflicts exist, get accurate information and coordinate with utilities as early as possible.

Title	Best Practice for Utility Investigations
Utility Coordinator	Collect existing utility data, notify utility owners, identify potential conflicts, request Level A SUE if needed, confirm conflicts.
ROW Program Specialist	Communicate with the utility company. Explain need for cooperation. Let them know that you may be able to design around the facility.
District Utility Coordinator	Establish and maintain good professional relationships with the local utility companies. Visit the project site with the utility company. I get more done in 1 hour on site than with three week' worth of emails and phone calls.
Director /Head	Preplanning the need and scope of the utility investigations is the most overlooked area. Coordination with design and right-of-way staff.
Supervisor, Design Utility Coordination Section	All utility investigations should start in the preliminary design phase and supplemented prior to the 30% design complete phase. On smaller projects, the TxDOT designer should exhaust in-house resources to discover utilities and their location within project limits before requesting SUE provider services. On smaller projects, we may limit the SUE provider to only QLB and QLA. On larger projects, it is usually more feasible for a SUE provider to conduct QLD through QLA.
Utility Coordinator	Time spent doing a thorough utility investigation during the design phase can reap huge benefits when the project undergoes construction; lack of utility considerations can adversely affect project construction immensely.
Staff Support	Early notification and investigation, followed by conflict review.

Question 35. Briefly describe what challenges you have experienced with the use of utility investigations/SUE technology, if any. (18 Responses, 111 Skipped.)

Table 76. Responses to Question 35.

Title	Challenges with the Use of Utility Investigations/SUE Technology
Design Engineer	Quality and completeness of survey.
Utility Coordinator	Accuracy of data, timely response, lost time, irritation, etc. If I can avoid it, I do; otherwise I "re-do," using the utility(ies) "of interest."
Transportation Specialist	Accuracy of the information in the areas of specific need.
Project Manager	I think the process is working fairly well. Maintain 100% communication, coordination, cooperation.
Director of TPD	Information provided is not always accurate
Engineer Supervisor	We have had questionable data if we receive anything less than Level A. Also, utilities don't seem to know (or won't tell us) where their own lines are.

Title	Challenges with the Use of Utility Investigations/SUE Technology
Utility Coordinator	In the oil/gas industry it common practice to abandoned their facilities without notifying TxDOT and that is creating a massive problem. I think the laws/rules need to be enforced. No one notifies TxDOT when abandoning a utility and that needs to change
Transportation Engineer Supervisor.	Two challenges have been the level, (got C, should have been B or A) and dealing with some of the consultant utility coordinators.
Engineering Specialist	Not all of SUE plans are correct in the SUE plan.
Design Technician	I didn't answer questions 23 and 24 because I have observed quality from excellent to poor across the board on SUE contracts. I think this relates to the failure to give poor evaluations to poorly performing consultants, thereby causing us to continue to use them. SUE is a tremendous benefit on some projects if the work is done to a satisfactory level.
Utility Supervisor	More data = more work.
Transportation Engineer	Coordination with utility owners and receiving SUE data in a timely manner from SUE consultants.
Transportation Engineer	A new location freeway through an oil field. Our usual SUE providers were unable to handle the complexity of the oil field piping system. It was necessary to get help from a contractor that specialized in the oil and gas business to help us sort out what lines were abandoned and which ones were needed for well operation.
Project Manager	Going through the process of obtaining this information with in-house resources increases 1) familiarity with data, thus decreasing design effort, and 2) opportunity to discover related issues and further develop the investigation, ensuring completeness and reliability of data, which contracted SUE does not provide.
Director of TPD	Contractor's loss of experienced personnel. Contractor had equipment failures.
District Design Engineer	Getting the SUE information in a timely manner due to short project schedules. Some unknown utilities show up during the investigation.
Transportation Engineer Supervisor	Identifying the locations you need verified in the field based off of inaccurate information.
Design Engineer	Sometimes the utility locates/line markings are slow to occur and/or inaccurately marked thru the Texas One Call/Dig TESS requests.
ROW Program Specialist	Allowed a provider to sell me level A services and not needed that. Now I tell them what I need and when I need it.
Supervisor, Design Utility Coordination Section	Some technologies, such as GPR, have limited capabilities in soils with a high clay content. Also, standing water can limit the effectiveness of SUE technology.
Engineer	Accuracy of locations in tight urban areas.
Utility Coordinator	Lack of utilizing appropriate SUE has generally made utility coordination twice as difficult.

Question 37. Briefly describe current utility investigation practices in your district/ region that could be improved. (67 Responses, 62 Skipped).

Table 77. Responses to Question 37.

Title	Utility Investigation Practice that Could be Improved
Director of TP&D	Need several ongoing contracts available within the region.
Utility Coordinator	Already addressed specifically in previous responses.
Engineering Specialist	Make the consultant to be reliable to continue investigation when coordinator/designer asks for further survey, pot holes, etc.
Design Technician	To my understanding, we have no money available for SUE work at this time. However, I think that the requestor should have a right of refusal for a particular firm that they have received poor work from in the past.
Advance Project Development Director	Avoidance of major utilities should be stressed more in preliminary design stage.
Transportation Engineer	It is the decisions to protect or relocate reimbursable utilities that become an issue. TxDOT is trying to do everything as cheaply as possible in the short run. For utility conflicts that are reimbursable by TxDOT, the District Utility Coordinator and the upper management do not want to spend the money to do the best solution (pay for adjustment of utilities). They stretch the rules (shown on the Texas Administrative Code). The District Utility Coordinator, who is not an engineer, then wants the Project Manager to do some protection which is cheaper than relocation and assume all the liability. I have a high pressure gas line in my project right now where the solution my bosses and especially the District Utility Coordinator are proposing is probably not the best solution. I will not be signing and sealing any sheet, but they will get it done. This is driven by lack of time, lack of resources, and a desire to save money in the short run. However, stretching the rules and taking chances could end up costing TxDOT much more if something goes wrong. Also, our district utility section has downsized (every section has) and they don’t have enough resources to get everything done. They are also not paid well and are not engineers. It is my opinion, but I don’t think it is ethical to have the decision makers to be non-engineers when it involves public safety and liability, etc.
Utility Coordinator	More funding for SUE investigation.
Engineering Specialist	Follow the utility investigation provided by FHWA, review passed performance of other states, and research past performance by the department.
Project Manager	We are in the process of hiring a utility coordinator. Hopefully this will centralize the process. Currently the designers have to complete the entire process, which tends to not be very efficient.

Title	Utility Investigation Practice that Could be Improved
Project Manager	Personal communication with utility owners is underutilized. More useful and detailed data could be obtained from utility appurtenance surveys, if survey crews and consultant contract administrators received adequate training on utility investigation techniques.
Transportation Engineer Supervisor	The entire process needs to be standardized.
Utility Coordinator	Need to place more of a focus on SUE.
Transportation Engineer Supervisor	We should have full-time utility coordinators for each design section that only focuses on utility coordination for assigned projects.
Engineering Specialist	Need money for consultants to do the investigations.
ROW Program Specialist	Bring the utility companies to the table earlier. Let the projects for construction that you say are going to let. Be proactive by asking the utility companies about their facility upgrades or new construction.
Supervisor, Design Utility Coordination Section	TxDOT needs to commit to funding SUE provider contracts. The inability of a district to secure SUE provider services is a hindrance to designing certain projects, as well as increasing the cost of the overall project when an engineering solution could have been used to avoid a utility conflict, but SUE data was not available.
Engineer	Utilities that are actually identified during the design phase.
Utility Coordinator	Our approach to utility investigation is inconsistent throughout our design sections. Some are very good and some are very poor.

Question 39. Briefly describe the policy and/ or regulations that constrain or obstruct the use of utility investigations in the project development process. (11 Responses, 118 Skipped.)

Table 78. Responses to Question 39.

Title	Policy and/or Regulations that Constrain or Obstruct the Use of Utility Investigations in the Project Development Process
Transportation Engineer	Usually there seems to be little or no money for SUE contracts. That is what I have heard.
Utility Coordinator	Old, outdated policies reflecting an attitude of bureaucratic arrogance for many years hindered 1) our cooperative relationships with public utilities, 2) new, innovative approaches to obtaining data, and even 3) intra-departmental communication.
Design Technician	A lack of contract money for SUE contracts. Also, a lack of understanding by some project managers of when SUE is beneficial and when it isn't.
Design Project Supervisor	This is handled by the District Utility Coordinator.

Title	Policy and/or Regulations that Constrain or Obstruct the Use of Utility Investigations in the Project Development Process
Transportation Engineer	Again, TxDOT is trying to do everything cheaper and with less people. The resources of people to handle the utility agreements and relocations are not there. Everything is about saving money and justifying stretching what is allowable. The final decisions about relocations versus protection usually come from the District Utility Coordinator and not the Project Engineer. However, it is the Project Engineer who is always blamed if there is a problem in the field. Also, the data about adjustments made is not sent back to the Project Manager once an adjustment is done. There is too much separation between design and construction tasks.
Utility Coordinator	Unfortunately funding is always an issue.
Area Engineer	Companies not wanting to expose lines when requested.
Engineering Specialist	TxDOT's policy of doing more with less means having less or no money for consultants to do the investigations. Bad policy.
Director of Construction	Takes too long to adjust.
Engineer	Lack of funding.
Utility Coordinator	The policies that obstruct are unwritten: inconsistency and cheapness.

Question 41. What other information would help you decide when and how to use utility investigation or SUE technology in the project development process? (37 Responses, 97 Skipped.)

Table 79. Responses to Question 41.

Title	Other Information to Decide When and How to Use Utility Investigations or SUE Technology
Transportation Engineer Supervisor	I have always been able to acquire utility information without a SUE contract. The SUE process is only a time saver for TxDOT personnel in our district. Because of this, and because money is not available for SUE contracts, we have not used a SUE contract in years.
Transportation Engineer	A clear policy manual, explaining existing laws and requirements. A policy manual, that explains what authority TxDOT has to require utility companies to provide location information, or when the location services should be paid by TxDOT.
Engineering Technician	Field guide, best practices handbook.
Utility Coordinator	TMI: TxDOT has spewed out much info for which there is little effective use. Reduce, organize, and probably index, for greater usefulness.
Transportation Specialist	Experience of the designer.
Director of TPD	Historical data on potential for cost savings.

Title	Other Information to Decide When and How to Use Utility Investigations or SUE Technology
Engineer Supervisor	It's all project specific. If it is likely that we will encounter utilities and we can design around the conflicts we will try to get SUE early in the project so that we don't have to go back and redesign.
District Design Eng.	Project scope and location; utility density; availability of a SUE consultant contract; availability of consultant funds to pay for a SUE investigation.
Transportation Engineer Supervisor.	None.
Engineering Specialist	Ask the utilities to see if the SUE plan is up to date with their lines.
Design Technician	The complexity of the project, the amount of utilities present and the remaining right-of-way space left for relocations.
Transportation Engineer	As-built plans.
Plan Reviewer	Complexity of proposed underground work and estimated major existing utilities such as pipelines.
Transportation Engineer Supervisor	Funding availability.
Design Project Supervisor	If unknown utilities are in the area.
Transportation Engineer	In my case, the consultants we hire make many of the decisions. However, our district has eliminated construction services for consultants who design the projects. So when there is a field problem, it is harder to have the consultant help solve the problem, especially when it is not a design error. I anticipate this will become a continuing problem and could become severe. The people making these decisions are upper management and do not have to handle the problems as they arise. They also do not get involved with the engineers (in the trenches and doing the work).
ROW Utility Coordinator	Project site visit and the scope of work of the highway improvements.
Engineering Specialist	The FHWA provide an excellent guide when to use or not couple with other state information. The area that needs major improvements is overhead lines be part of the SUE technology. Ninety-eight percent of the time, the aerial lines such as telecommunication, television are mounted on power poles. The One Call dig does not provide any information regard multiple users on aerial lines. The issue becomes a concern when certain utilities are not required to be register with One Call before you dig, call for preliminary marking. Be registered with One Call: Not all utilities are registered with one call before digging like water lines, sewer lines, and TxDOT department communication lines like fiber optic. Also, it will be a huge help if local city, county and TxDOT fiber optic be mandatory to register with One Call to assist perform level, D, C, B & A.
Design Engineer	Project complexity.
Staff Support	None.

Title	Other Information to Decide When and How to Use Utility Investigations or SUE Technology
District Utility Coordinator	Complexity of project, safety of employees (state, utility) and traveling public.
Advanced Project Development	Good QLD/C data to help determine the need of QLA.
Utility Coordinator	Unknown depths/locations.
ROW Program Specialist	Timing and budget.
Director /Head	Chart – Utility Focused Right of Way Coordination in the Project Development Process Research Project 5475.
Supervisor, Design Utility Coordination Section	Determining the complexity of utilities early in the process is helpful.
Utility Coordinator	Past experience.
Staff Support	Knowing design time lines and changes in design. Reaction time is critical to SUE investigations.

APPENDIX C. STATE DOT INTERVIEW GUIDELINE AND QUESTIONNAIRE

Overview

The purpose of the interviews is to identify best practices for utility investigations that are used at State Departments of Transportation (DOTs) outside of Texas. This will help the research team identify potential strategies to integrate such best practices into the TxDOT project development process. Prior to conducting interviews, the researchers will identify and review current best practices and use of utility investigation practices by gathering information, sample documentation, and other available data at state DOT websites. The researchers will then conduct a series of interviews with a number of DOT officials that will focus on the following:

- Request internal DOT documents that detail recommended practice for use of utility investigations in that state that may indicate when, how, and at what stages of the project development process the state uses utility investigation techniques, and for what type of projects and project sizes.
- Ask questions that will help the research team identify and document the following with respect to utility investigation techniques and technologies:
    - How do states overcome and/or manage institutional barriers for use of these technologies?
    - How do states manage design changes?
    - How do states manage relevant liability and security issues?
    - How do states deal with training and capacity building issues?
    - What successful information management systems are in use?
- Request undocumented expert advice on the subject of utility investigations.

Communications with the selected state DOTs will be by phone and email.

General Interview Guidelines

- Schedule interviews at least one week in advance. Make sure to send a copy of the questionnaire to use as reference during the interview. Although the effective duration of individual interviews could vary, indicate that interviews should last no more than one hour.
- Conduct interview. The topics to discuss during the interview will focus on innovative practices, procedures, and lessons learned, as included in section "Topics for Discussion." Read the following interview script and make sure that the interviewee is familiar with the details of the interview and terminology related to project development process and subsurface utility engineering.
- Compile and send interview notes to Edgar Kraus no later than one week after the interview (see template on page 6). The notes should include the following:
    - Description of innovative/best practices.
    - Recommendations for implementation.
    - Lessons learned.

    - Other issues, recommendations, or comments.
    - Description of sample documentation gathered (if applicable).
    - Additional contact names.

- If applicable, destroy the recording after completing the interview notes but no later than two weeks after the interview.
- If applicable, follow up with other contacts regarding sample documentation and recommendations for best practices, and forward that material to Edgar Kraus.
- Complete all assigned interviews and forward interview notes to Edgar Kraus by 12/17/2010.

Email to Potential State DOT Survey Participants

From: Edgar Kraus
To: Potential participants at state departments of transportation
Subject: TxDOT Study "Best Practices for Use of Utility Investigation Techniques and Technologies"

The Texas Transportation Institute (TTI) is conducting research for the Texas Department of Transportation (TxDOT) and Federal Highway Administration (FHWA) to gather information about techniques and technologies used for utility investigations in the project development process. The primary focus of the study is to review nationwide trends and identify best practices that may be applicable to the TxDOT project development process.

To achieve this objective, we would like to ask a few questions about the use of utility investigation techniques and technologies used in [name of state].

Your input is critical to the research. There is a need for state departments of transportation to optimize the use of funding that is available for utility investigations. We are relying on practitioners like you to help us identify best practices. The outcome of this research will be a report and companion documents that will contribute to more effective use of utility investigation techniques and technologies.

Interview details:

- Participation in this interview is voluntary.
- At any time during the interview, you may discontinue the interview.
- With your permission, we will record the interview to facilitate transcribing the interview. Once the interview is transcribed, we will delete the recording, and we will keep the recording no longer than 14 days after the interview.
- Responses to questions are confidential, and the final report will not identify individuals or link responses to individuals.

For additional information, please contact Edgar Kraus (210-979-9411, e-kraus@tamu.edu).
Your input is critical to the research. Thank you for participating.
Sincerely,

Edgar Kraus

____

Edgar Kraus, P.E.
Associate Research Engineer
Texas Transportation Institute, Texas A&M University System
1100 NW Loop 410, Suite 400, San Antonio, TX 78213
Phone: (210) 979-9411, Ext. 17202 Fax: (210) 979-9694 Email: e-kraus@tamu.edu

Questionnaire/Topics for Discussion with DOT Representatives

The following are a list of questions that the researchers will ask the interview participants. For questions related to satisfaction, please use a scale from 1 (completely unsatisfied) to 10 (completely satisfied).

Utility Investigation Techniques and Technologies

1. What methods, techniques, or technologies does the DOT use to perform utility investigations?
2. What methods, techniques, or technologies does the DOT use at the following stages of the project development and design? (It may be helpful to use quality levels of subsurface utility engineering to indicate technologies.)
    a. Planning phase
    b. Preliminary design phase
    c. 0–30% detailed design phase
    d. 30–60% detailed design phase
    e. 60–100% detailed design phase
    f. Construction phase
3. How are procedures for utility investigation different for the following:
    a. Urban vs. rural projects?
    b. Project location (new/existing)?
    c. Project type (added capacity/non-added capacity)?
4. Can you describe the decision and approval process for use of the following utility investigation technologies?
    a. QLD
    b. QLC
    c. QLB
    d. QLA
5. Who makes the final decision to use utility investigation technologies, and what does the decision depend on?
6. Are there differences in the decision and approval process for use of utility investigation technologies (QLD, QLC, QLB, QLA) with respect to the following?
    a. Urban vs. rural projects?
    b. Project location (new/existing)?
    c. Project type (added capacity/non-added capacity)?
7. How do design changes affect utility identification in the project development process?

Utility Investigation Contracts and Procurement

8. What kind of utility investigation services does the DOT procure and what kind does the DOT perform using in-house staff?
    a. Does the decision depend on the project type (i.e., new versus existing location, urban versus rural, added capacity versus non-added capacity)?
9. How does the DOT procure utility investigation services?
    a. Does the DOT use "stand-by" or "evergreen" contracts? How effective are they? Are there any drawbacks? (If available, ask for copies.)
10. Do consultant contracts include a requirement that prescribes a minimum positional accuracy for the data collected?
11. Are you aware of issues with regard to utility data *liability*?
    a. Have you experienced data liability issues in the past?
    b. How does the DOT manage liability issues?
    c. Is it important that deliverables from SUE providers be sealed by an engineer or surveyor?
12. Are you aware of issues with regard to utility data *access and security*?
    a. Have you experienced data access and security issues in the past?
    b. How does the DOT manage data access and security issues?
13. How satisfied are you with QLA and QLB SUE deliverables from consultants in terms of the following:
    a. Quality and accuracy
    b. Completeness
    c. Reliability

Documentation and Regulations

14. What types of manuals or other relevant documents does the DOT have to support utility investigations? (If available, ask for copies.)
    a. Is there a guideline for the use of SUE/utility investigations?
    b. Is there a manual, Standard Operation Procedure (SOP), or field guide?
    c. Does the DOT have Memoranda of Understanding (MOUs) with utility companies or SUE providers?
15. Are there state laws or rules that affect the ability of the DOT to use utility investigations technology?
    a. Which rules?
    b. What is the effect? (e.g., enable/prescribe vs. prohibit/restrict use)

Institutional and Regulatory Issues

16. What kind of barriers or hurdles does the DOT encounter when attempting to use utility investigation technologies (Examples)?
    a. Are there institutional, regulatory, or legislative barriers?
    b. Are there barriers related to business process, coordination, familiarity, and knowledge of the technologies?
    c. Are there financial limitations that prevent use of utility investigation services?
17. What barrier or hurdle is the most difficult to overcome?

18. How does your state deal with training and capacity building issues?
19. What types of information management systems are used to record, identify, and manage utility investigation data?

Best Practices for Utility Investigations

20. What best practices does the DOT use when collecting utility data?
21. What practice does the DOT currently use that could be improved?
22. What best practice would you recommend that is not currently used?
23. What practice or procedure would warrant further evaluation to determine if it is a best practice?
24. Can you recommend a contact that could provide further insight into these issues?

APPENDIX D. DATA ANALYSIS TABLES AND FIGURES

Project Design Cost

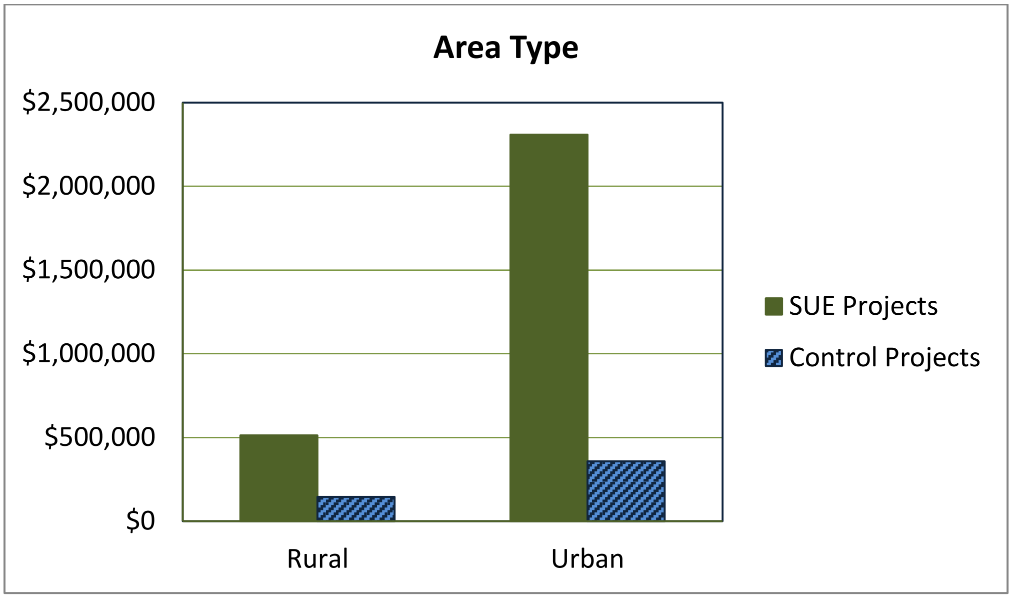

Figure 50. Mean Total Design Cost (2011 Dollars) by Area Type.

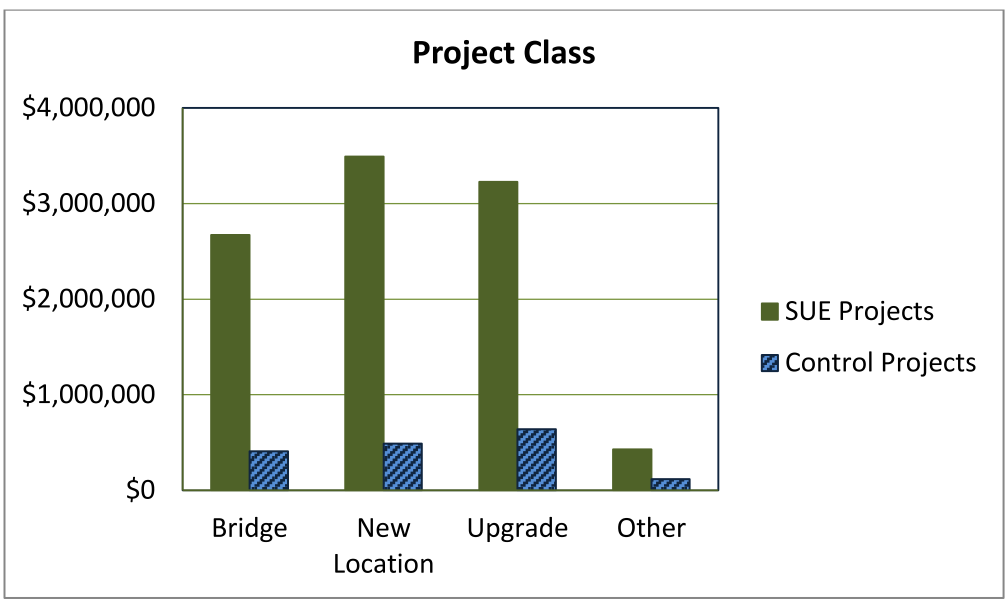

Figure 51. Mean Total Design Cost (2011 Dollars) by Project Class.

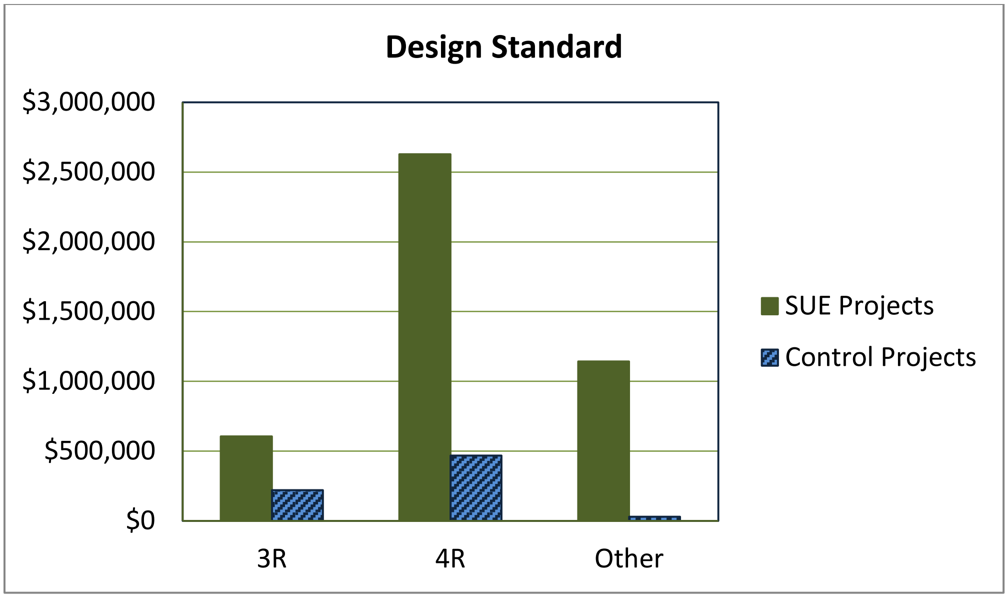

Figure 52. Mean Total Design Cost (2011 Dollars) by Design Standard.

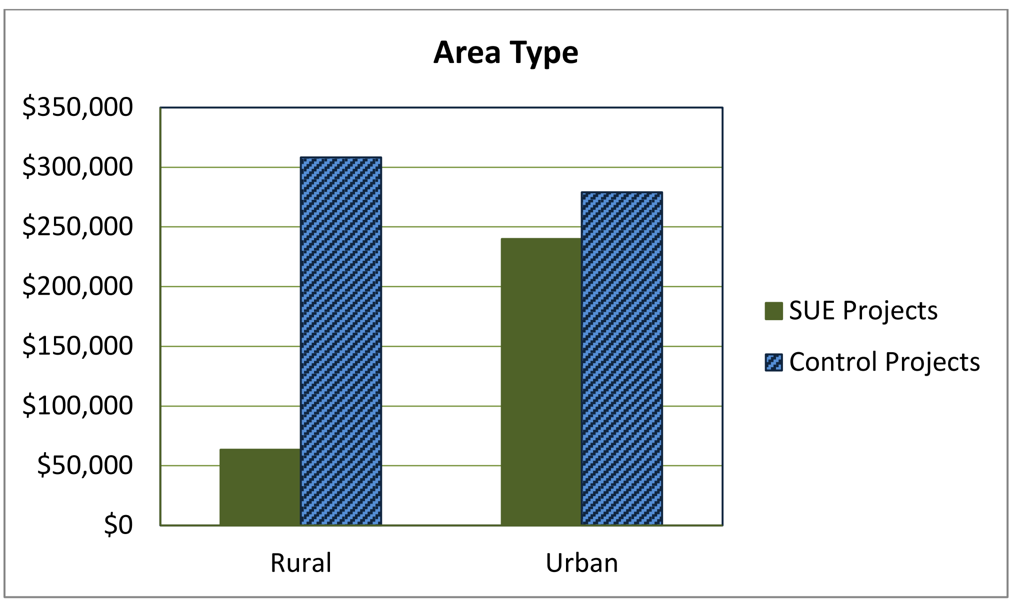

Figure 53. Mean Design Cost per Lane-Mile (2011 Dollars) by Area Type.

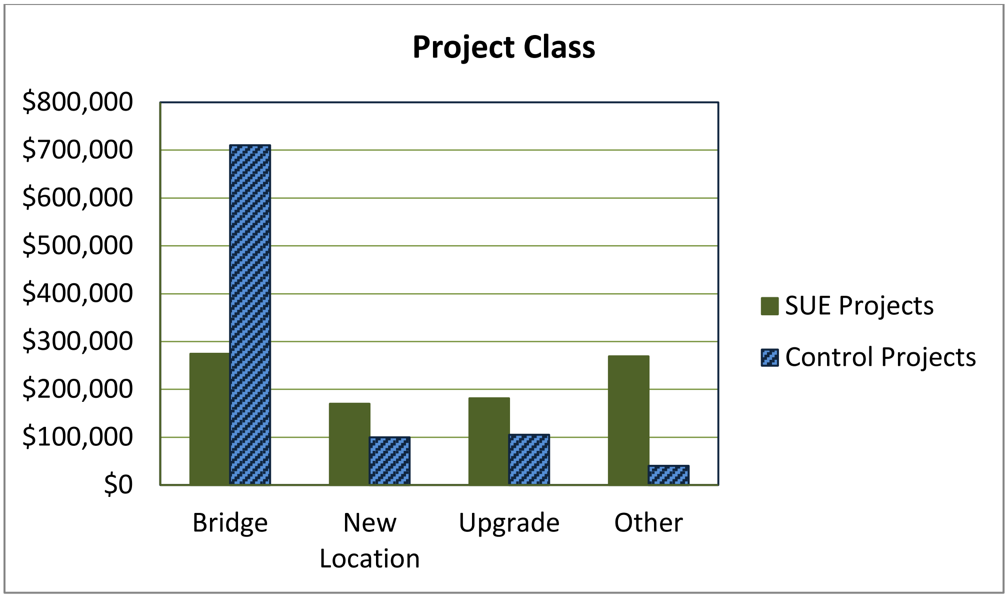

Figure 54. Mean Design Cost per Lane-Mile (2011 Dollars) by Project Class.

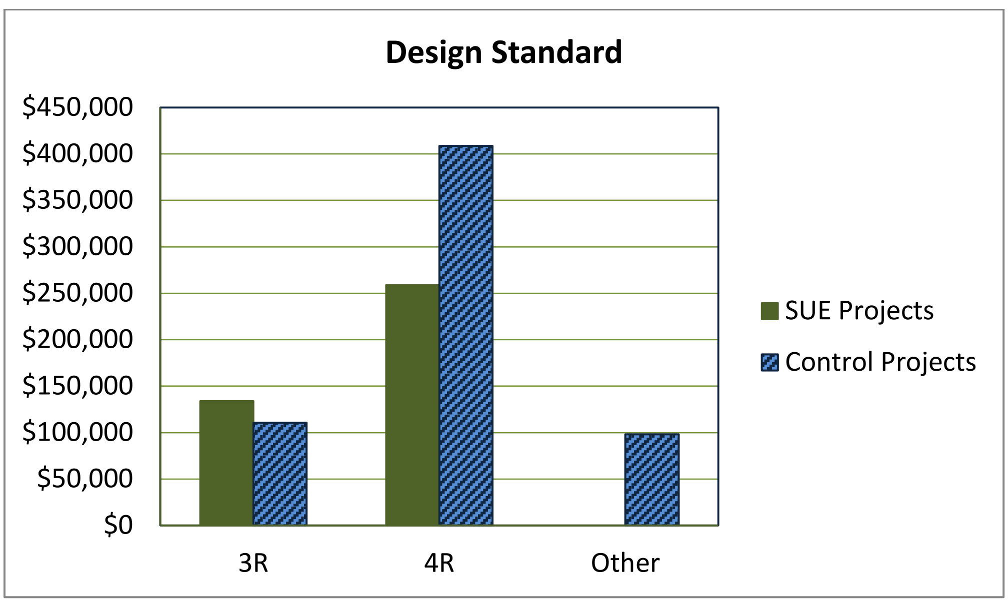

Figure 55. Mean Design Cost per Lane-Mile (2011 Dollars) by Design Standard.

Table 80. T-Test Results for Mean Total Design Cost.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	3	219	0.0944	Yes	0.0053	0.245
	Urban	23	345	<.0001	Yes	<.0001	**0.0059**
	Total	*26*	*564*				
Project Class	Bridge	7	110	<.0001	Yes	<.0001	0.2487
	New location	2	26	0.0088	Yes	0.0054	0.4504
	Upgrade	8	94	<.0001	Yes	<.0001	**0.0207**
	Other	8	84	0.0003	Yes	<.0001	**0.0516**
	Total	*25*	*314*				
Design Standard	3R	4	194	1	No	0.1302	0.2205
	4R	19	236	<.0001	Yes	<.0001	**0.0131**
	Other	3	369	<.0001	Yes	<.0001	0.1037
	Total	*26*	*799*				
All Projects		26	820	<.0001	Yes	<.0001	**0.0031**

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Table 81. T-Test Results for Mean Design Cost per Lane-Mile.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	1	91	-	-	-	-
	Urban	16	139	<.0001	Yes	0.8294	0.6376
	Total	*17*	*230*				
Project Class	Bridge	3	78	0.1802	No	0.4144	0.0871
	New location	1	15	-	-	-	-
	Upgrade	8	76	0.6005	No	0.1775	0.2449
	Other	4	28	<.0001	Yes	0.0023	0.277
	Total	*16*	*197*				
Design Standard	3R	4	50	0.8571	No	0.7162	0.6887
	4R	13	153	0.0001	Yes	0.4719	0.1075
	Other	0	34	-	-	-	-
	Total	*17*	*237*				
As One Category		17	246	<.0001	Yes	0.6876	0.3723

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Project Design Effort

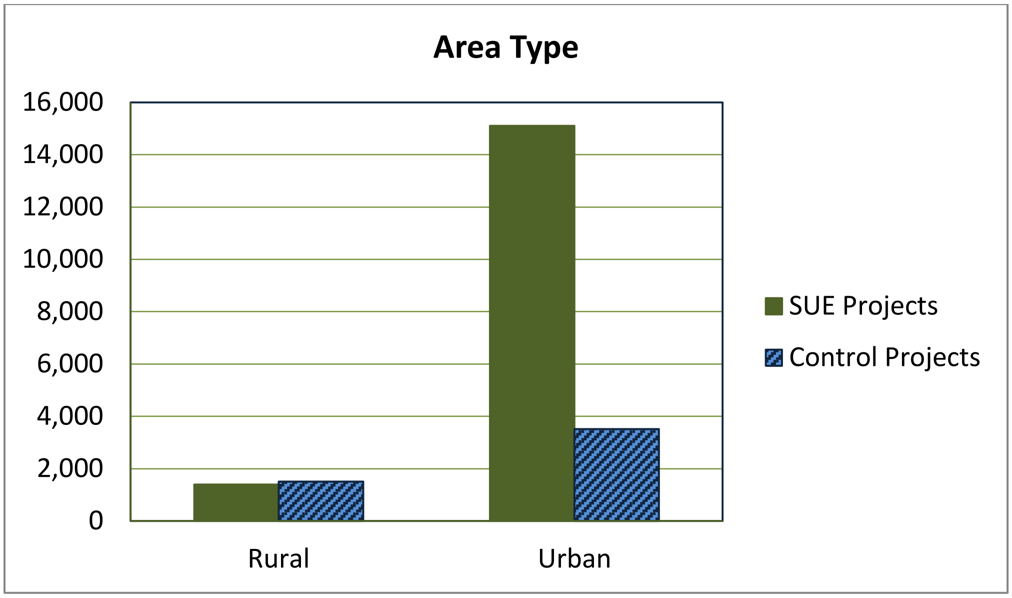

Figure 56. Mean Project Total Design Man-Hours by Area Type.

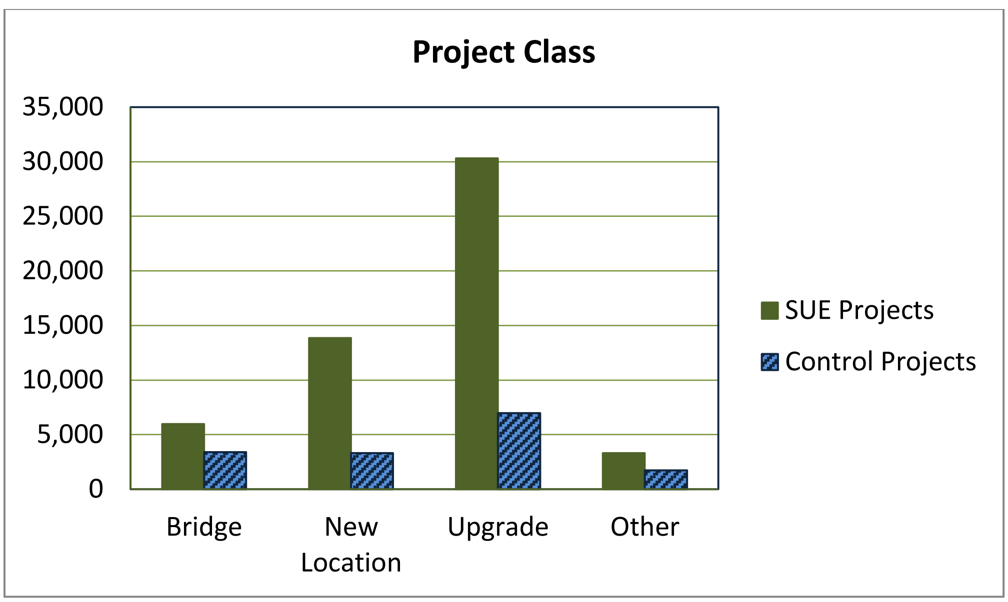

Figure 57. Mean Project Total Design Man-Hours by Project Class.

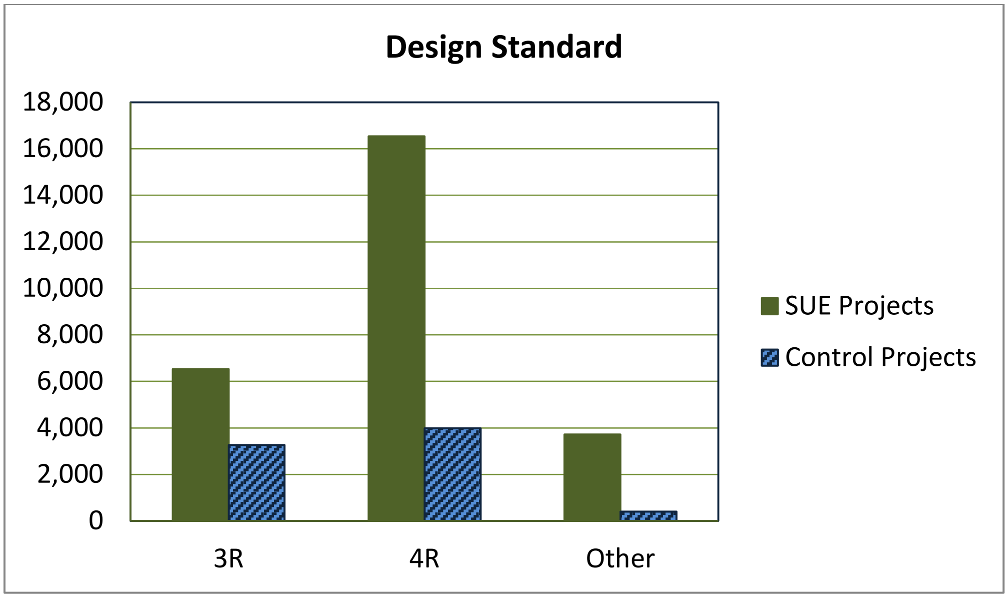

Figure 58. Mean Project Total Design Man-Hours by Design Standard.

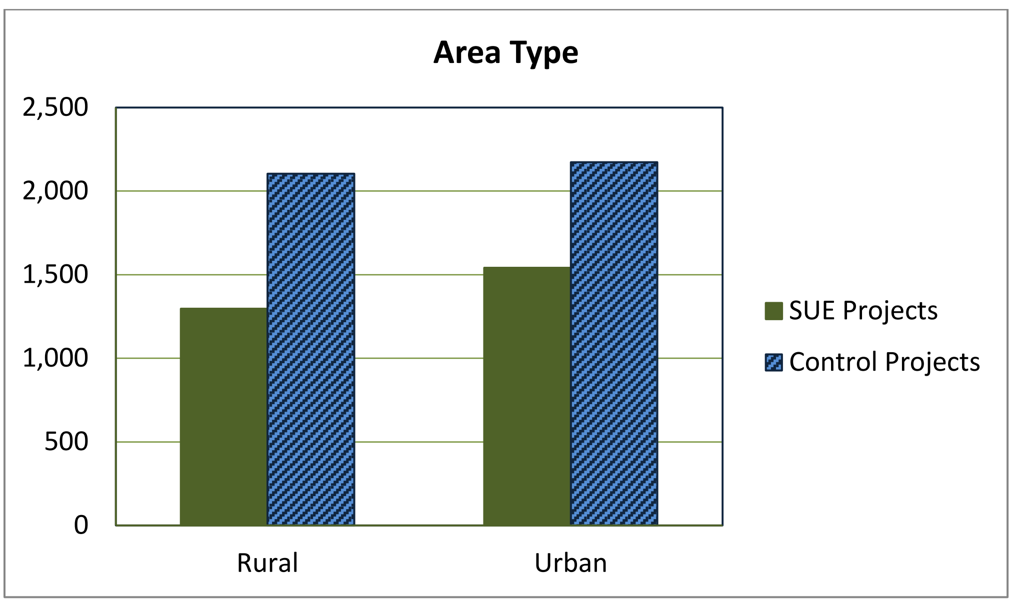

Figure 59. Mean Design Man-Hours per Lane-Mile by Area Type.

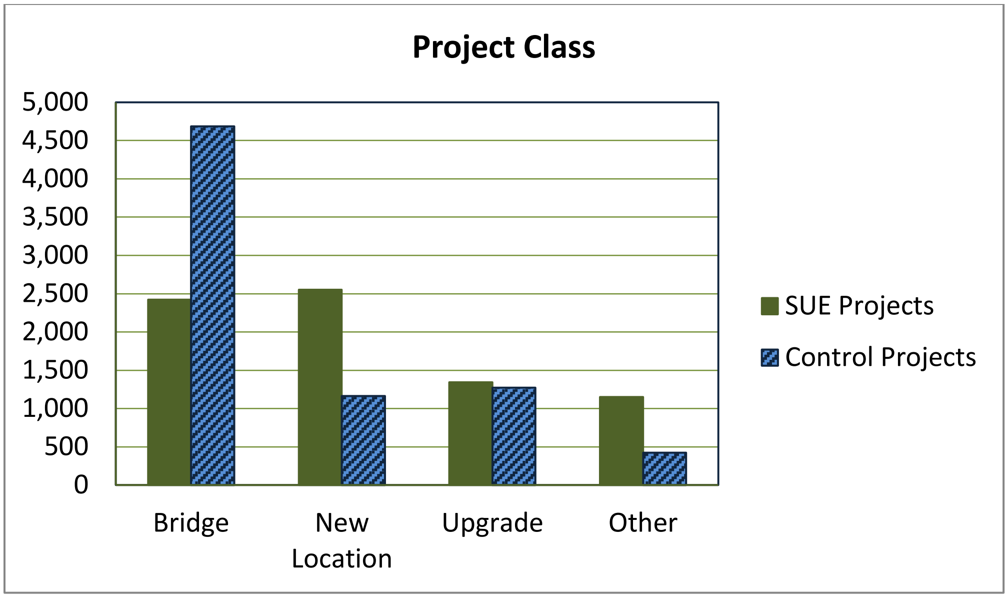

Figure 60. Mean Design Man-Hours per Lane-Mile Project Class.

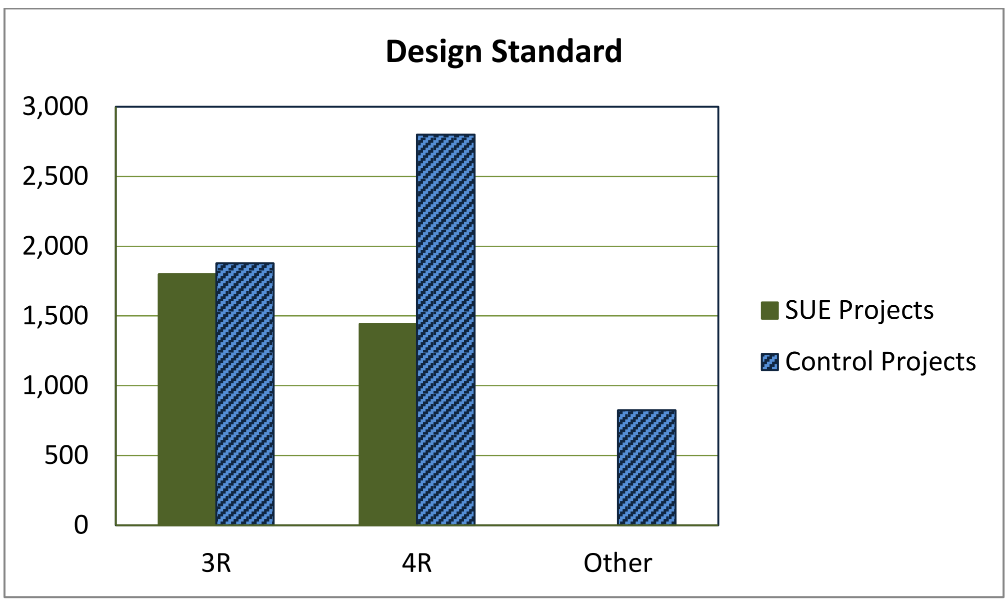

Figure 61. Mean Design Man-Hours per Lane-Mile by Design Standard.

Table 82. T-Test Results for Mean Total Design Man-Hours.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	3	218	0.0855	Yes	0.9587	0.8405
	Urban	23	345	<.0001	Yes	<.0001	**0.0131**
	Total	*26*	*563*				
Project Class	Bridge	7	110	0.2171	No	0.358	0.1959
	New location	2	26	0.2867	No	**0.0859**	0.0004
	Upgrade	8	94	<.0001	Yes	<.0001	**0.0602**
	Other	8	84	0.9862	No	0.1903	0.2038
	Total	*25*	*314*				
Design Standard	3R	4	192	0.7243	No	0.4043	0.4761
	4R	19	236	<.0001	Yes	<.0001	**0.0247**
	Other	3	367	0.8695	No	**<.0001**	0.0107
	Total	*26*	*795*				
All Projects		26	816	<.0001	Yes	<.0001	**0.0071**

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Table 83. T-Test Results for Mean Design Man-Hours per Lane-Mile.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	1	91	-	-	-	-
	Urban	16	139	<.0001	Yes	0.6488	0.297
	Total	*17*	*230*				
Project Class	Bridge	3	78	0.0904	Yes	0.5956	0.1105
	New location	1	15	-	-	-	-
	Upgrade	8	76	0.5639	No	0.8943	0.8767
	Other	4	28	0.0224	Yes	0.1438	0.4464
	Total	*19*	*197*				
Design Standard	3R	4	50	0.5832	No	0.949	0.9331
	4R	13	153	<.0001	Yes	0.3952	**0.0308**
	Other	0	34	-	-	-	-
	Total	*17*	*237*				
All Projects		17	246	<.0001	Yes	0.5438	0.1346

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Project Construction Cost Increase

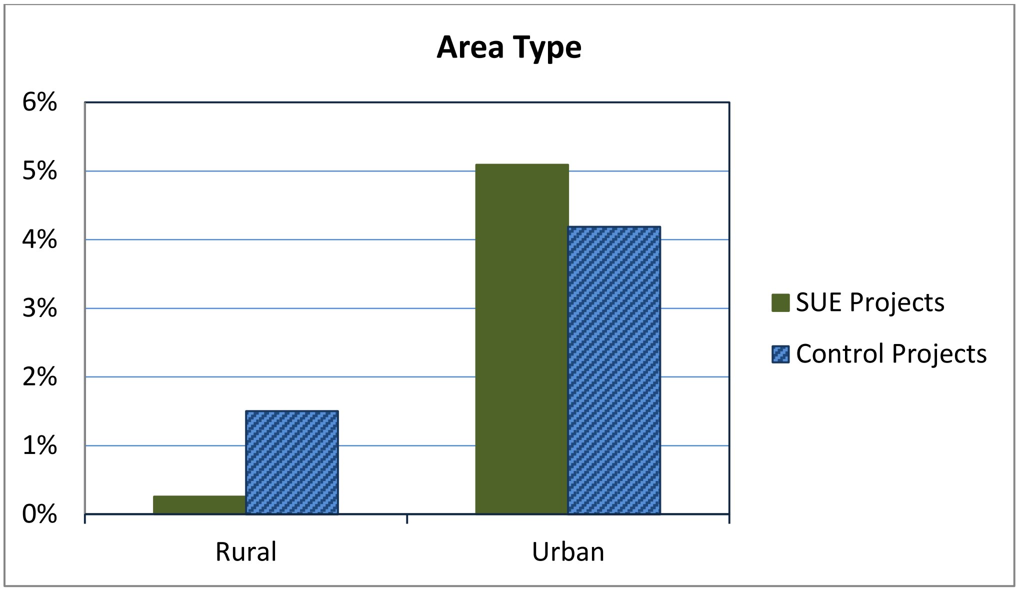

Figure 62. Mean Percent of Construction Cost Increase by Area Type.

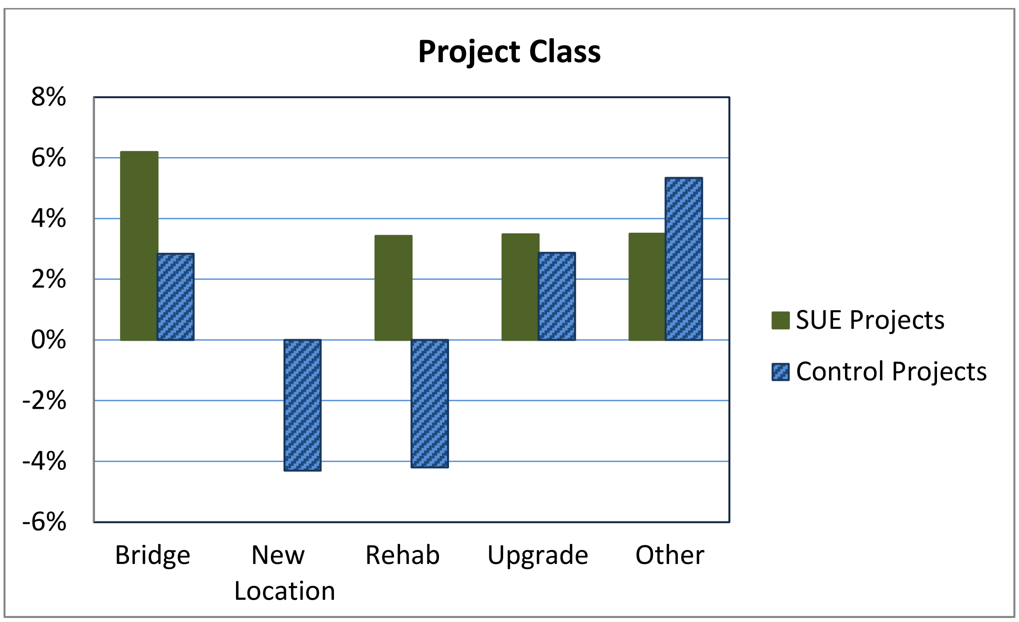

Figure 63. Mean Percent of Construction Cost Increase by Project Class.

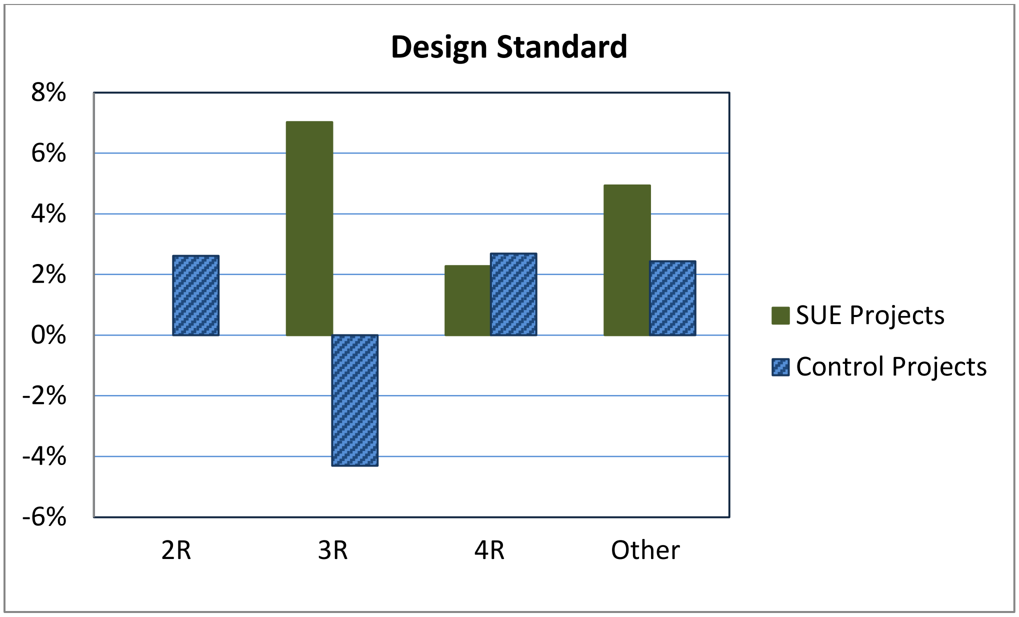

Figure 64. Mean Percent of Construction Cost Increase by Design Standard.

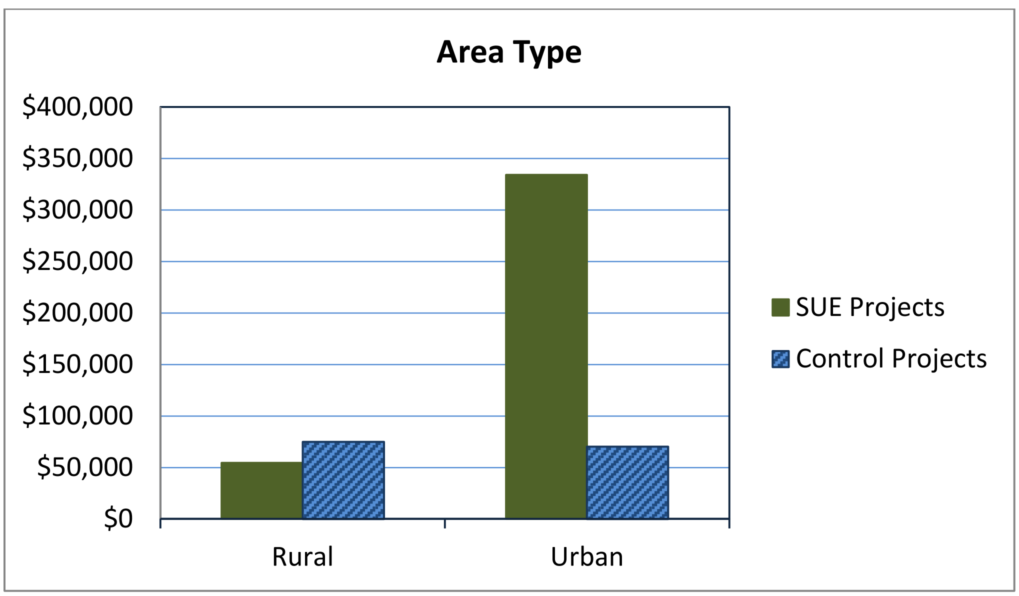

Figure 65. Mean Construction Cost Increase per Lane-Mile by Area Type.

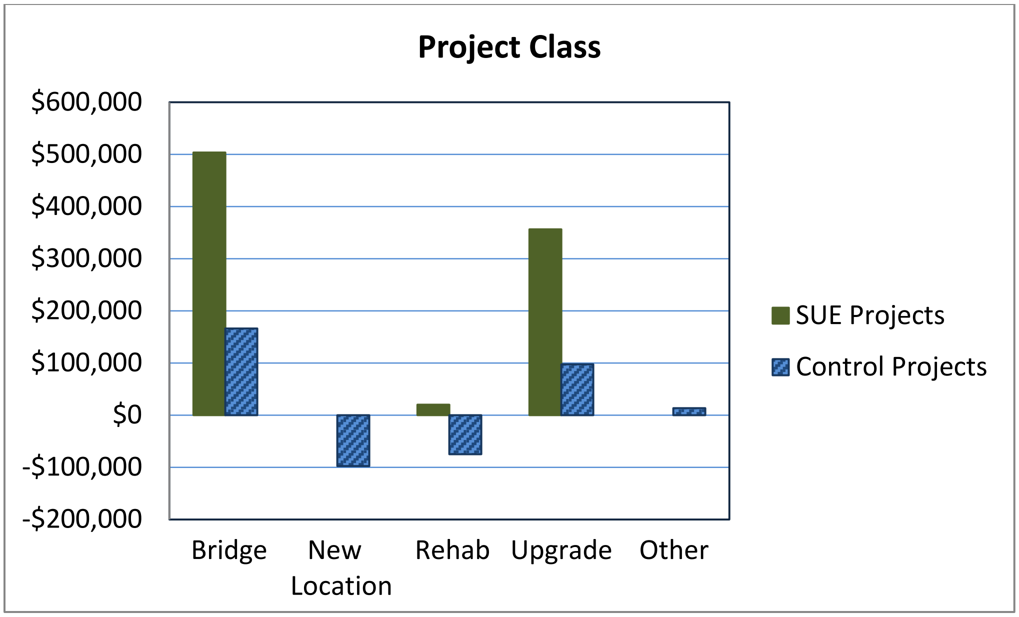

Figure 66. Mean Construction Cost Increase per Lane-Mile by Project Class.

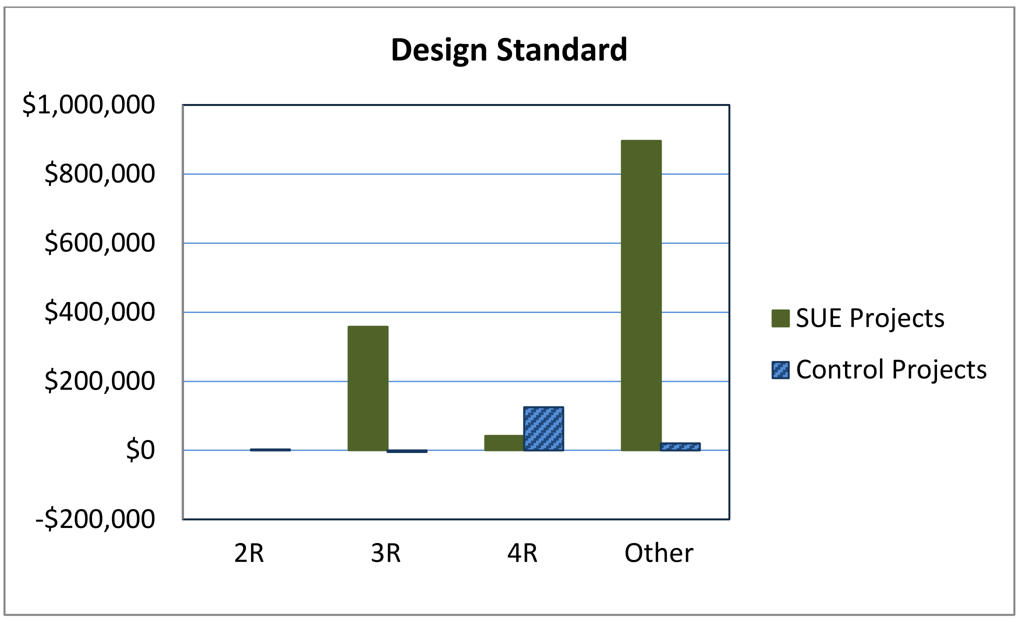

Figure 67. Mean Construction Cost Increase per Lane-Mile by Design Standard.

Table 84. T-Test Results for Mean Percent Construction Cost Increase.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	**Rural**	3	443	0.0088	Yes	0.8426	**0.0834**
	Urban	11	420	0.0144	Yes	0.8277	0.6757
	Total	*14*	*863*				
Project Class	Bridge	3	196	0.3301	No	0.4244	0.6096
	New location	3	99	0.3223	No	0.9232	0.8453
	Upgrade	4	86	0.7404	No	0.8534	0.8675
	Other	4	335	0.1072	No	0.814	0.5594
	Total	*14*	*716*				
Design Standard	3R	3	292	0.6132	No	0.7261	0.6218
	4R	7	318	0.2189	No	0.8716	0.8057
	Other	4	504	0.2826	No	0.762	0.5924
	Total	*14*	*1114*				
All Projects		14	1175	0.0025	Yes	0.7657	0.5353

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Table 85. T-Test Results for Mean Construction Cost Increase per Lane-Mile.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	2	212	0.2287	No	0.9586	0.7912
	Urban	5	144	0.1425	No	**0.0463**	0.2355
	Total	*7*	*356*				
Project Class	Bridge	2	143	0.5063	No	0.3297	0.5473
	New location	3	42	0.0014	Yes	0.8281	0.4157
	Upgrade	2	64	0.5857	No	0.4082	0.5698
	Other	0	23	-	-	-	-
	Total	*7*	*272*				
Design Standard	3R	2	77	1	No	0.3799	0.458
	4R	4	207	0.0026	Yes	0.7338	**0.0559**
	Other	1	79	-	-	-	-
	Total	*7*	*363*				
All Projects		7	385	0.6786	No	0.284	0.2433

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Project Construction Duration

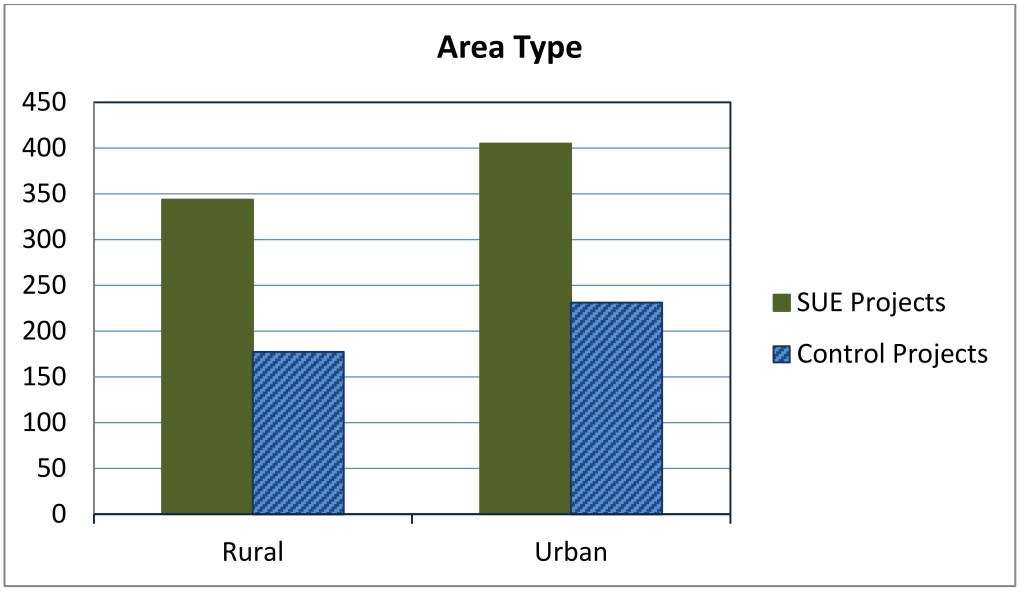

Figure 68. Mean Project Construction Duration (Days) by Area Type.

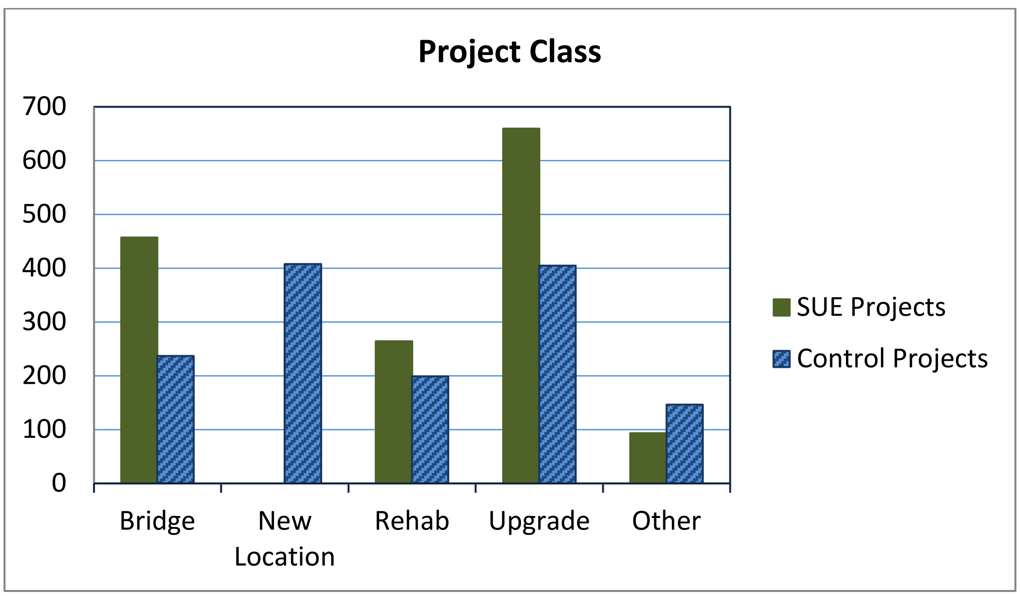

Figure 69. Mean Project Construction Duration (Days) by Project Class.

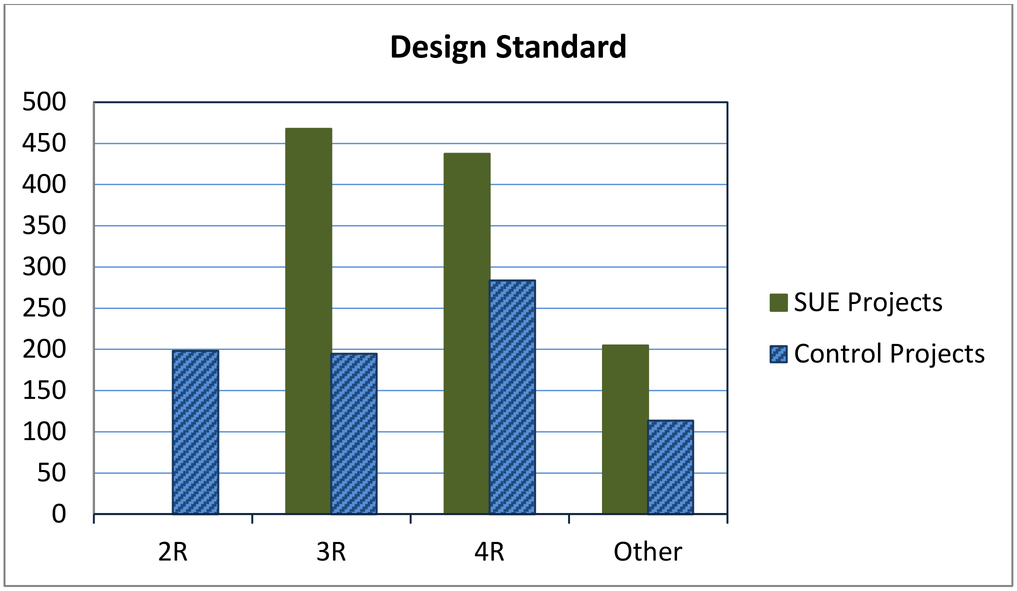

Figure 70. Mean Project Construction Duration (Days) by Design Standard.

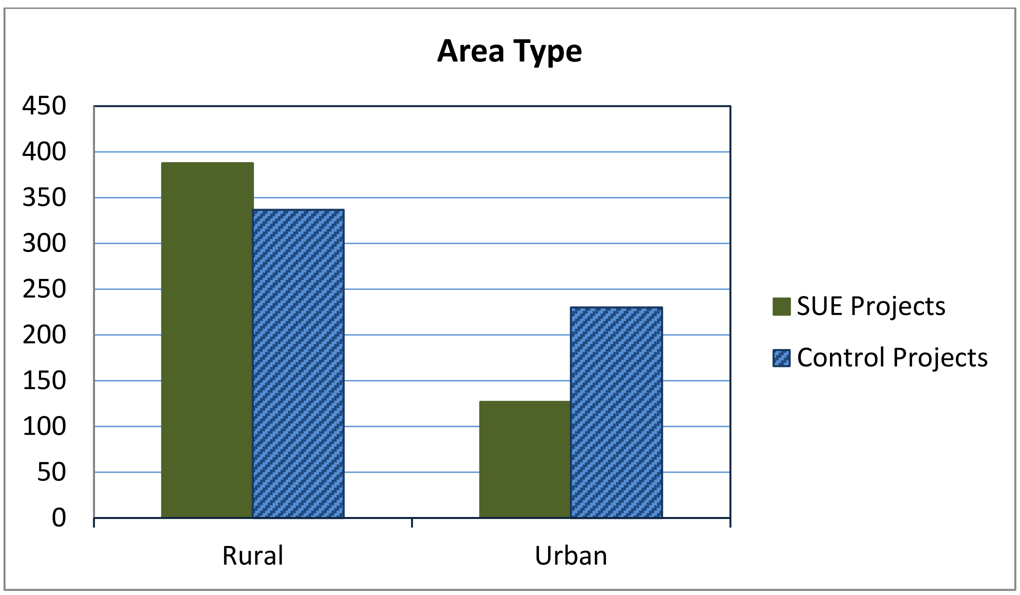

Figure 71. Mean Per-Lane-Mile Construction Duration (Days) by Area Type.

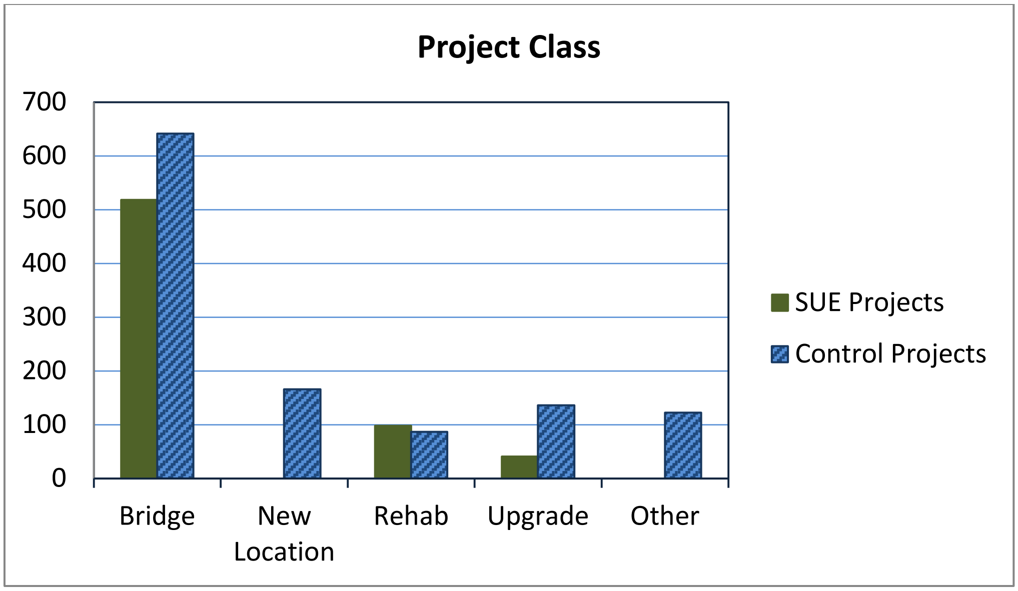

Figure 72. Mean Per-Lane-Mile Construction Duration (Days) by Project Class.

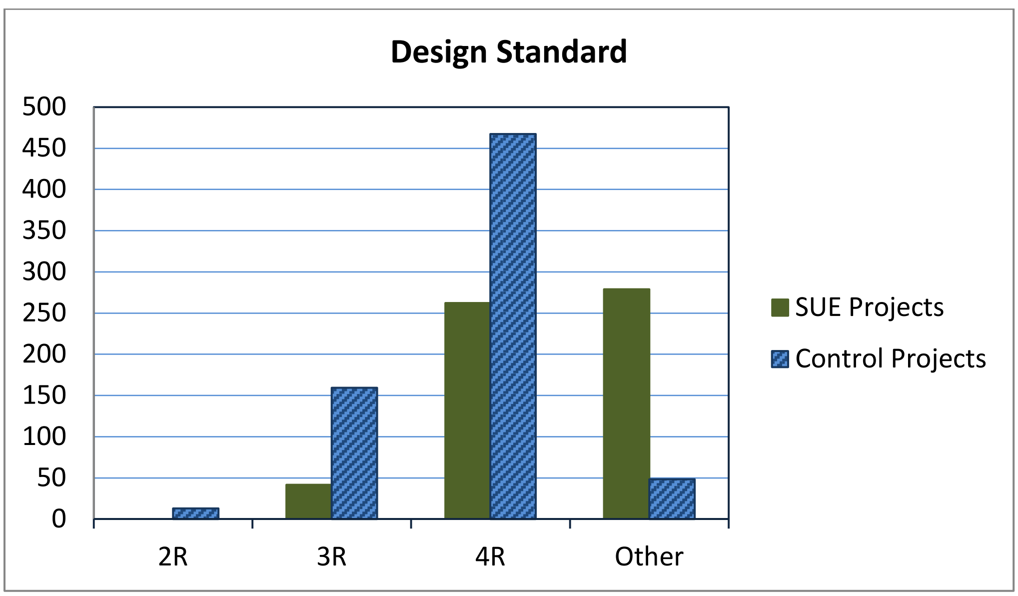

Figure 73. Mean Per-Lane-Mile Construction Duration (Days) by Design Standard.

Table 86. T-Test Results for Mean Project Construction Duration.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	4	454	0.0835	Yes	0.246	0.5313
	Urban	19	449	0.0625	Yes	0.0159	**0.0757**
	Total	*23*	*903*				
Project Class	**Bridge**	7	207	0.7277	No	**0.0222**	0.0671
	New location	5	103	1	No	0.671	0.6778
	Upgrade	8	105	0.0195	Yes	0.492	0.6703
	Other	3	344	0.9018	No	0.5082	0.4821
	Total	*23*	*759*				
Design Standard	3R	4	310	0.0228	Yes	0.0936	0.4413
	4R	17	351	0.0613	Yes	0.1404	0.2726
	Other	4	508	0.0018	Yes	0.0101	0.3476
	Total	*25*	*1169*				
All Projects		25	1230	0.0008	Yes	<.0001	**0.0073**

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Table 87. T-Test Results for Mean Project Construction Duration per Lane-Mile.

Project Category		**Effective Sample Size**		**Equity of Variances**		**T-Test p-Values**	
		SUE	**Control**	**p-Value**	**Reject H_0?**	**Equal**	**Unequal**
Area Type	Rural	2	212	0.5381	No	<u>0.8791</u>	0.9127
	Urban	5	144	0.0426	Yes	0.5245	<u>0.137</u>
	Total	*7*	*356*				
Project Class	Bridge	2	143	1	No	<u>0.717</u>	0.6963
	New location	3	42	0.3631	No	<u>0.9439</u>	0.8978
	Upgrade	2	64	0.0259	Yes	0.5428	<u>**0.0009**</u>
	Other	0	23	-	-	-	-
	Total	*7*	*272*				
Design Standard	**3R**	2	77	<.0001	Yes	0.5938	<u>**0.0013**</u>
	4R	4	207	0.6583	No	<u>0.395</u>	0.3208
	Other	1	79	-	-	-	-
	Total	*7*	*363*				
All Projects		7	385	0.2308	No	<u>0.5692</u>	0.4028

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
<u>Underscored p-Values</u> should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Additional Project Construction Days

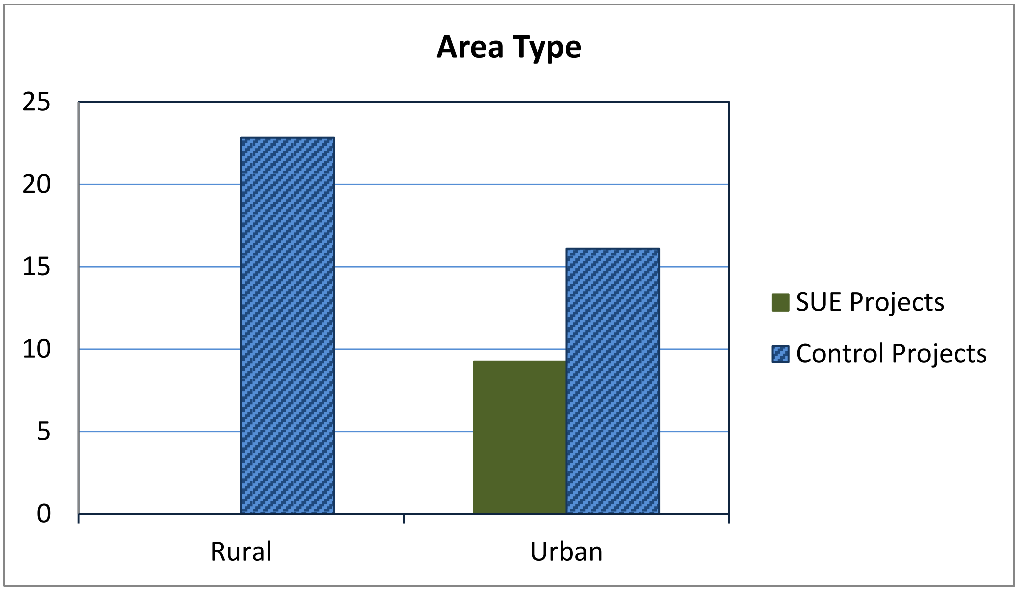

Figure 74. Mean Additional Construction Days per Lane-Mile (Days) by Area Type.

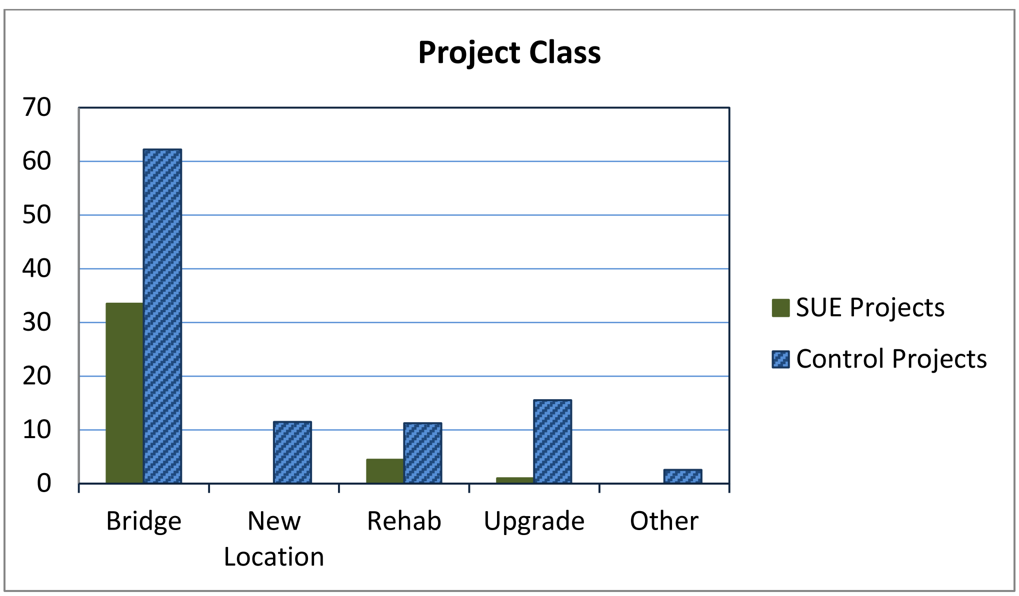

Figure 75. Mean Additional Construction Days per Lane-Mile (Days) by Project Class.

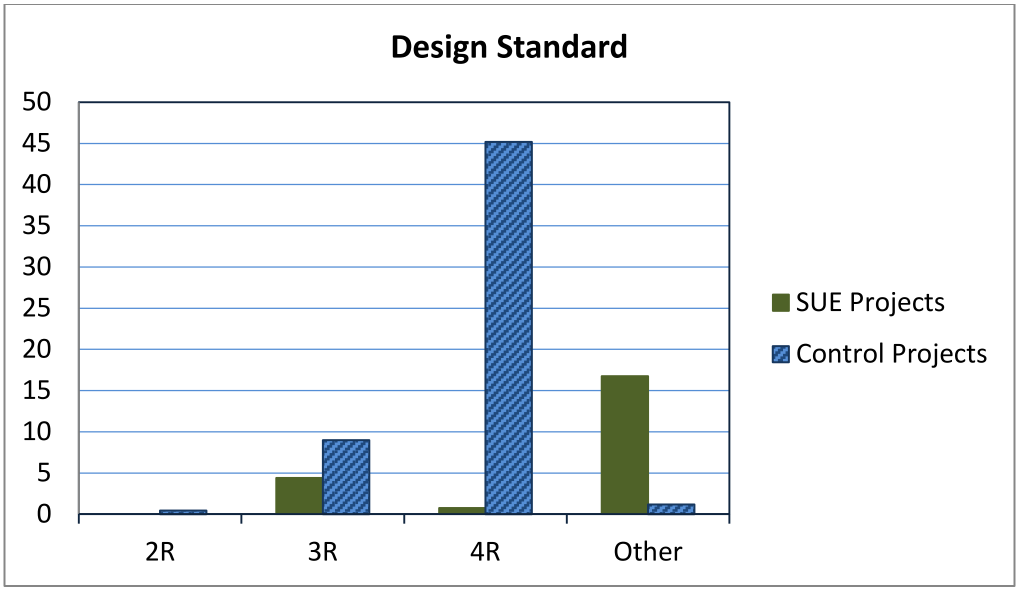

Figure 76. Mean Additional Construction Days per Lane-Mile (Days) by Design Standard.

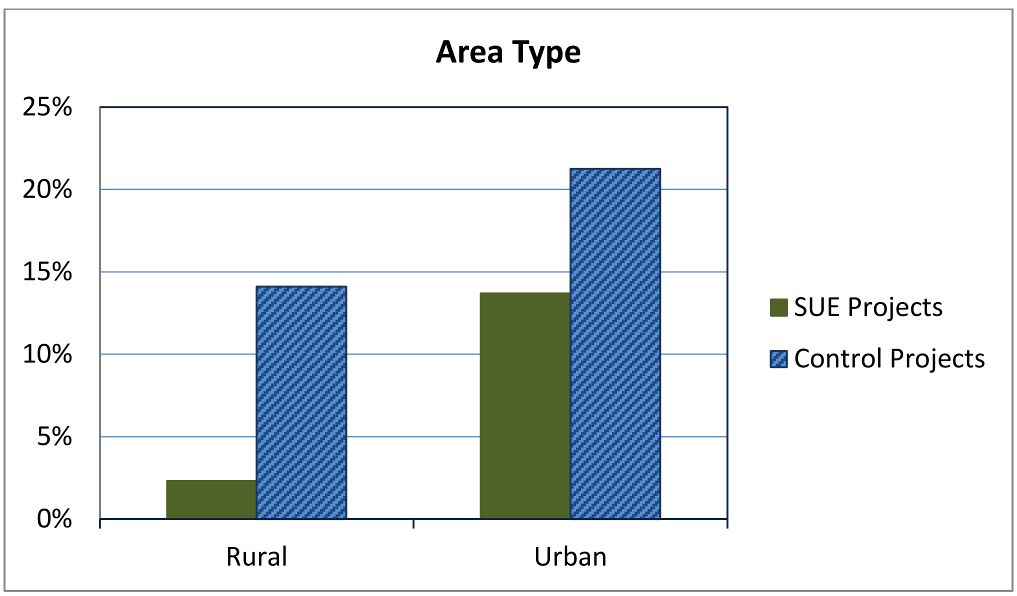

Figure 77. Mean Percent of Additional Construction Days (Days) by Area Type.

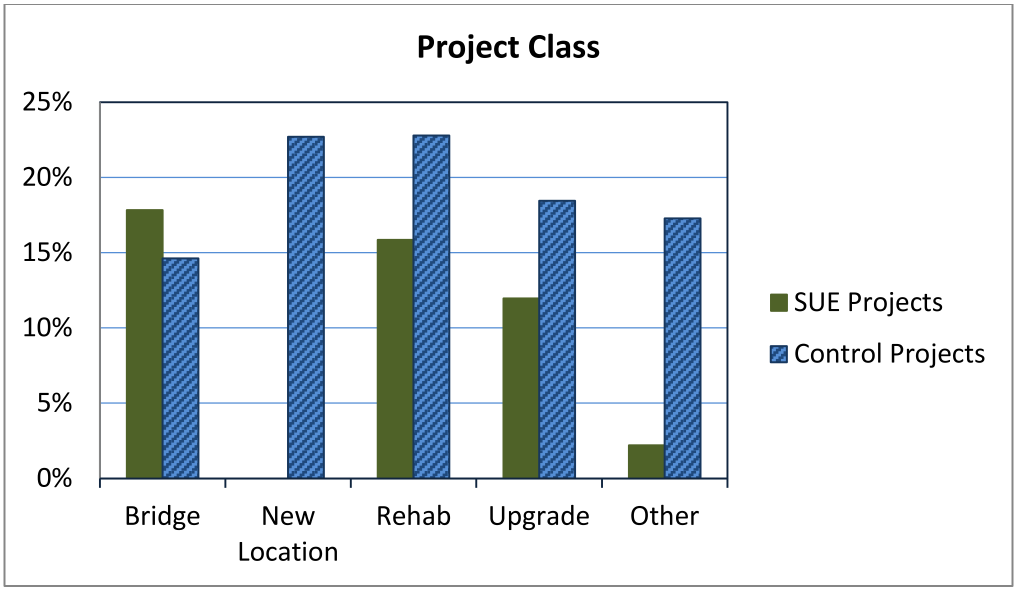

Figure 78. Mean Percent of Additional Construction Days (Days) Project Class.

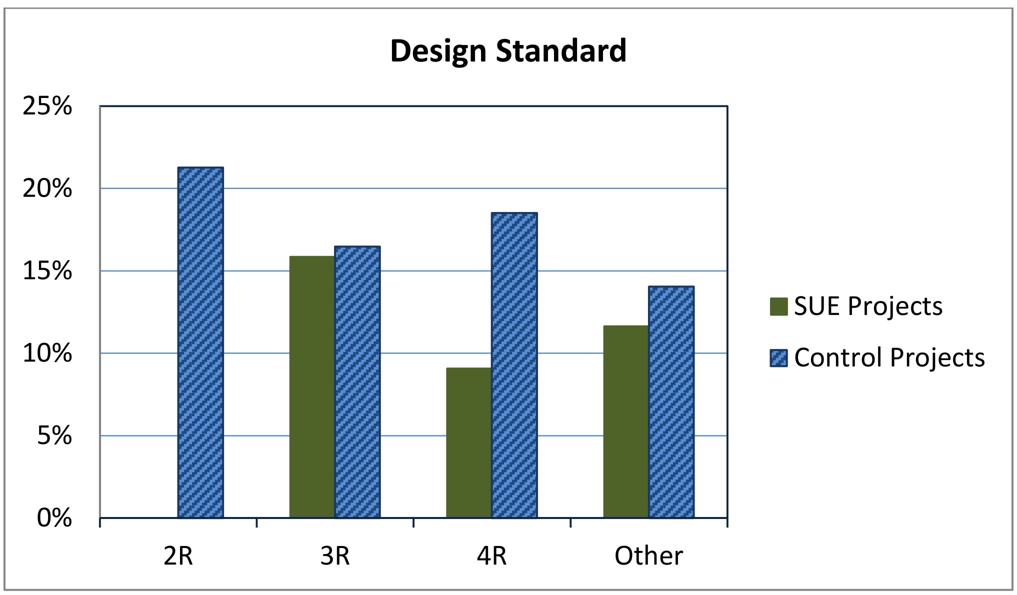

Figure 79. Mean Percent of Additional Construction Days (Days) by Design Standard.

Table 88. T-Test Results for Mean Additional Construction Days per Lane-Mile.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	**Rural**	4	343	<.0001	Yes	0.6255	**<.0001**
	Urban	22	294	0.0005	Yes	0.6274	0.3974
	Total	*26*	*637*				
Project Class	**Bridge**	8	175	0.0035	Yes	0.4927	**0.0909**
	New location	6	70	<.0001	Yes	0.6935	0.2019
	Upgrade	9	88	<.0001	Yes	0.428	**0.0145**
	Other	3	206	<.0001	Yes	0.833	**0.0811**
	Total	*26*	*539*				
Design Standard	3R	5	218	0.002	Yes	0.7512	0.1563
	4R	18	274	<.0001	Yes	0.204	**0.0005**
	Other	5	343	0.5813	No	0.2669	0.3734
	Total	*28*	*835*				
All Projects		28	873	<.0001	Yes	0.5701	0.1553

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Table 89. T-Test Results for Mean Percent Additional Construction Days.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	**Rural**	5	455	0.0014	Yes	0.2212	**<.0001**
	Urban	24	450	<.0001	Yes	0.112	**0.001**
	Total	*29*	*905*				
Project Class	Bridge	9	207	0.1733	No	0.4773	0.3118
	New location	6	103	0.1694	No	0.334	0.1411
	Upgrade	10	106	0.0456	Yes	0.1279	**0.0226**
	Other	4	345	0.004	Yes	0.4497	**0.0005**
	Total	*29*	*761*				
Design Standard	3R	5	312	0.3475	No	0.7	0.5668
	4R	21	353	<.0001	Yes	0.0718	**<.0001**
	Other	6	508	0.4745	No	0.8171	0.7621
	Total	*32*	*1173*				
All Projects		32	1234	<.0001	Yes	0.1006	**0.0011**

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Utility-Related Change Order Cost

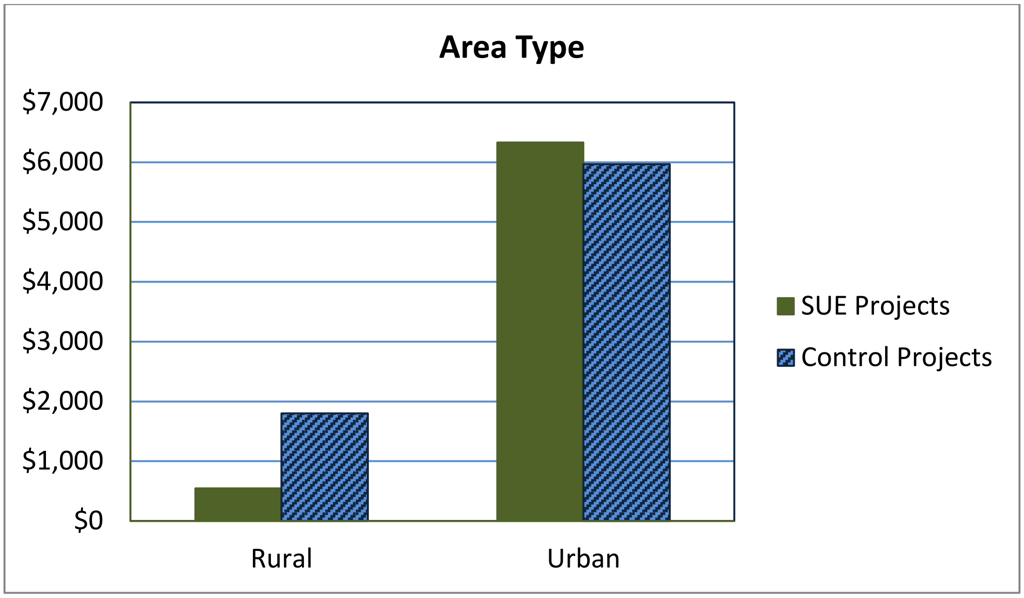

Figure 80. Mean Utility-Related Change Order Cost per Project by Area Type.

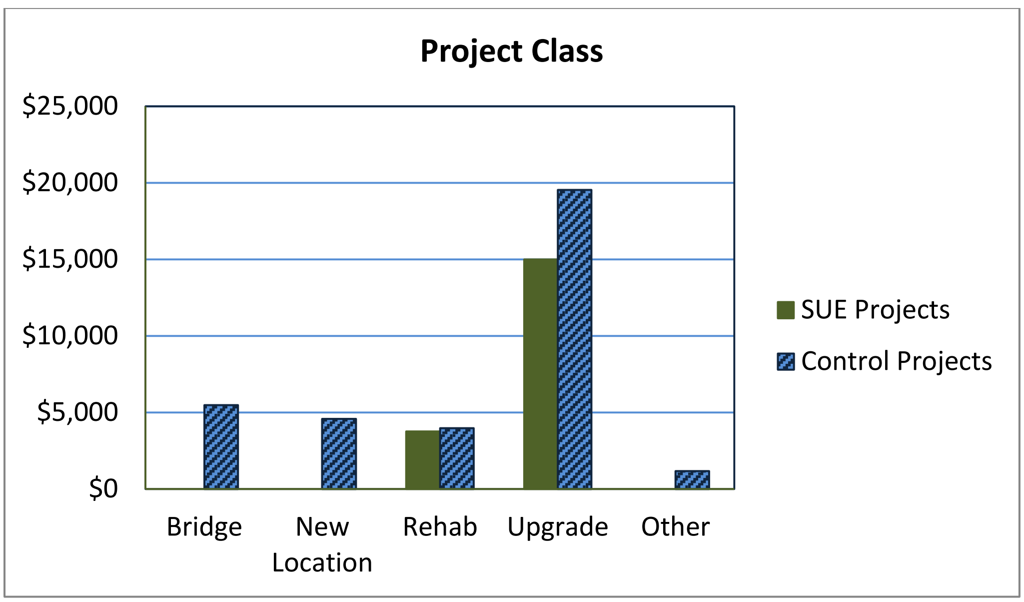

Figure 81. Mean Utility-Related Change Order Cost per Project by Project Class.

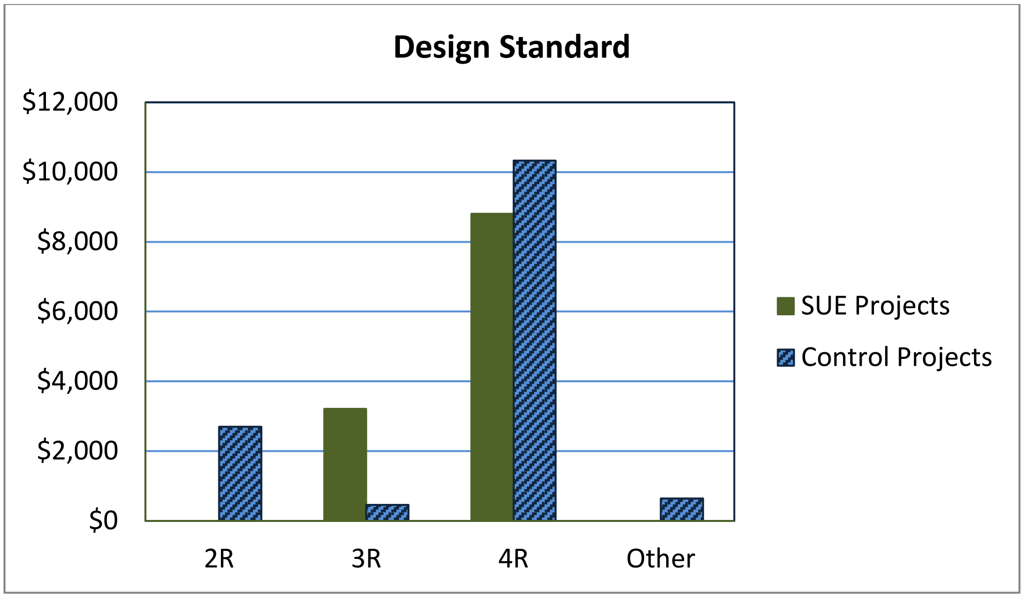

Figure 82. Mean Utility-Related Change Order Cost per Project by Design Standard.

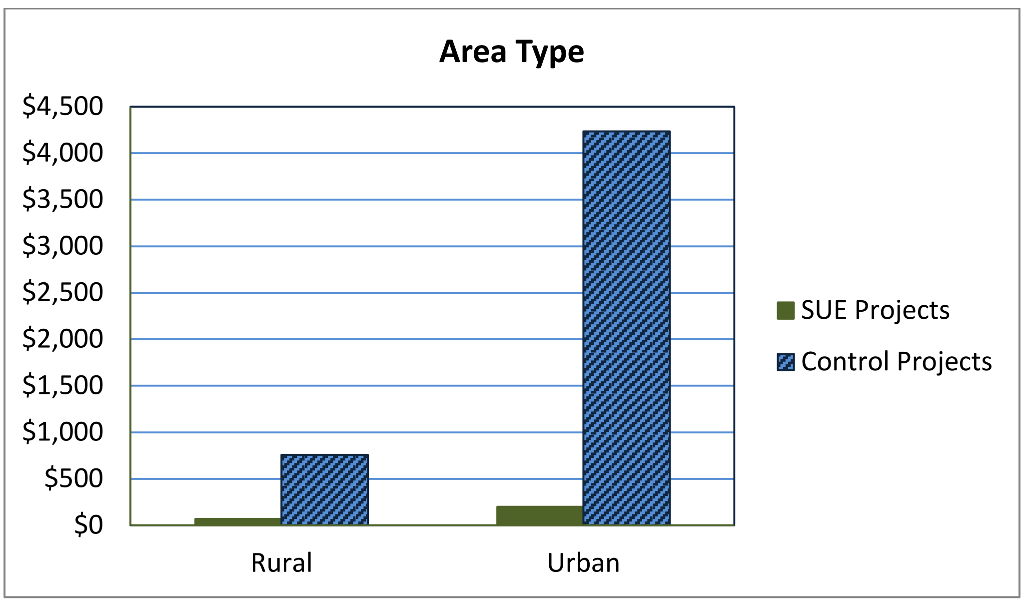

Figure 83. Mean Utility-Related Change Order Cost per Lane-Mile by Area Type.

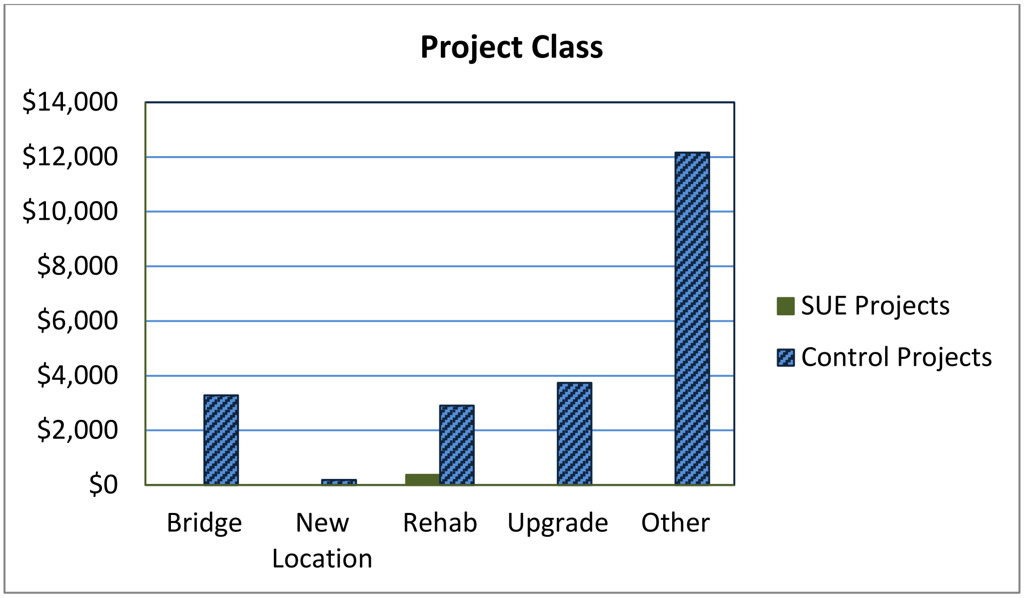

Figure 84. Mean Utility-Related Change Order Cost per Lane-Mile by Project Class.

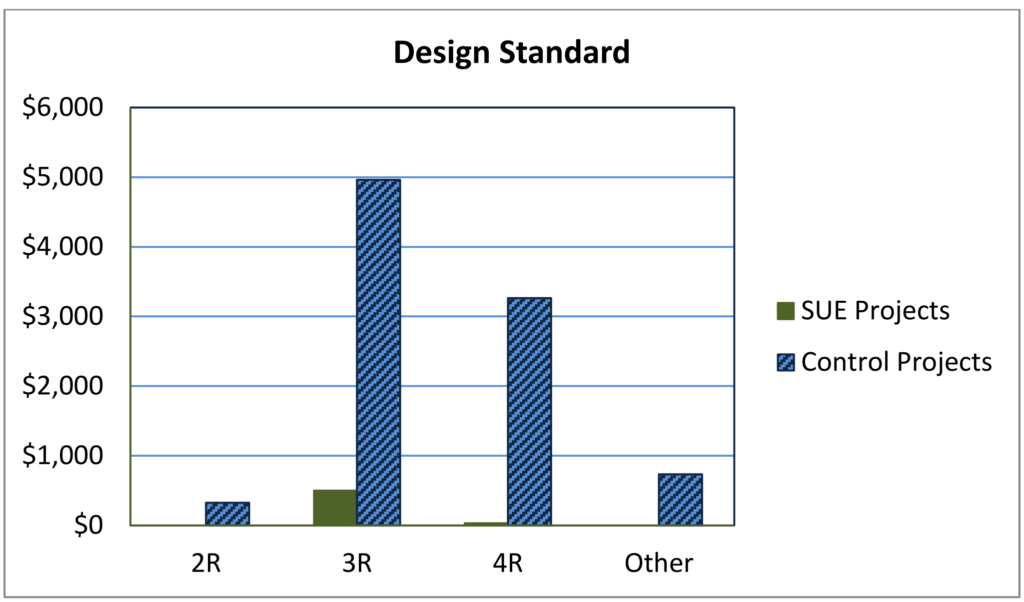

Figure 85. Mean Utility-Related Change Order Cost per Lane-Mile by Design Standard.

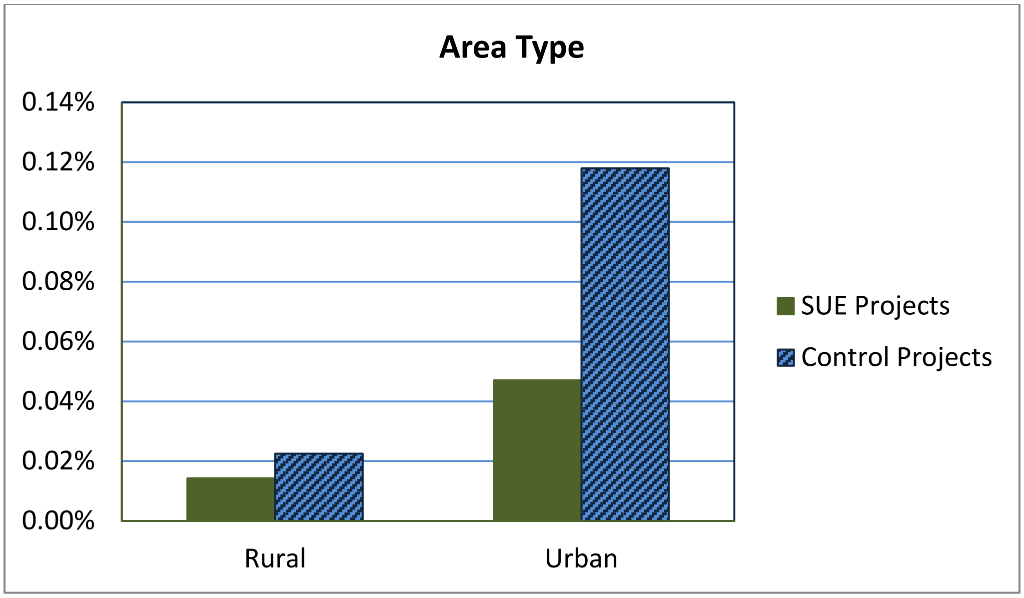

Figure 86. Mean Percent of Change Order Amount in Construction Cost by Area Type.

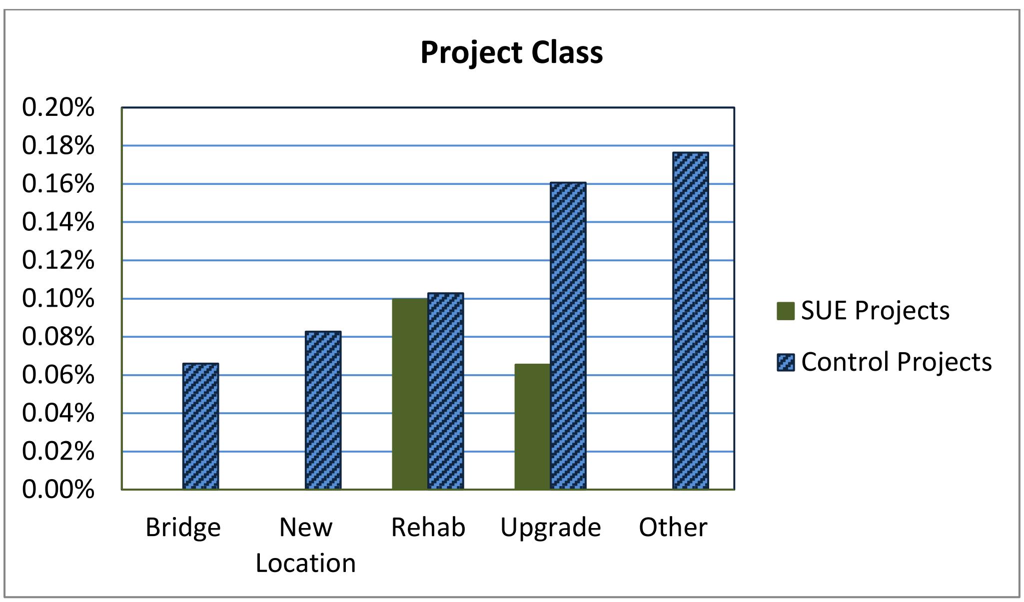

Figure 87. Mean Percent of Change Order Amount in Construction Cost by Project Class.

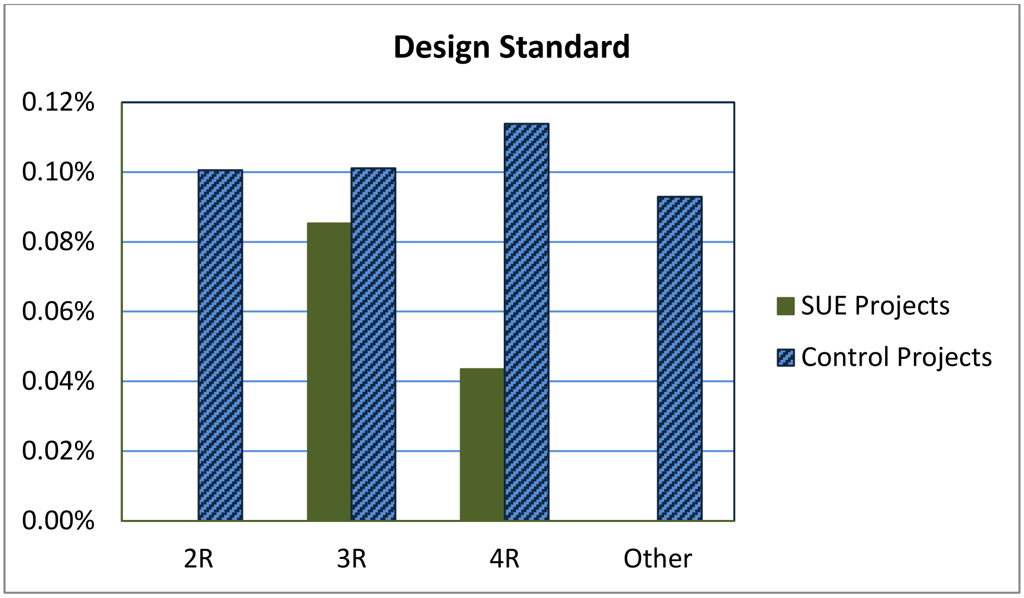

Figure 88. Mean Percent of Change Order Amount in Construction Cost by Design Standard.

Table 90. T-Test Results for Mean Utility-Related Change Order Amounts.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	3	443	0.0029	Yes	0.9302	0.3379
	Urban	11	420	0.0006	Yes	0.9821	0.9526
	Total	*14*	*863*				
Project Class	**Bridge**	3	196	<.0001	Yes	0.8143	**0.0582**
	New location	3	99	0.1544	No	0.9842	0.9553
	Upgrade	4	86	0.0493	Yes	0.9365	0.8202
	Other	4	335	<.0001	Yes	0.9238	0.3808
	Total	*14*	*716*				
Design Standard	3R	3	292	0.0319	Yes	0.9136	0.5306
	4R	7	318	0.022	Yes	0.945	0.8715
	Other	4	508	<.0001	Yes	<.0001	0.3212
	Total	*14*	*1118*				
All Projects		14	1175	0.001	Yes	0.8622	0.695

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Table 91. T-Test Results for Mean Utility-Related Change Order Amounts per Lane-Mile.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	**Rural**	2	212	0.0314	Yes	0.8439	**0.0478**
	Urban	5	144	<.0001	Yes	0.7752	0.1268
	Total	*7*	*356*				
Project Class	**Bridge**	2	143	<.0001	Yes	0.8091	**0.0419**
	New location	3	42	0.0045	Yes	0.7065	0.1654
	Upgrade	2	64	<.0001	Yes	0.9	0.4749
	Other	0	23	-	-	-	-
	Total	*7*	*272*				
Design Standard	3R	2	77	0.0267	Yes	0.8827	0.3609
	4R	4	207	<.0001	Yes	0.7013	**0.0062**
	Other	1	79	-	-	-	-
	Total	*7*	*363*				
All Projects		7	385	<.0001	Yes	0.7486	**0.0186**

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Table 92. T-Test Results for Mean Utility-Related Change Order Amounts per Construction Cost.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	3	443	0.0071	Yes	0.9725	0.7387
	Urban	11	420	<.0001	Yes	0.8235	0.242
	Total	*14*	*863*				
Project Class	**Bridge**	**3**	**196**	**<.0001**	**Yes**	**0.7911**	**0.0329**
	New location	3	99	0.1428	No	0.9911	0.9739
	Upgrade	4	86	0.001	Yes	0.9174	0.6466
	Other	4	335	<.0001	Yes	0.8575	0.1006
	Total	*14*	*716*				
Design Standard	3R	3	292	0.0274	Yes	0.9827	0.8934
	4R	7	318	0.0002	Yes	0.7512	0.1701
	Other	4	504	<.0001	Yes	0.9022	0.1678
	Total	*14*	*1114*				
All Projects		14	1175	<.0001	Yes	0.851	0.1621

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Project Utility Agreement Amount

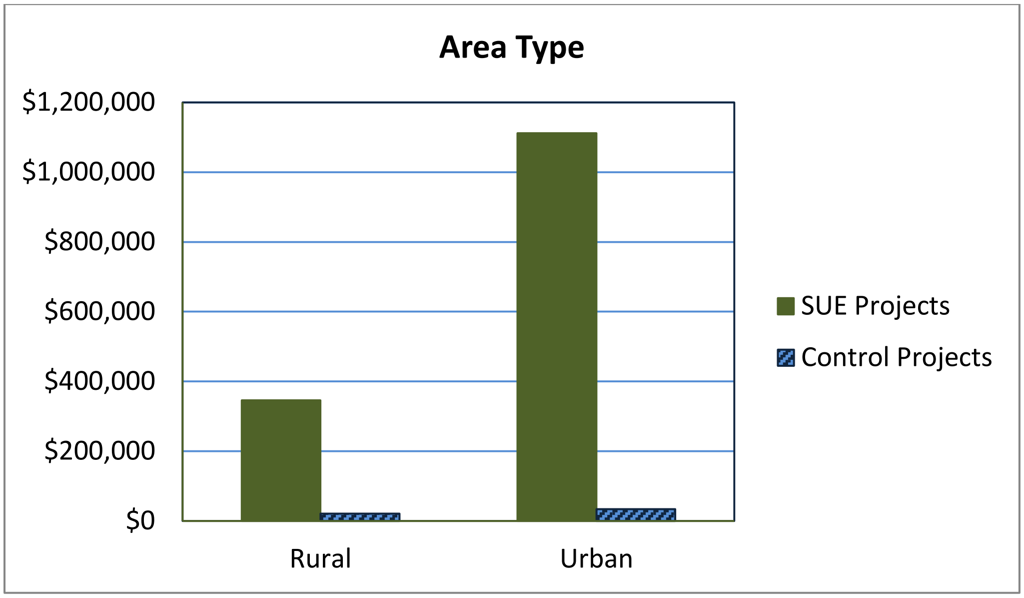

Figure 89. Mean Total Agreement Amount per Project (2011 Dollars) by Area Type.

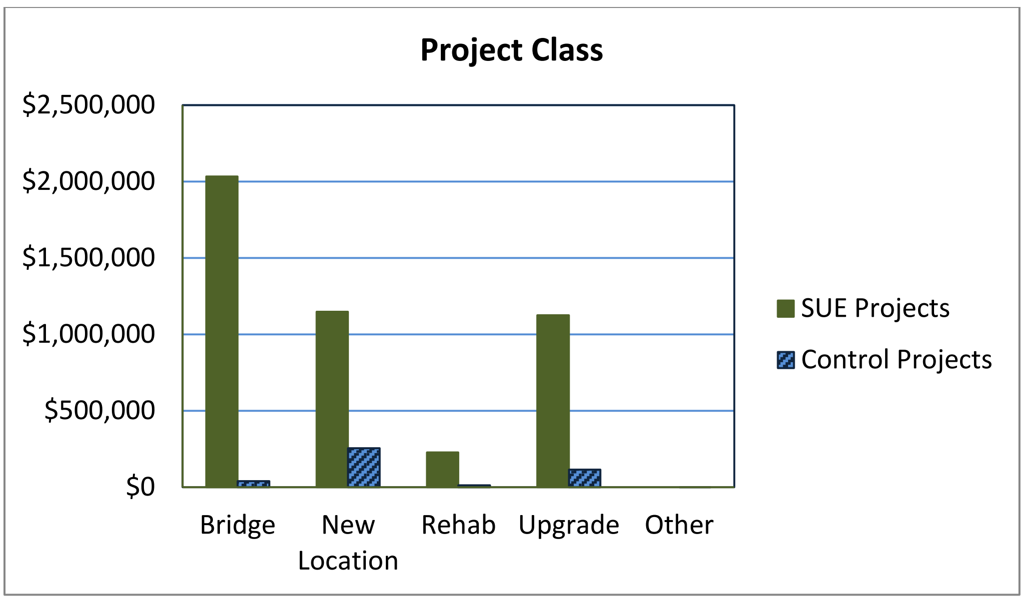

Figure 90. Mean Total Agreement Amount per Project (2011 Dollars) by Project Class.

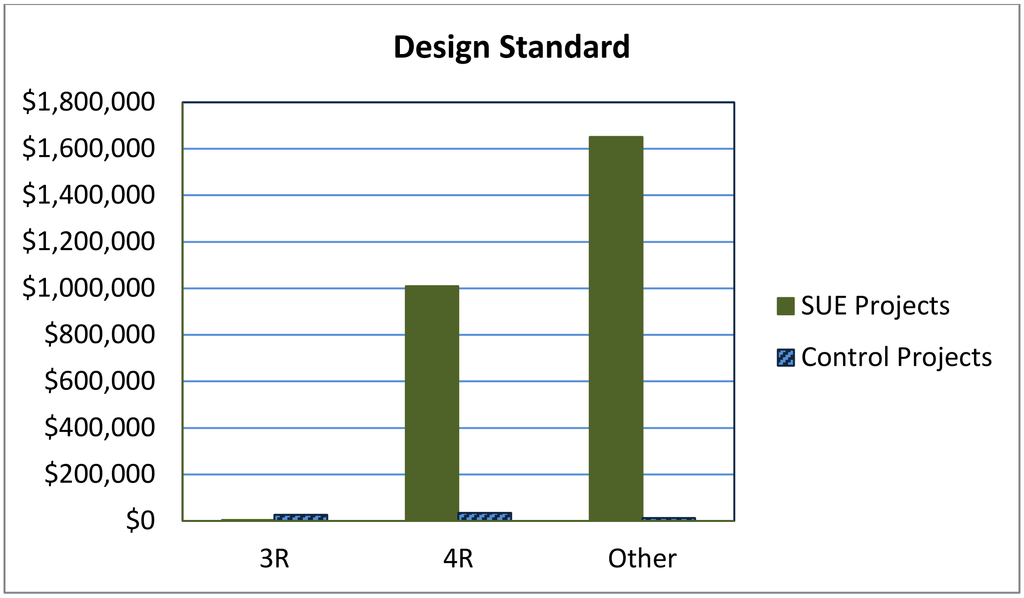

Figure 91. Mean Total Agreement Amount per Project (2011 Dollars) by Design Standard.

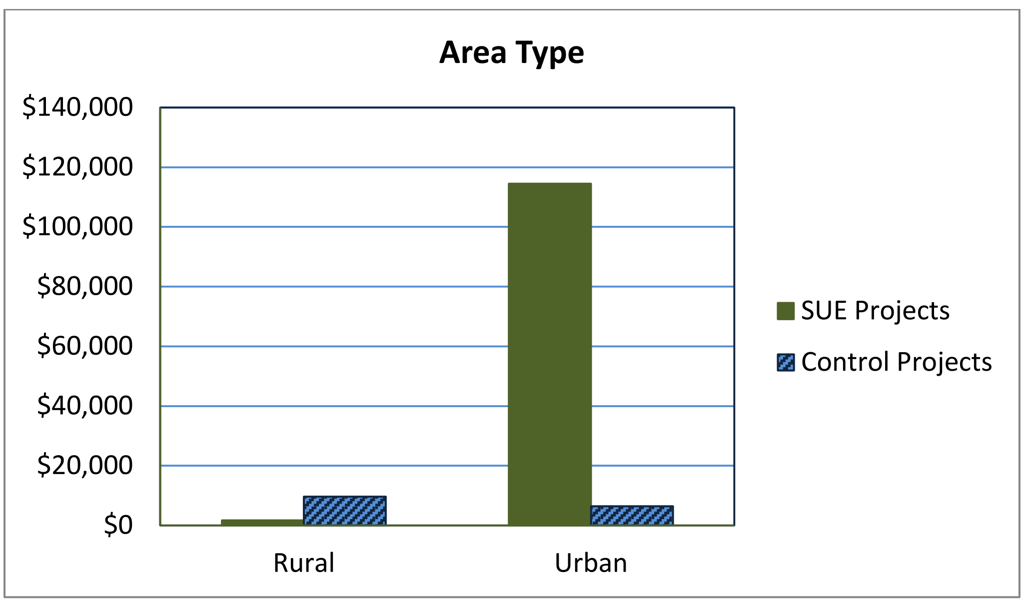

Figure 92. Mean Agreement Amount per Lane-Mile (2011 Dollars) by Area Type.

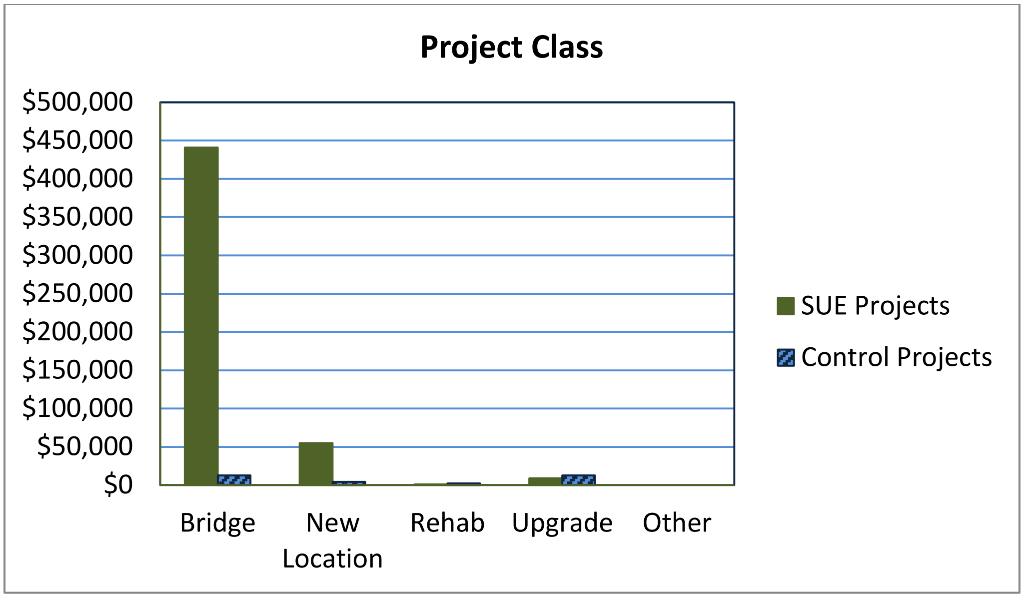

Figure 93. Mean Agreement Amount per Lane-Mile (2011 Dollars) by Project Class.

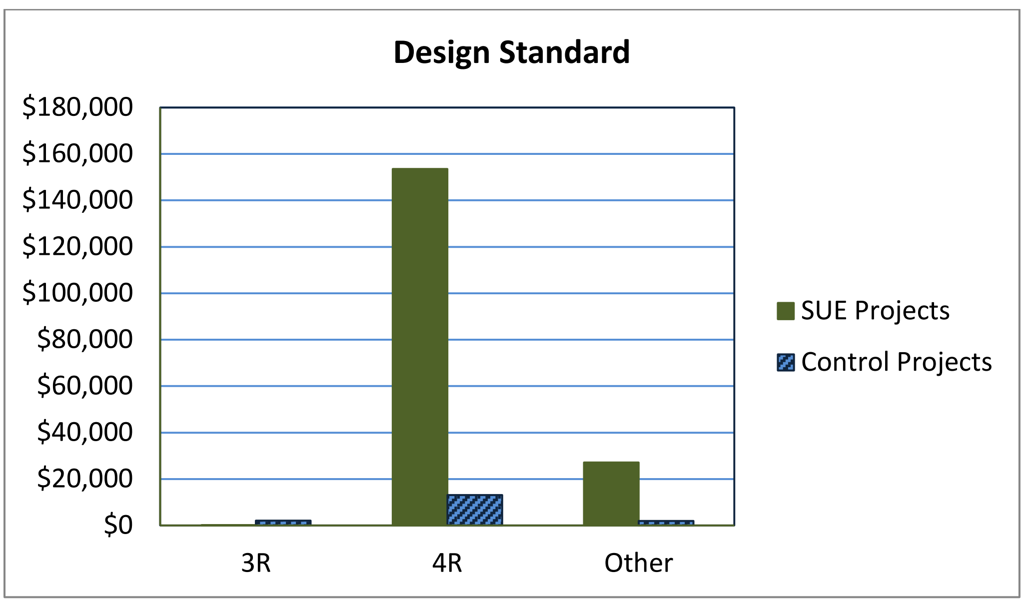

Figure 94. Mean Agreement Amount per Lane-Mile (2011 Dollars) by Design Standard.

Table 93. T-Test Results for Mean Agreement Amount per Project.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	4	507	<.0001	Yes	0.0005	0.4127
	Urban	27	650	<.0001	Yes	<.0001	**0.0379**
	Total	*31*	*1157*				
Project Class	**Bridge**	7	211	<.0001	Yes	<.0001	**0.1**
	New location	2	39	0.4157	No	0.1431	0.4365
	Rehabilitate	6	118	<.0001	Yes	0.0003	0.3872
	Upgrade	12	136	<.0001	Yes	0.0341	0.298
	Other	4	628	<.0001	Yes	0.9071	0.1438
	Total	*31*	*504*				
Design Standard	3R	5	450	<.0001	Yes	0.8534	0.1006
	4R	18	365	<.0001	Yes	<.0001	**0.0438**
	Other	8	1101	<.0001	Yes	<.0001	0.2687
	Total	*31*	*1916*				
All Projects		31	1969	<.0001	No	**<.0001**	0.0286

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Table 94. T-Test Results for Mean Agreement Amount per Project Lane-Mile.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	**Control**	**p-Value**	**Reject H_0?**	**Equal**	**Unequal**
Area Type	Rural	3	206	0.003	Yes	0.8618	0.1704
	Urban	17	208	<.0001	Yes	0.0007	0.3093
	Total	*20*	*414*				
Project Class	Bridge	4	151	<.0001	Yes	<.0001	0.4003
	New location	2	17	<.0001	Yes	0.002	0.4769
	Rehabilitate	6	50	0.0007	Yes	0.7872	0.4767
	Upgrade	8	103	0.0026	Yes	0.8931	0.7442
	Other	0	25	-	-	-	-
	Total	*20*	*346*				
Design Standard	**3R**	4	76	0.0003	Yes	0.6089	**0.0304**
	4R	12	233	<.0001	Yes	0.0007	0.3565
	Other	4	116	<.0001	Yes	0.0002	0.385
	Total	*20*	*425*				
All Projects		20	442	<.0001	Yes	0.0001	0.3177

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Project Utility Agreements

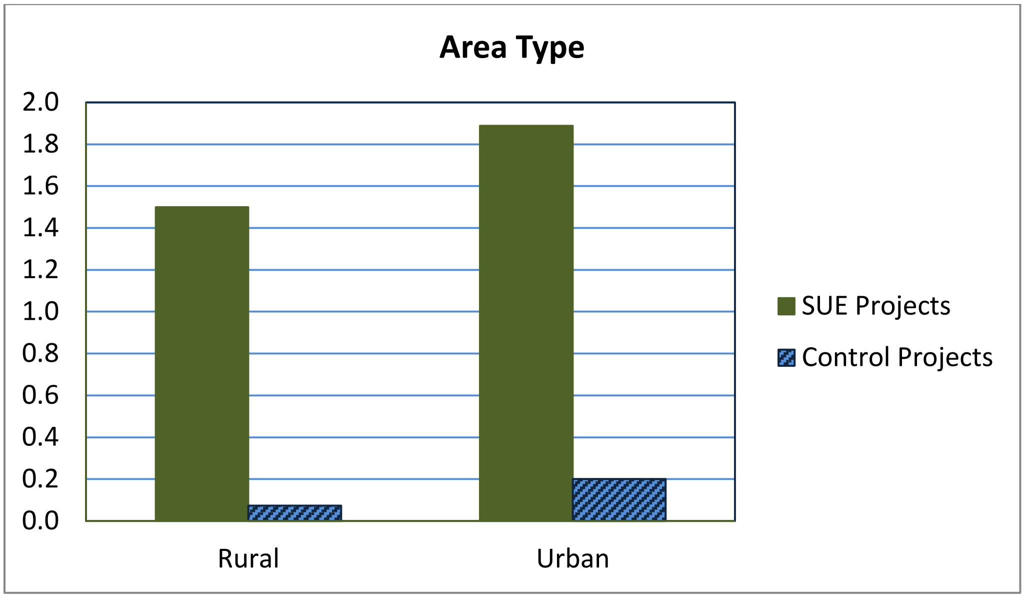

Figure 95. Mean Number of Reimbursable Utility Agreements per Project by Area Type.

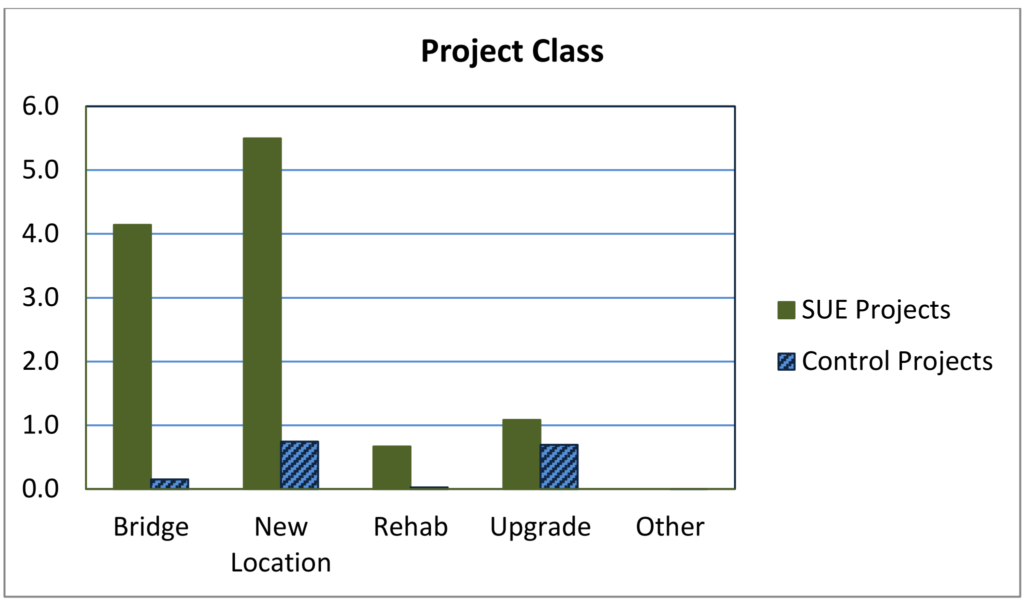

Figure 96. Mean Number of Reimbursable Utility Agreements per Project by Project Class.

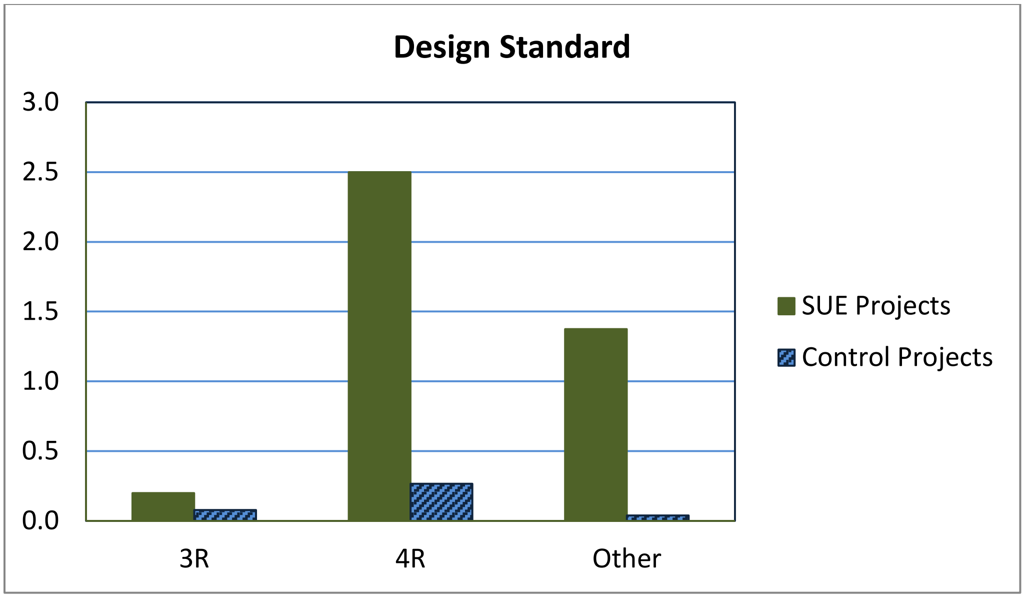

Figure 97. Mean Number of Reimbursable Utility Agreements per Project by Design Standard.

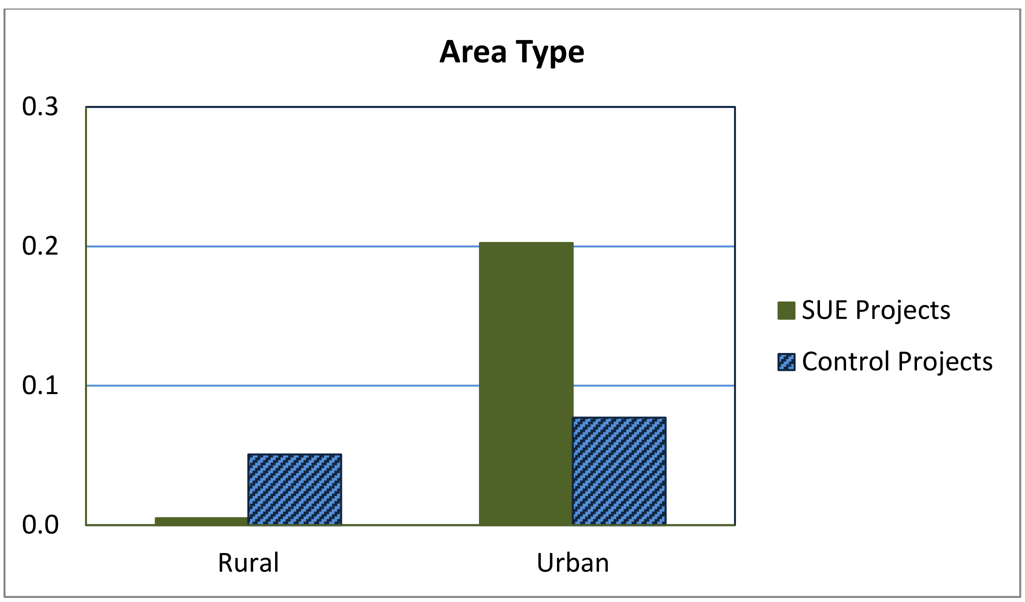

Figure 98. Mean Number of Reimbursable Utility Agreements per Lane-Mile by Area Type.

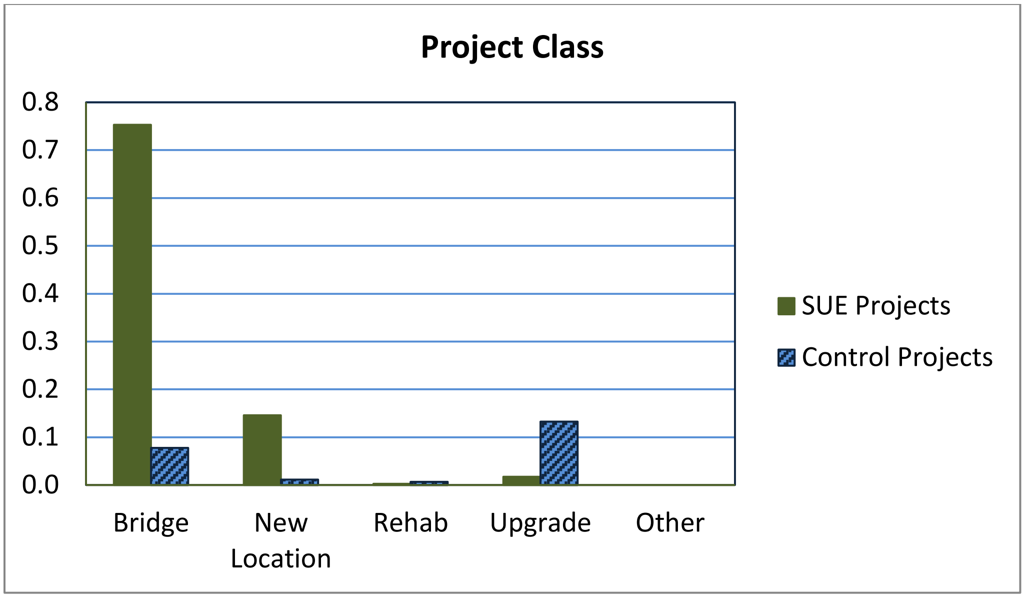

Figure 99. Mean Number of Reimbursable Utility Agreements per Lane-Mile by Project Class.

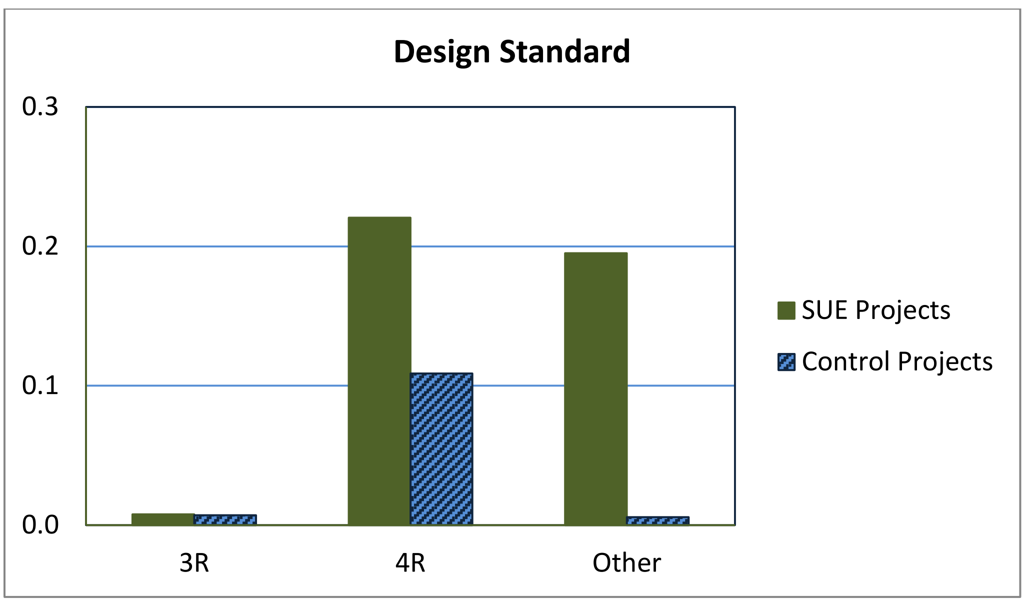

Figure 100. Mean Number of Reimbursable Utility Agreements per Lane-Mile by Design Standard.

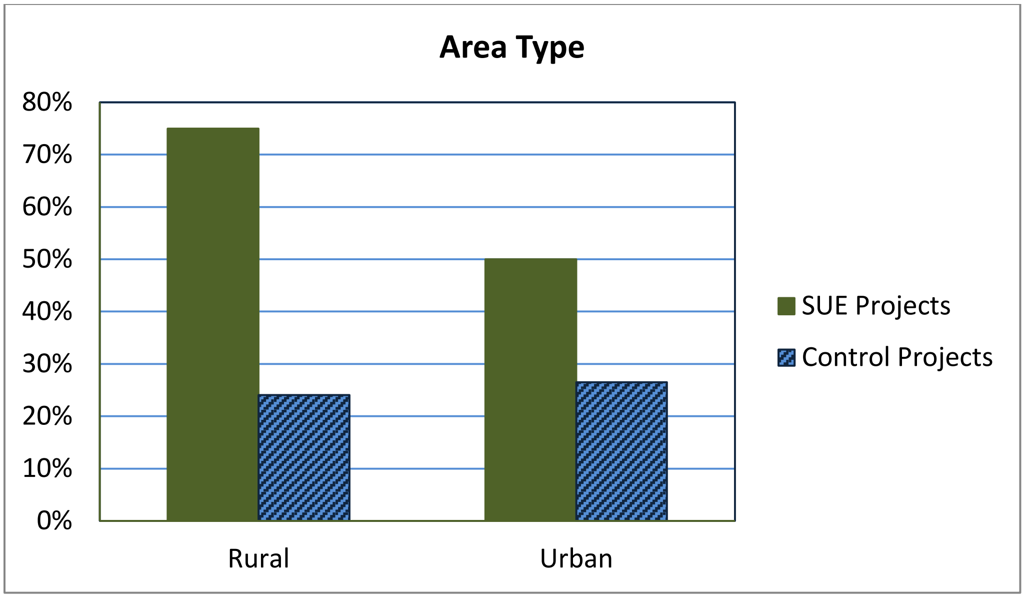

Figure 101. Mean Percent of Agreement Not Needed by Number by Area Type.

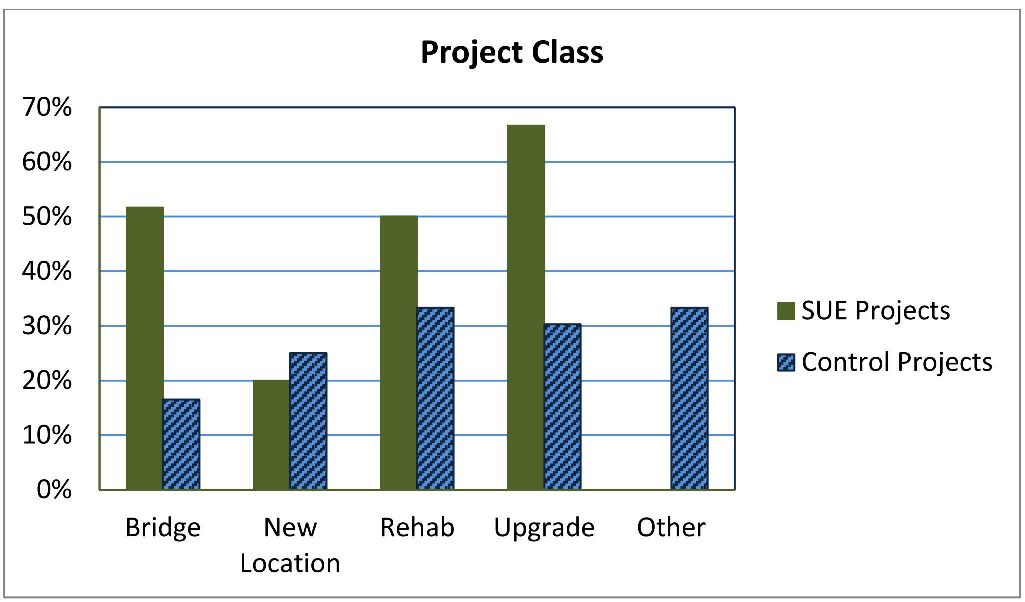

Figure 102. Mean Percent of Agreement Not Needed by Number by Project Class.

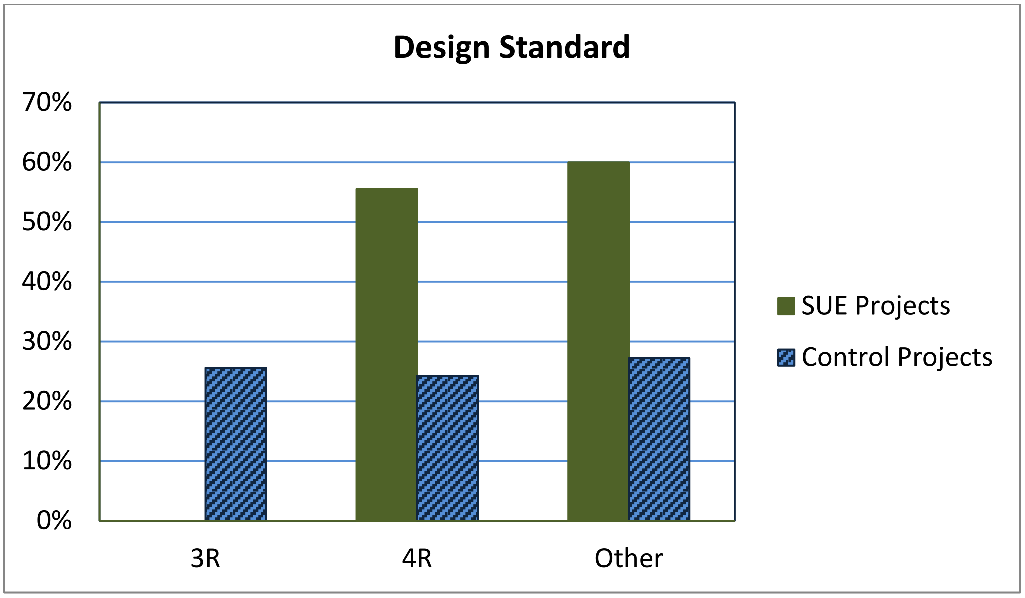

Figure 103. Mean Percent of Agreement Not Needed by Number by Design Standard.

Table 95. T-Test Results for Mean Number of Agreements per Project.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	4	507	<.0001	Yes	<.0001	0.2329
	Urban	27	650	<.0001	Yes	<.0001	**0.0108**
	Total	*31*	*1157*				
Project Class	**Bridge**	7	211	<.0001	Yes	<.0001	**0.0449**
	New location	2	39	0.0042	Yes	0.0042	0.4818
	Rehabilitate	6	118	<.0001	Yes	<.0001	0.3804
	Upgrade	12	136	0.3905	No	0.4887	0.412
	Other	4	628	<.0001	Yes	0.89	**0.0833**
	Total	*31*	*1132*				
Design Standard	3R	5	450	0.2594	No	0.7338	0.5785
	4R	18	365	<.0001	Yes	<.0001	**0.0203**
	Other	8	1101	<.0001	Yes	<.0001	**0.0599**
	Total	*31*	*1916*				
All Projects		31	1969	<.0001	Yes	<.0001	**0.0032**

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Table 96. T-Test Results for Mean Number of Agreements per Project Lane-Mile.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	**Rural**	3	206	0.001	Yes	0.8388	**0.0979**
	Urban	17	208	0.1505	No	0.5412	0.4354
	Total	*20*	*414*				
Project Class	Bridge	4	151	0.0016	Yes	0.0103	0.3381
	New location	2	17	<.0001	Yes	0.0004	0.4196
	Rehabilitate	6	50	0.0008	Yes	0.7913	0.4888
	Upgrade	8	103	<.0001	Yes	0.7778	0.3123
	Other	0	25	-	-	-	-
	Total	*20*	*346*				
Design Standard	3R	4	76	0.4649	No	0.9577	0.9387
	4R	12	233	0.5237	No	0.6582	0.6117
	Other	4	116	<.0001	Yes	<.0001	0.2008
	Total	*20*	*425*				
All Projects		20	442	0.596	No	0.4283	0.391

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Table 97. T-Test Results for Mean Percent of Agreements Not Needed.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	2	19	1	No	<u>0.112</u>	0.2594
	Urban	13	39	0.1134	No	**<u>0.0452</u>**	0.1013
	Total	*15*	*58*				
Project Class	Bridge	6	11	0.0761	Yes	0.0407	<u>0.1076</u>
	New location	2	6	1	No	<u>0.8407</u>	0.852
	Rehabilitate	1	3	-	-	-	-
	Upgrade	6	32	0.2546	No	**<u>0.0479</u>**	0.1506
	Other	0	3	-	-	-	-
	Total	*15*	*55*				
Design Standard	3R	1	8	-	-	-	-
	4R	9	39	0.6969	No	**<u>0.0226</u>**	0.045
	Other	5	18	0.2733	No	<u>0.1384</u>	0.2635
	Total	*15*	*65*				
All Projects		15	65	0.2498	No	**<u>0.0096</u>**	0.0319

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
<u>Underscored p-Values</u> should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Project EWA Utility Agreements

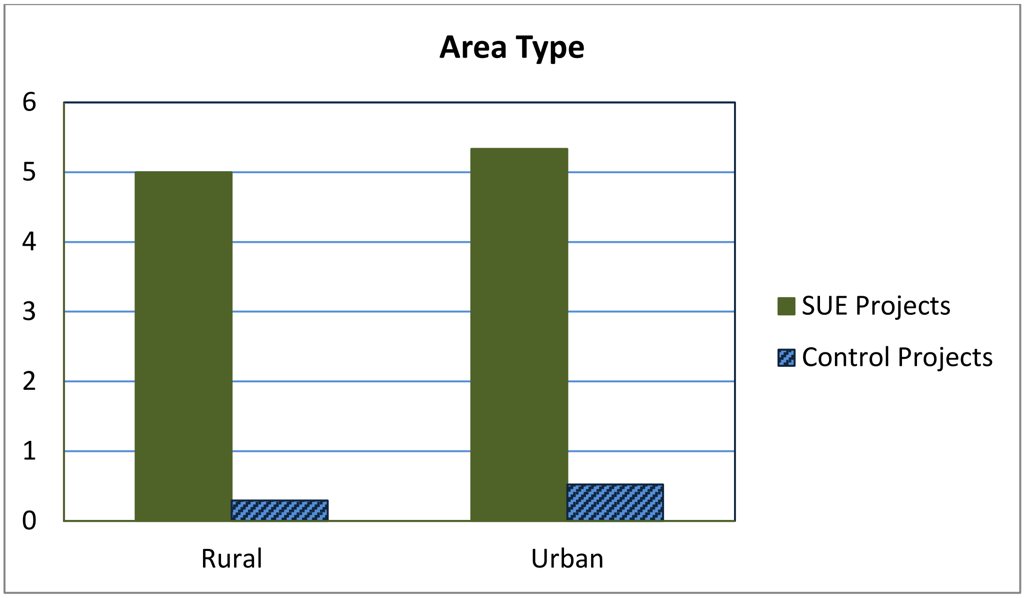

Figure 104. Mean Number of Reimbursable EWA Utility Agreements per Project by Area Type.

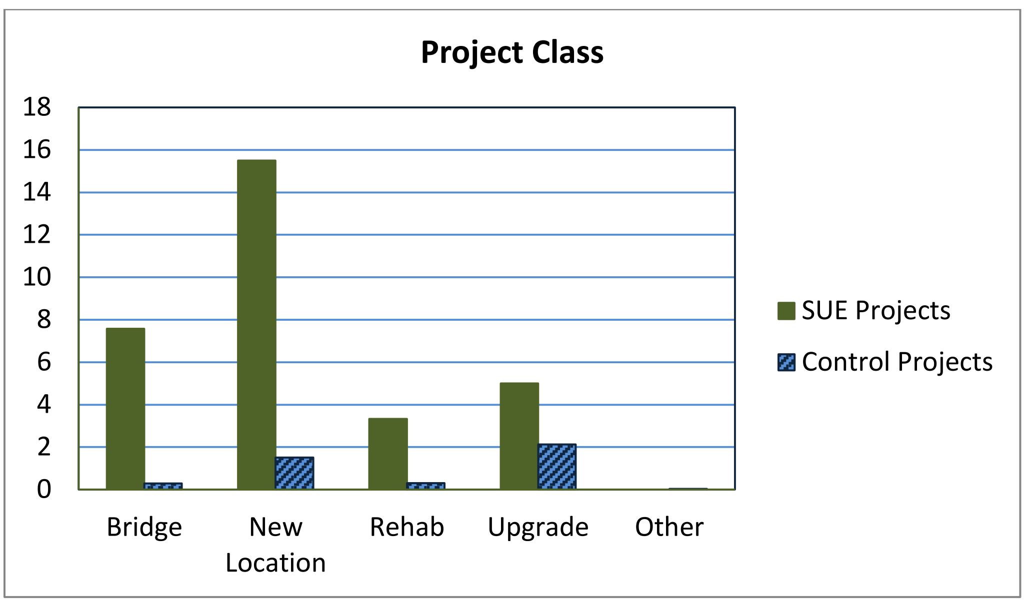

Figure 105. Mean Number of Reimbursable EWA Utility Agreements per Project by Project Class.

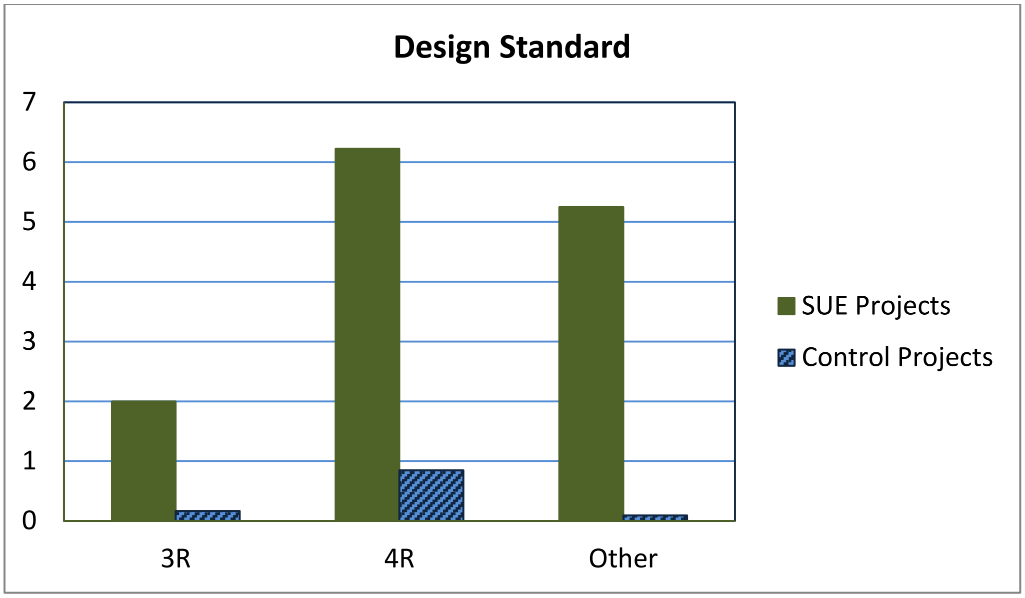

Figure 106. Mean Number of Reimbursable EWA Utility Agreements per Project by Design Standard.

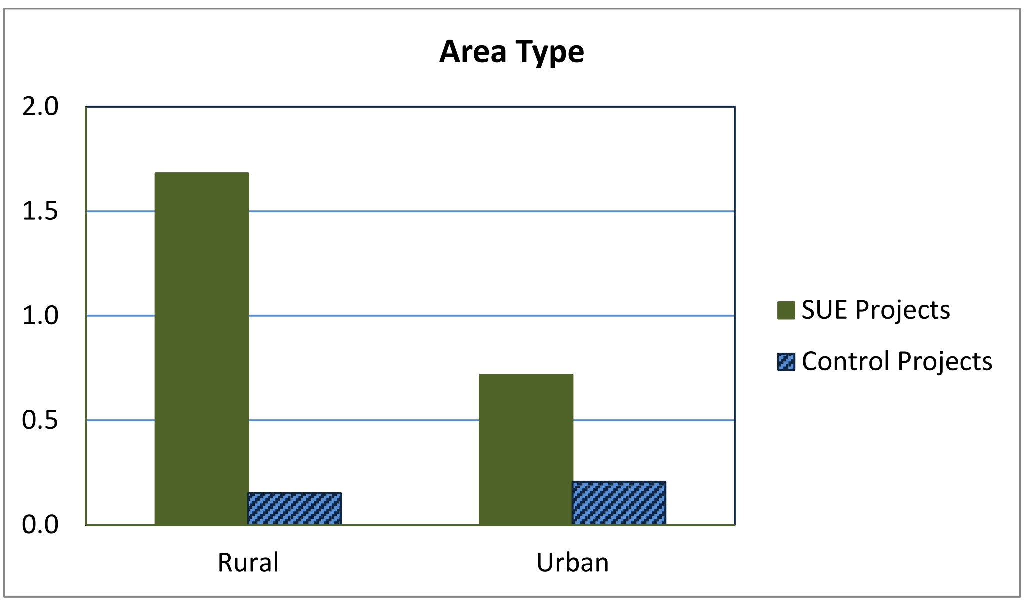

Figure 107. Mean Number of Reimbursable EWA Utility Agreements per Lane-Mile by Area Type.

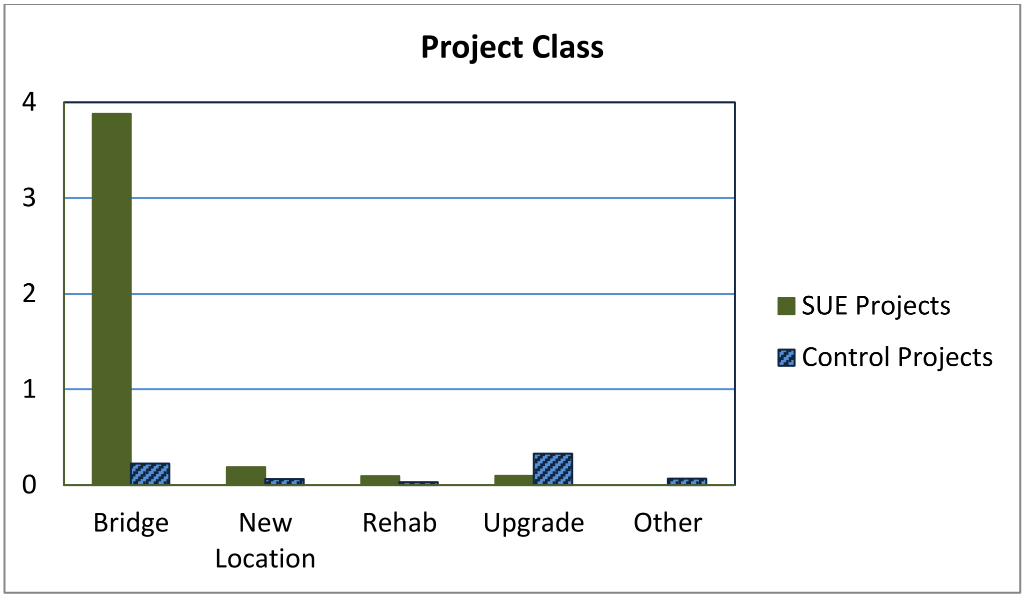

Figure 108. Mean Number of Reimbursable EWA Utility Agreements per Lane-Mile by Project Class.

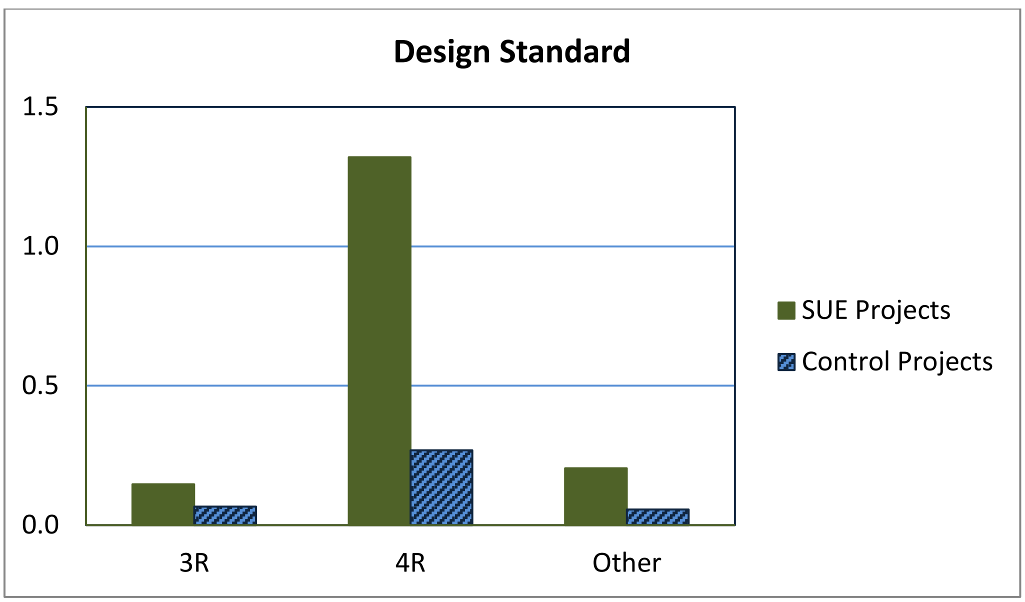

Figure 109. Mean Number of Reimbursable EWA Utility Agreements per Lane-Mile by Design Standard.

Table 98. T-Test Results for Mean Number of Reimbursable EWA Utility Agreements per Project.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	4	507	<.0001	Yes	<.0001	0.1732
	Urban	27	650	<.0001	Yes	<.0001	**0.0045**
	Total	*31*	*1157*				
Project Class	**Bridge**	7	211	<.0001	Yes	<.0001	**0.0144**
	New location	2	39	<.0001	Yes	0.0002	0.5113
	Rehabilitate	6	118	<.0001	Yes	<.0001	0.222
	Upgrade	12	136	0.0002	Yes	0.0281	0.2198
	Other	4	628	<.0001	Yes	0.8309	**0.0076**
	Total	*31*	*1132*				
Design Standard	3R	5	450	<.0001	Yes	0.0001	0.3017
	4R	18	365	<.0001	Yes	<.0001	**0.0129**
	Other	8	1101	<.0001	Yes	<.0001	0.1291
	Total	*31*	*1916*				
All Projects		31	1969	<.0001	Yes	<.0001	**0.001**

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

Table 99. T-Test Results for Mean Number of Reimbursable EWA Utility Agreements per Project Lane-Mile.

Project Category		Effective Sample Size		Equity of Variances		T-Test p-Values	
		SUE	Control	p-Value	Reject H_0?	Equal	Unequal
Area Type	Rural	3	206	<.0001	Yes	0.001	0.4538
	Urban	17	208	0.231	No	0.3164	0.4045
	Total	*20*	*414*				
Project Class	Bridge	4	151	<.0001	Yes	<.0001	0.2143
	New location	2	17	1	No	0.1093	0.2725
	Rehabilitate	6	50	0.0105	Yes	0.2318	0.4999
	Upgrade	8	103	<.0001	Yes	0.815	0.41
	Other	0	25	-	-	-	-
	Total	*20*	*346*				
Design Standard	3R	4	76	1	No	0.572	0.581
	4R	12	233	0.0122	Yes	0.0809	0.2661
	Other	4	116	0.2449	No	0.531	0.2838
	Total	*20*	*425*				
All Projects		20	442	0.0002	Yes	0.044	0.2178

Note:
Null hypothesis for test of equity of variance: H0: the variances of the two samples are equal;
Null hypothesis for T-Test: H0: the two means of the two samples are equal;
Level of significance used: 0.1;
Underscored p-Values should be used based on test of variance equality;
Bolded values are groups for which t-test suggested a significant difference in mean.

APPENDIX E. SUE UTILITY IMPACT FORM

Located in the back pocket of the report on a CD