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Luevano, Jonathan A. ***The Development of an Underground Utility Management Plan for Company XYZ***

Abstract

Company XYZ is involved in various disciplines of design, construction, and maintenance projects across the United States. A common issue amongst all types of projects are damages to underground utilities. Damage to underground utilities can result in injuries, loss of life, schedule delays, and financial losses. Companies engaged in the design, construction, and maintenance of underground utilities face risk when relying on traditional underground utility management practices. The purpose of this study is to establish a company-wide Underground Utility Management Plan (UUMP) that will effectively manage the risk of damage to underground utilities during construction or maintenance activities. Objective goal of the UUMP is to develop a plan for verifying the presence of underground utilities on construction sites to minimize the risk of injuries, property damage, financial loss, and environmental damages. The UUMP will be developed by a review of current best practices and by a comprehensive analysis of Damage Reporting Information Tool (DIRT) reports over a 10-year span.

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Table of Contents

List of Figures

Chapter I: Introduction

Company XYZ is involved in various disciplines of design, construction, and maintenance projects across the United States. A common issue amongst all types of projects are damages to underground utilities. Urban areas contain a complex web of utilities that are critical for delivering water, gas, electricity, telecommunications, and other public services. Such utilities are often aged, in poor condition, and are in need of repair or replacement. Additionally, historical records and as-built information on utility infrastructure is often lacking. These factors make utility infrastructure extremely vulnerable to damage during earthwork activities. Poor information management of utility infrastructure poses risk for stakeholders involved in construction projects. Damages to underground utilities can result in direct costs for a project such as injuries, loss of life, schedule delays, repair costs, and financial penalties. There are also indirect costs that are more difficult to measure, such as service disruptions, inconvenience to the public, and reputation costs. Therefore, traditional underground utility management practices are no longer acceptable ways to work around utility infrastructure. This study aims to identify the leading causes of utility strikes; and to explore more precise utility management techniques. A quality underground utility management program can help Company XYZ create safer job sites and reduce the costs associated with utility damage.

Statement of the Problem

Company XYZ has seen growing occurrences of damage to underground utilities during construction and maintenance activities. Damage to underground utilities can result in injuries, loss of life, schedule delays, and financial losses. Companies engaged in the design, construction, and maintenance of underground utilities face risk when relying on traditional underground utility management practices.

Purpose of the Study

The purpose of this study is to establish a company-wide UUMP that will effectively manage the risk of damage to underground utilities during construction or maintenance activities. The primary objective of the UUMP is to develop a plan for verifying the presence of underground utilities on construction sites to minimize the risk of injuries, property damage, financial loss, and environmental damages. This UUMP will be developed by 1) identifying existing practices for underground utility management based on literature review, 2) exploring best practices and new technologies adopted by comparable companies performing subsurface work, and 3) evaluating DIRT report data to identify the leading cause for utility strikes during construction activities.

Assumptions of the Study

Regarding this study, the following assumptions exist.

1. This UUMP is intended for use by Company XYZ; however, this may be applicable to other organizations involved in design, construction, or maintenance operations.
2. The development of this UUMP is an ongoing process, which should be amended continually as technology, information, and data trends become available.

Definition of Terms

The following is a list of keywords with definitions:

As-Built Drawings

As-built drawings are a set of drawings that are marked up based on how a project was actually built versus the way it was originally designed.

Building Information Modeling

Building Information Modeling (BIM) is the holistic process of managing information for building, based on models and multi-disciplinary data sets to create a digital representation of a project.

Excavation Works

Excavation works is the act of digging a hole, trench, or channel in the ground, especially with a machine. This is one of the most common activities on a construction site.

Geographic Information System

Geographic information system (GIS) is a computer system that analyzes and displays geographical information based on data sets.

Ground Penetrating Radar

A ground penetrating radar is a geophysical method that utilizes radar technology to image/map the subsurface.

Underground Utility Management Plan

UUMP is an integrated plan for identifying the presence of underground utilities to reduce the potential for injuries, property damage, increased costs, and environmental damage.

Utility Strikes

Utility strikes is making contact with an underground utility during excavation activities. This can lead to injuries, property damage, increased costs, and environmental damage.

Utility Tunnels

Utility tunnels are an underground or above ground corridor or passage that carries utility lines such as electricity, steam, gas, water supplies, and sewer pipes.

Vacuum Excavation

Vacuum excavation is a non-mechanical and less invasive method of excavation that uses a blast of air or water directed into an excavation to loosen soil and expose underground utilities.

Limitations of the Study

There is no legal requirement to report utility strikes to the Common Ground Alliance's DIRT reports. Therefore, not all utility damages are captured in the data used in this study. This study is limited to the United States and Canada and does not have a worldwide focus.

Methodology

To minimize the occurrence of accidental damage to underground utilities, this study will review data from the Common Ground Alliance's DIRT reports between the years of 2012 and 2021. DIRT reports provide a comprehensive analysis of damages to buried infrastructure in the U.S. and Canada. A literature review of best practices across the industry will be applied to the DIRT report data to develop the UUMP.

Chapter II: Literature Review

A lack of quality utility infrastructure data poses a risk for stakeholders involved in construction projects. Damages to underground utilities can result in direct costs for a project such as injuries, loss of life, schedule delays, repair costs, and financial penalties. There can also be indirect costs that are more difficult to measure, such as service disruptions, inconvenience to the public, and repution costs. Therefore, traditional underground utility mangement practices are no longer acceptable ways to work around utility infrastructure.

Key topics to be discussed within this literature review include: 1) a general overview of the history, development, and current state of underground utility infrastructure, 2) a brief review of major incidents of loss in connection to underground utilities, 3) an overview of the general risks associated with construction and maintenance around underground utilities, and 4) a review of the best current practices in subsurface utility management. This chapter is intended to provide background information that will guide the development of an Underground Utility Management Plan UUMP or Company XYZ. A review of the literature will help mitigate the risks associated with construction and maintenance works around underground utilities.

General Overview of Utility Infrastructure

There are millions and millions of underground utilities across the United States. In the most densely populated urban areas utilities are packed tightly underground within the first three meters of the subsurface (Jaw & Hashim, 2014). Public utilities provide essentials to the individual such electricity, water, sanitary, natural gas, phone, and internet. Also, there are other more complex systems used for the public such as national defense communication grids, traffic grids, petroleum product pipelines, public lighting, drainage, and flood control. As populations continue to grow, demand for utility infrastructure will also continue to grow (Jaw & Hashim, 2014). In order to keep our urban areas visually pleasant, the use of overhead utilities has become less frequent. With the large number of utilities being buried, the space for underground utilities has continued to shrink. It is estimated that a city intersection may alone have up to 15 utilities buried in the area (Li et al., 2019). Public utilities typically consist of a wide range of construction material, come in many sizes, are buried at various depths, and can rest in a variety of soil types including rock, sand, or clay. The combination of these issues creates major challenges when constructing new utilities or when performing maintenance or repairs on existing infrastructure. Therefore, it is essential for urban planners, designers, contractors, and municipalities to carefully plan out utility infrastructure for sustainable development.

Another major concern with current utility infrastructure is the over-aged system and poor condition. For example, in the United States, the majority of the municipal sewer systems are over 60 years old, with some being more than 100 years old (Wang et al., 2019). Aged systems are less efficient and should be replaced. Additionally, these systems are highly susceptible to damage during construction and excavation activities. Therefore, traditional trenching and earthwork techniques are no longer applicable ways to working around underground utilities. Moreover, with the limited space available, it becomes difficult to install new infrastructure while keeping the old infrastructure active. Construction or repairs on aged systems generally leads to service disruptions to the public, associated social costs, and increased life cycle cost of the utility infrastructure.

Aged systems were not well tracked and/or the historical information has been lost over time. In cases where as-built information is available, it is often incomplete or inaccurate. Mapping the underground utility network is thus a challenging task as the stakeholders cannot guarantee the current conditions of a work area. Furthermore, mapping can be difficult due to the various materials used for utilities, various rock or soil conditions, and the various depths at which they are located. To add to the problem, there are a broad range of public authorities and companies who are responsible for underground utilities (Canto-Perello & Curiel-Esparza, 2013). In some cases, a construction site may be for a private client, such as a hospital, university, or factory. Private clients are responsible for locating their utility infrastructure which can account for 85% of the utilities in your construction site (Common Ground Alliance [CGA], 2021), and this leads to an overall lack of knowledge, information, and coordination while performing construction around underground utilities. The overall lack of governance of underground space inhibits the harmonious development of the third dimension (Canto-Perello, 2013).

Risks Associated with Underground Utilities

Poor management of underground utilities in combination with the issues listed above can lead to several serious consequences. Incidental utility strikes often lead to disruption to public services, property damage, injuries, deaths, and overall rise in costs for owners of utility infrastructure. Due to the extensive networks of underground utilities, the frequency of damage has continued to rise. In 2021, there were over 228,000 total utility damages reported between Canada and the United States (CGA, 2021). This has risen every year since 2016 when there were roughly 222,000 total utility damages reported. With the demand for utility infrastructure on the rise, these numbers are expected to increase in the future (Maree et al., 2021).

It is estimated that damages to underground utilities adds a cost of $50 to $100 billion to the U.S. economy (Maree et al., 2021). Damage to utilities can cause immediate costs for repair, and often causes delays in the construction project. A study by the Florida Department of Transportation suggests that a contractor is delayed 30% of the time a utility strike occurs

(Dockter & Beamer, 2008). Construction delays lead to extensions of schedule deadlines and can disrupt the flow of the construction sequence on a project. In some cases, a utility strike could lead to a spill of hazardous material. Spills can lead to additional costs incurred by the need for emergency services, lawyers, and to pay any incurred fines. If soil or waterways are impacted, additional efforts will be needed to remediate the area.

Other indirect costs can also be incurred due to the disruption of public services. If a public service does not have electricity, fuel, or other resources, it can disrupt the flow of the economy. One example of this is an incident in North Carolina where an underground natural gas pipeline was unintentionally damaged and out of service for six hours. While the cost of the repair to the pipeline was only $15,000, the actual total cost was $300,000 for the loss of production and legal fees (Dockter & Beamer, 2008).

Underground utilities have elevated risk potential as they may be energized, pressurized, or contain a hazardous material. Damage to these hazardous utilities can cause serious and sometimes fatal injuries to nearby workers. In the United States, it is estimated that 25.1% of pipeline incidents caused 163 fatalities and 650 injuries (Wang et al., 2019). The city of Manhattan experiences hundreds of manhole events each year, such as smoke, fire, and explosions due to electric arc flashes from underground electrical lines (Garcez & Almeida, 2014). This sudden release of electricity is often fatal to nearby workers and creates a hazard to the public.

Injuries to workers on a jobsite can also lead to serious cost consequences. According to the National Safety Council (2022), the average cost for an injury on a construction site is $35,000, and the average cost for a fatality is $1.3 million. Some of the costs include hospital bills, lawyer fees, insurance premiums, compensation for days lost, and other expenses.

Another major incident involving underground utilities is an accident in St. Cloud Minnesota in 1998. A cable construction company struck and ruptured a high-pressure natural gas line. As emergency response personnel and utility workers were assessing the situation, an explosion occurred. As a result, there were four fatalities, one severe injury, 10 minor injuries, and six buildings were destroyed (Occupational Safety & Health Association, 2000).

Best Management Practices

Due to the current conditions of underground utilities previously described, traditional trenching and excavation techniques are no longer acceptable ways to perform work. To mitigate potential risks, builders and contractors have used several best management practices while working around utilities. Some best practices to be discussed are: 1) pre-planning and calling in utility locates, 2) alternative excavation techniques, 3) development of as-built information, and 4) advanced technology such as BIM and Ground Penetrating Radar.

Pre-Planning and Utility Locates

The first and most crucial step to underground utility management is pre-planning, which involves analyzing project plans, as-builts, and historical information to foresee utility impacts. Identifying the locations of greatest risk on a jobsite can help guide the work plans around these areas. A major step in this process is identifying the owners of any utilities on a site, which can include both municipalities and private entities. Most construction projects require a joint-utility meeting before a project begins to alert all entities of the upcoming work. Utility meetings also allow utility owners to mark existing infrastructure before excavation begins. Additionally, many municipalities have a 24-hour call system that is required before any activities commence. One of the primary causes of accidental damage to underground utilities is a failure to provide adequate notice of intrusive subsurface activities (Dockter & Beamer, 2008).

Due to the old age of various sites, not all utilities may be known or claimed. This requires companies to perform additional locates to confirm if a line is live or dead. It is beneficial for construction companies to have this technology in-house to expedite any locating needs. Once all utilities are confidently marked, further planning can be made to investigate any conflicts and confirm locations. Best practice for confirming locations typically involves alternative excavation techniques that will be described in the next section.

Alternative Excavation Techniques

The hit and miss approach with an excavator is not an acceptable method to working around utilities. Some entities require a contractor to locate the exact spot of a utility before using any machines or mechanical tools, which often involves hand-digging around utilities to begin excavation. Digging needs to be performed by competent personnel that understands the dangers associated with working around live utilities. Hand digging should be done with a blunt-nosed shovel and dug in an angled and gentle manner. Sharp-edged shovels or pickaxes shall not be used. Another method is to dig alongside a known utility. Digging alongside allows for a lateral approach and soil can be pried away from a utility. This technique may require contractors to consider the integrity of the utility, as it may need to be supported to avoid any damage.

Another common technique is potholing via vacuum excavation, which is considered a soft digging technique where a combination of air and water pressure is used to loosen soil, and a vacuum truck is used to collect the loose material. This technique is ideal for shallow excavations and in subsurface containing loose sand or stone. Vacuum excavation is typically done in one of two techniques, air knifing or water jetting, depending on the soil conditions. Air knifing uses limited to no water and is commonly used where soils are soft such as sands. Air knifing can be slower; however, it allows for the reuse of the disturbed soil. Water jettying is the extensive use of the high-pressured water alongside the vacuum. Water jettying is faster than air knifing and is the most efficient method for vacuum excavation (Dockter & Beamer, 2008). The main drawback to water jettying is that it does not allow for the reuse of the soil. Material that is vacuumed into the truck has a slurry-like composition and must be contained and dried out before disposal. This also requires contractors to pay for additional fill material for the vacuum excavated areas.

Some drawbacks to this technique are that contractors still need accurate information to begin locating subsurface utilities. If locates are off, it can lead to expansive potholes, and leaves the risk of cutting through a pipe or cables with the high-pressure water supply. Once utilities are located, trench boxes or some other safe entry technique to survey the utilities is still required. As utilities increase in depth, vacuum excavation becomes more challenging and safe survey access may no longer be possible. Another challenge can be access to a quick water supply, which is necessary for vacuum excavation. This can either rule out vacuum excavation as an option or can extend the length of time it takes to pothole due to the travel distance to the nearest water supply. Wet spoils produced by water jetting systems are often more difficult to dry out, handle, and dispose, which leads to additional costs for the contractor (Dockter & Beamer, 2008). A final drawback is the maintenance needed on vacuum excavation machines. The extensive network of pressurized lines and hoses on the machine needs to be maintained. Vacuum excavation machines are especially susceptible to breakdowns during winter conditions.

Development of As-Builts

A crucial step in the development of sustainable underground utility development is the collection and storage of accurate as-built information. In many cases, historical information can be difficult to attain or may be lacking quality information. Even when historical information is available, it often lacks the accuracy needed to find existing infrastructure. A study by FDOT observed that construction plans were inaccurate in 15% of the cases where damage to an underground utility occurred (Dockter & Beamer, 2008). Past projects were less likely to track field changes, so the location of structure or utilities may differ from historical plan sets. Low quality as-built drawings not only increase the risk of subsurface risk, but also significantly increases operational costs. Maree et al. (2021) suggests that a lack of quality as-built drawings leads to cost increases and productivity losses due to the need to verify the position of existing onsite utility assets continuously.

Continuous survey and data collection throughout a project can help complete a precise as-built drawing set. Once a project is complete contractors can turn in a simple drawing set to the owner or municipality in control of the subsurface utilities. The as-built drawings should include location and depth of utilities, visual markers, and any other information that can reduce the risk of damage to the utility. This additional information can help identify areas that strayed for the initial plans due to field conditions or design changes. Accurate as-builts can be crucial for providing system information during emergency situations, such as a pipe burst or leak (Maree et al., 2021). Contractors and municipalities can greatly benefit from the survey and mapping of underground utilities as they are installed. Focus on survey and mapping will greatly assist future projects or maintenance around these utilities.

Advanced Technologies

Ground Penetrating Radar. Scanning, detecting, locating, and mapping of subsurface utilities are leading engineering practices for work around underground utilities. One non-destructive sensing technology is ground penetrating radar. Ground penetrating radar directs an electromagnetic pulse into the subsurface. Subsurface infrastructure, rock layers, sediment layers, and other objects contrast in physical and chemical properties that will cause reflections that are sent back to the ground penetrating radar receiver (Watt & Britt, 2021). The two-way travel time of the pulse allows the radar equipment to calculate speed and energy of the refracted signal, which allows for the calculation of the depth of various objects or layers (Watt & Britt, 2021). This is an extremely favorable tool in ideal conditions such as loose soil layers or sandy soils. Looser soils allow for the transmission of the pulse, and the ground penetrating radar technology can identify the depths of objects in the ground. However, a disadvantage to ground penetrating radar is its limitations in non-ideal conditions. Rocky or mixed sediment soils may scatter the radar signal and give false data (Watt & Britt, 2021). Additionally, high electrical conductivity of fine-grained sediments, such as clay or silt, can limit the penetration and overall performance of ground penetrating radar technology (Watt & Britt, 2021).

Ground penetrating radar has been widely used as the top non-destructive sensing tool for subsurface utility mapping due to its reliable performance in delivering high resolution imagery, and its fast and cheap level of data acquisition (Jaw & Hashim, 2014). The processed data renders images, contour maps, or color-ramped amplitude maps (Watt & Britt, 2021). These maps can be used to visualize patterns, geometric shapes, anomalies, and layers in the subsurface. These 3D models can help minimize the risks to working around underground utilities. A study by Jaw & Hashim (2014), showed that ground penetrating radar technology yielded detection accuracy within ±10cm when used for urban underground utility mapping. This accuracy has shown superior performance when compared to other sensing or detecting technologies. According to Khazmin et al. (2017) ground penetrating radar technology can even be used to assess the integrity of subsurface structures. Data collected can be used to visualize any void or deformations in structures which can suggest possible deterioration or damage to the structure (Khazmin et al., 2017).

Although ground penetrating radar technology can be extremely efficient and beneficial, it also has its drawbacks. As previously stated, some soil conditions can be less than ideal for electromagnetic pulses. This requires previous knowledge of soil conditions and may ground penetrating radar may not be applicable. Other issues can occur if proper field techniques are not followed. Incorrect use of radar equipment, mis-calibration of equipment, incorrect data interpretations, and other issues can lead to inadequate results (Khazmin et al., 2017). Therefore, proper core controls and ground penetrating radar techniques must be verified before use.

Building Information Modeling & Graphic Information System. Two other additional technologies used for underground utility management are BIM and GIS. Both are 3D modeling and design tools that can be modified and used to map underground utilities. 3D visualization of utility infrastructure can have a huge impact on construction activities. GIS provides geospatial models that provides information about existing facilities in a geographic context (Sharafat et al., 2021). This helps provide accurate coordinate information, provides storage for geospatial data, and can help guide design for new infrastructure. On the other hand, BIM stores, manages, visualizes, and interprets project information over the lifecycle of a project (Sharafat et al., 2021). BIM models allow for project managers to visualize and plan for utility work before the start of the project. Managing BIM models throughout the design and construction stage can help facility the accuracy of subsurface utility locates and changing information can be updated easily in the models (Wang et al., 2019).

The application of integrated BIM-GIS software allows for an effective management tool over the planning, designing, construction, and post-construction phases. Models can be used in a variety of applications and can help future maintenance or construction projects. Many researchers have shown that BIM-GIS software has enhanced facility management, supply chain management, emergency response, pedestrian route planning, building infrastructure, climate adaptation, and underground utility management (Wang et al., 2019). This technology is a fast-growing trend in recent years but is still in its infancy in regards to construction management for utility infrastructure.

Chapter III: Methodology

Damage to underground utilities can result in injuries, loss of life, schedule delays, and financial losses. Therefore, traditional underground utility management practices are no longer acceptable ways to work around utility infrastructure. Company XYZ has seen a rise in underground utility damage, and work practices are often inconsistent from project to project. To minimize the occurrence of accidental damage to underground utilities, this study will review data from the Common Ground Alliance's DIRT reports, between the years of 2012 and 2021. DIRT reports provide a comprehensive analysis of damages to buried infrastructure in the U.S. and Canada. This data will be used to create a companywide UUMP for Company XYZ that will minimize the risks associated with construction or maintenance activities around underground utilities. The following will describe the research methods, the subject of the research, the instrumentation used, and the data collection procedures.

Subject Selection and Description

Subject matter of this study is the Annual DIRT Analysis provided by the CGA. The CGA is an association that is committed to preventing underground utility damage and protecting those who work or maintain underground infrastructure. They published comprehensive reports and analysis of damages to underground infrastructure in the U.S. and Canada. DIRT reports provide a wide range of data such as: type of utility damaged, root causes of damages, and estimates of the financial impacts of utility damage. DIRT reports from 2012 through 2021 will be used to observe potential trends over a span of 10 years.

Instrumentation

The data collected for this study includes an evaluation of DIRT reports over a ten-year period between 2012 and 2021. This evaluation will include: 1) a review of total reports and reporting entities, 2) an assessment of root causes, 3) an assessment of damages to specific utility types, 4) a breakdown of the root causes, and 5) an analysis of historical trends. when performing subsurface activities.

Data Collection Procedures

The following will break down the assessment process and procedures used for this study.

Assessment of Total Reports

The CGA collects utility damage and near miss history from various stakeholders in the U.S. and Canada. Data is submitted by various stakeholders such as: facility owners, facility operators, utility locators, excavators, call-in centers, and federal agencies. This section will review the year-to-year report totals and stakeholder trends.

Assessment of Root Causes

DIRT reports collect information on root causes of utility damage. Root causes are broken into 25 known root causes, which fall into four categories: excavation practices not sufficient, notification practice not sufficient, locating practice not sufficient, and miscellaneous root cause. This section will analyze the root causes of utility strikes between 2012 and 2021.

Assessment of Damages by Utility Type

There are various types of underground utilities. DIRT reports break down utility strikes by utility type using the following categories: telecommunications, natural gas, cable TV, electric, and water/sewer. The utility types vary in shape, size, depth, and provide different safety hazards when damaged. This section will review the reported damages by utility strikes and will assess the severity of strikes.

Further Breakdown of Root Causes

This section will analyze the root causes presented in a previous section. The main root cause categories include excavation practices not sufficient, notification practice not sufficient, locating practice not sufficient, and miscellaneous root cause. Each of these root causes will be further analyzed to include sub-category root causes, the utility types hit for each root cause, and suggested corrective action for each category.

Review of Historical Trends

This section will identify any historical trends that are displayed in the DIRT report data. Historical trends can help display issues in a specific year, can identify corrections in work practices over time, and can be used to identify potential issues with current practices.

Data Analysis

The information obtained in the DIRT reports will be used alongside current best practices obtained from the literature review to achieve the goals of this study. DIRT report data will help guide the creation of a companywide UUMP with the goal of minimizing the risk of injuries, property damage, financial loss, and environmental damages for Company XYZ. Conclusions and recommendations from this study will be the standard working procedures for the UUMP and will be presented to Company XYZ for use on various construction, maintenance, and design projects.

Limitations

There is no legal requirement to report utility strikes to the Common Ground Alliance's DIRT reports. Therefore, not all utility damages are captured in the data used in this study. This study is limited to the United States and Canada and does not have a worldwide focus.

Summary

The methodology and data collection outlined in this section was guided by the established goals of this study. A review of DIRT reports between the years of 2012 to 2021 will be the basis for this study. Data obtained will be used alongside the best practices studied in the literature review to help develop a companywide UUMP that will minimize the risks associated with intrusive underground utility work. The UUMP will be established based on the conclusions and recommendations of this study.

Chapter IV: Results

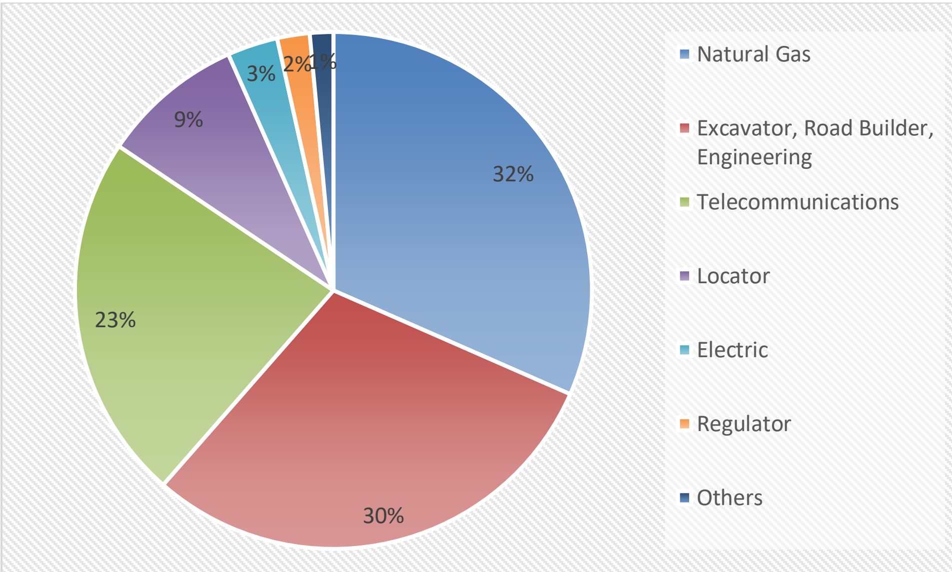
Company XYZ performs various construction activities that are intrusive to underground utilities. To minimize the potential risks associated with damage to underground utilities, the DIRT reports from 2012 to 2021 were analyzed. Based on the results, development of a UUMP will aim to establish a company-wide standard for working around underground utilities. The ultimate goal of the UUMP is to develop best practices to detect subsurface utilities and prevent any potential loss. Work around subsurface utilities happens in steps, including notification, locating, verifying, and excavating. Best practices for each step will be established by performing a comprehensive review of DIRT reports over a 10-year period, and by incorporating best work practices provided by the literature review. The following will analyze the total DIRT reports, root causes of utility strikes, and utility types of damages.

Assessment of Total Reports

Data compiled by DIRT is submitted by a variety of stakeholders in the U.S. and Canada. Stakeholders include facility owners, facility operators, locators, excavators, one call centers, and state federal agencies. There is no obligation for stakeholders to submit reports to DIRT, and all reports are confidential. Some states and local jurisdictions have rules and regulations that require reporting of specific events to DIRT. Reporting stakeholders vary from year to year, with no detectable trend over time. A snapshot of the reporting stakeholders from 2021 can be seen in Figure 1.

Figure 1

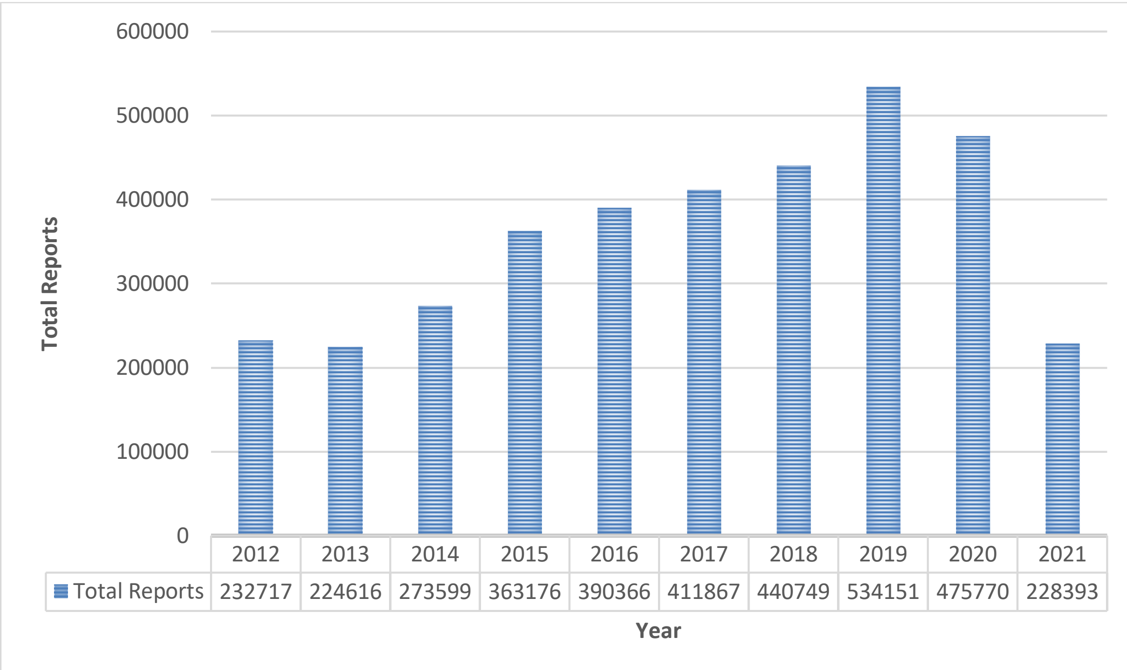
Reporting Stakeholders to DIRT in 2021



The number of reports submitted to dirt varies from year to year. However, there has generally been a yearly increase in reports since the first DIRT report in 2003. Reporting totals from 2012 to 2021 can be seen in Figure 2. Total number of reports hit its peak in 2019 with 534,151 reports, which is over double that of 2013. As seen in Figure 2, there is a constant increase in reporting from year to year, however, there was a decline in both 2020 and 2021. In 2021 there was a significant decline to 228,393 reports, which is the lowest number over the 10-year study period. The decline over the two years is believed to stem from the global pandemic and other economic and political influences. There is a strong correlation between construction spending and the total number of utility damages. Thus, it is assumed that the reduction in construction spending in 2020 and 2021 significantly reduced the number of underground utility damages.

Figure 2

Total Reports to DIRT Over Time



The mass quantity of reports collected by DIRT gives reasonable insight into the quantity, causes, and impacts of underground utility strikes in the U.S. and Canada. Root causes and the types of utilities impacted can be directly seen from the data. However, financial impacts of utility damages are estimated, as not all utility damages are reported to DIRT. The following sections will further break down the yearly data provided by DIRT.

Assessment of Root Causes

DIRT classifies each report based on root causes. DIRT has compiled a list of 25 unique root causes that can be grouped into one of four categories: (1) excavation practice not sufficient, (2) notification practice not sufficient, (3) locating practice not sufficient, and (4) miscellaneous or unknown root cause. These groups give a high-level overview of the key problems associated with underground utility damages. The list of 25 root causes and their groupings can be found in Table 1. Table 1 includes the total number of reports for each root cause in 2021. As seen in the data, the top 6 root causes account for slightly more than 76% of the total reports. The leading 6 root causes are considered the major root causes to focus reduction efforts.

Table 1

Root Cause Reports and Subgroup Chart

	Root cause	Reports	2021 % of total	Subgroups
1	No notification made to call center	34,617	25.72	
2	Facility not marked due to locator error	19,341	14.37	
3	Excavator failed to maintain clearance after verifying marks	18,782	13.95	
4	Improper excavation practice not listed elsewhere	12,181	9.05	
5	Marked inaccurately due to locator error	10,763	8.00	
6	Excavator dug prior to verifying marks by potholing	7,090	5.27	
7	Excavator failed to shore excavation/support facilities	3,584	2.66	
8	Marks faded, lost or not maintained	3,449	2.56	
9	Facility not marked due to no response from operator/contract locator	3,138	2.33	
10	Facility marked inaccurately due to incorrect facility record/map	2,764	2.05	
11	Excavator dug prior to valid start date/time	2,704	2.01	
12	Excavator dug after valid ticket expired	2,678	1.99	
13	Facility not marked due to unlocatable facility	2,532	1.88	
14	Facility not marked due to incorrect facility record/map	2,500	1.86	
15	Site marked but incomplete at damage location	1,985	1.47	
16	Excavator dug outside area described on ticket	1,750	1.30	
17	Facility marked inaccurately due to abandoned facility	1,099	0.82	
18	Excavator provided incorrect notification information	961	0.71	

	Root cause	Reports	2021 % of total	Subgroups
19	Previous damage	662	0.49	
20	Facility not marked due to abandoned facility	548	0.41	
21	Facility marked inaccurately due to tracer wire issue	548	0.41	
22	Facility not marked due to tracer wire issue	294	0.22	
23	Deteriorating facility	282	0.21	
24	Call center error	207	0.15	
25	Improper backfilling	151	0.11	
	Total	**134,610**	**100.00**	

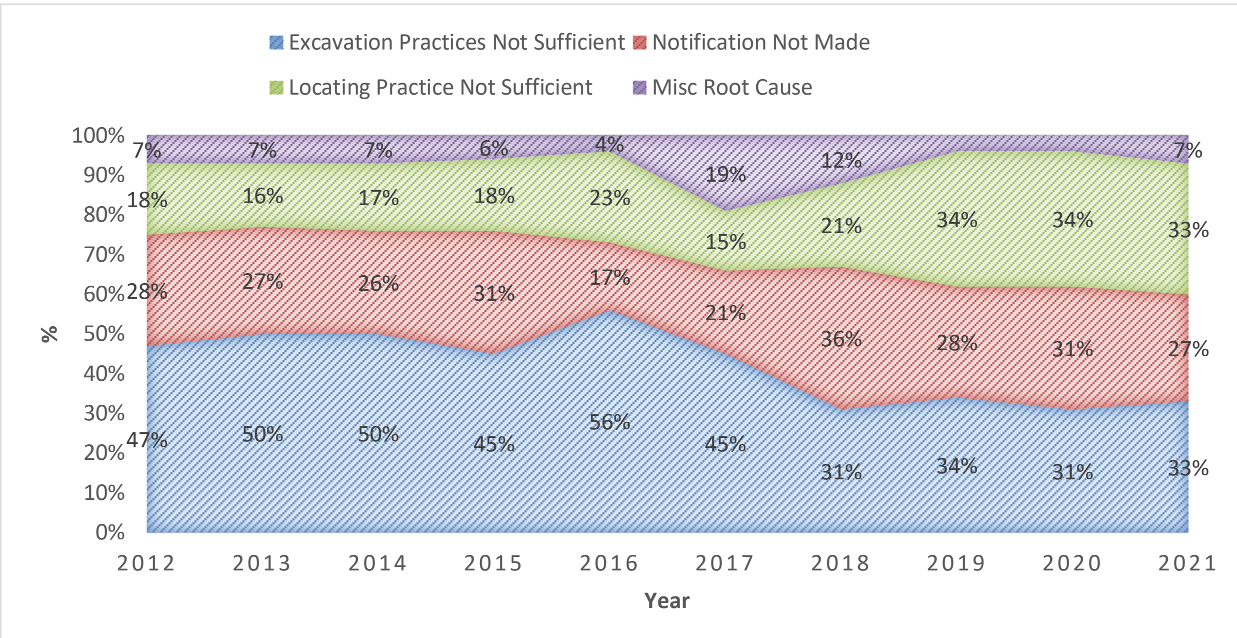
	Notification practice not sufficient
	Locating practice not sufficient
	Excavation practice not sufficient
	Miscellaneous

Note. The root causes listed in the chart are further divided by subgroup. The subgroups are defined by the yellow, orange, blue and green color code listed below the chart.

The percentages for each of the main four root cause groups have continued to fluctuate since the inception of the DIRT reporting program. Figure 3 shows the distribution of the four major root causes over a 10-year period between 2012 and 2021. Generally, insufficient excavation practices have been the leading root cause for utility damage. This is followed by insufficient notification practices, then insufficient locating practices. The miscellaneous root cause group has continued to be the smallest percentage, with the exception of 2017, where it was higher than insufficient locating practices. Trends held true for several years, until the three-year stretch between 2019 and 2021. This three-year span has shown close to equal percentages for insufficient excavations, insufficient notification, and insufficient locating, all accounting for approximately one-third of the total reports. Next will review the reported damages by utility type before going deeper into each root cause group.

Figure 3

Root Cause Distribution Over Time

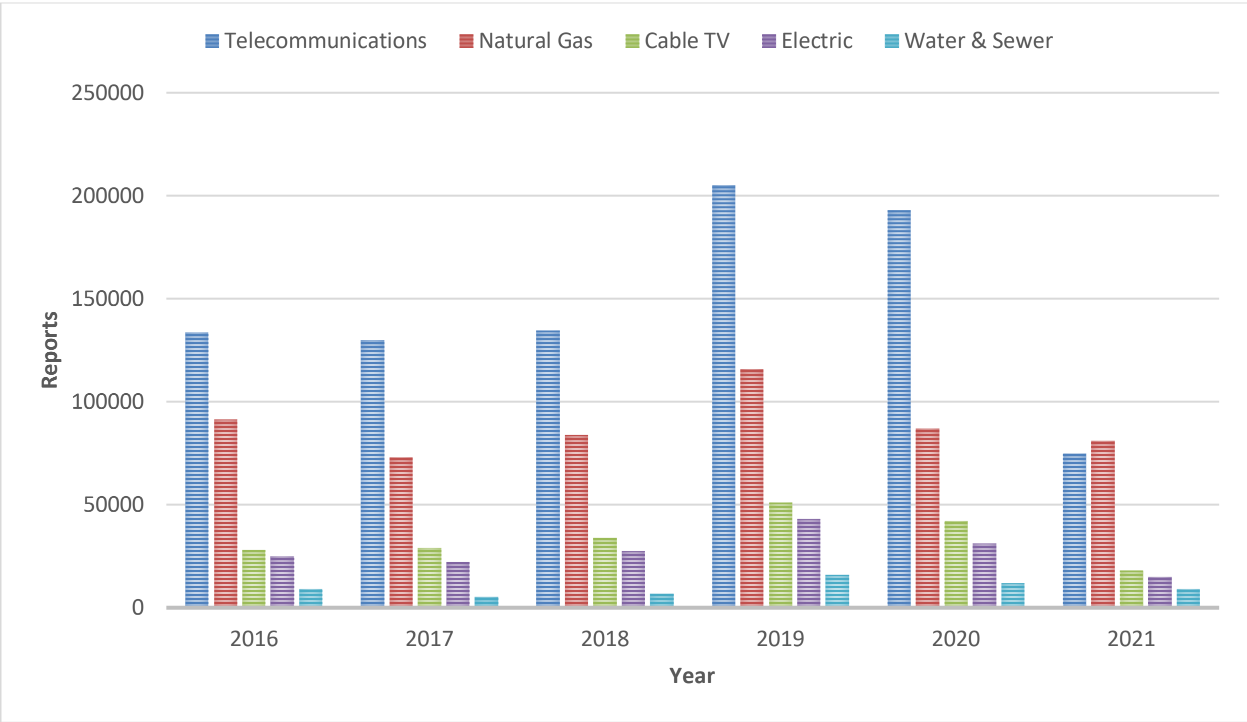


Assessment of Damages by Utility Type

Damage reports submitted to DIRT are sorted by utility type damaged. Utility types are broken into five categories: (1) cable TV, (2) electric, (3) natural gas, (4) telecommunications, and (5) sewer, water, and steam. Some reports have been omitted from these datasets due to unknown utility types, however, this is generally less than 5% of reports. Figure 4 shows the breakdown of reports by utility type from the years 2016 to 2021. Over the six-year span, telecommunications have been the leading utility hit every year, except for 2021 where it was edged out by natural gas. Natural gas was the second leading utility type damaged every year from 2016 to 2020, followed by cable TV, electric, and water sewer. The percentage of reports for cable TV, electric, and water/sewer remained consistent over the six-year span. However, percentages from 2021 may be an outlier due to significantly fewer total reports submitted to DIRT.

Figure 4

Reported Events By Utility Type Over Time



Further Breakdown of Root Causes

The following section will further define the results for each root cause and further describe each category.

Excavation Practices Not Sufficient

Excavation practices have been the leading root cause of reports submitted to DIRT over the 10-year study period. Of the 25 known root causes used by DIRT, five fall into the excavation practices category (see Table 1). These five include: (1) excavator failure to maintain clearance, (2) improper digging techniques, (3) excavator digging prior to verifying marks by potholing, (4) failure of shoring, supports, or backfill, and (5) failure to maintain marks. Categories 1 & 3 are combined in the datasets due to their close relation. The breakdown of the excavation root cause subcategories between the years 2016 and 2021 can be seen in figure 5. From 2016 to 2018 improper digging techniques were the leading subcategory for the excavation root cause. However, this category significantly dropped in 2019, and remained consistent for the next two years. Failure to maintain clearance or to pothole steadily increased over the six-year span and was the leading subcategory from 2019 to 2021. The remaining subcategories (4 and 5) were relatively consistent over the six-year span and accounted for less than 10% of the reports in four of the six years.

Figure 5

Excavation Root Causes

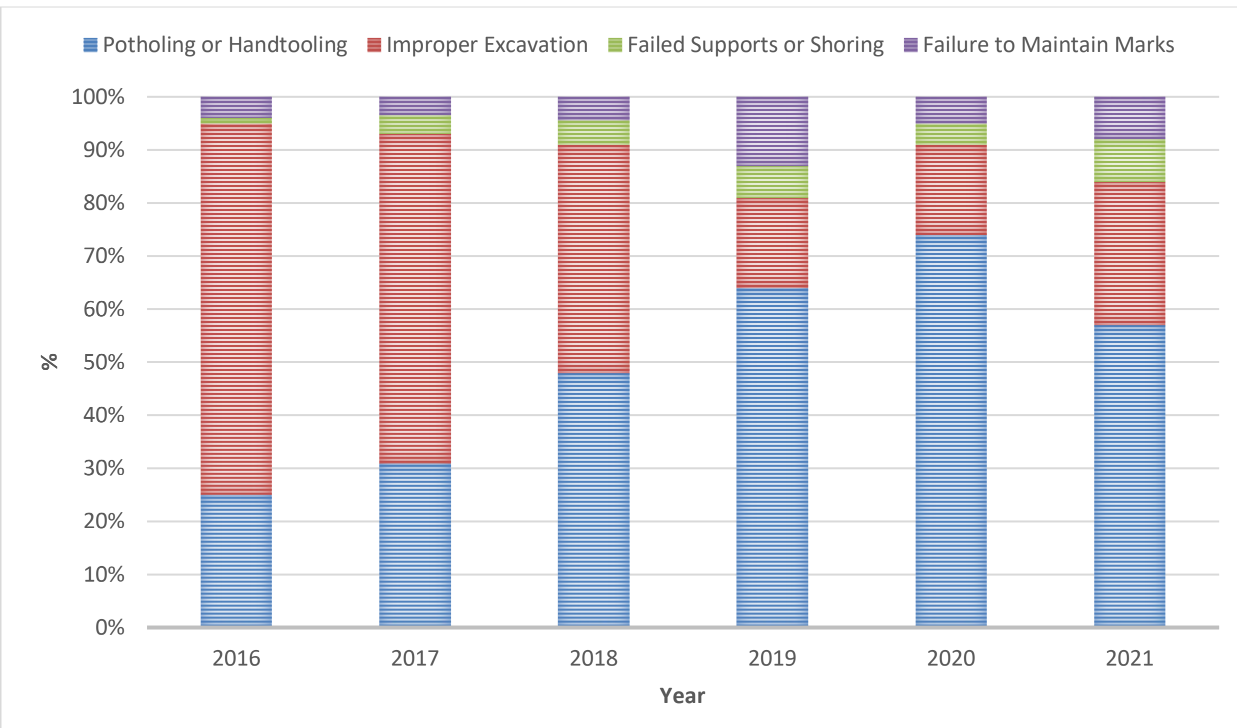
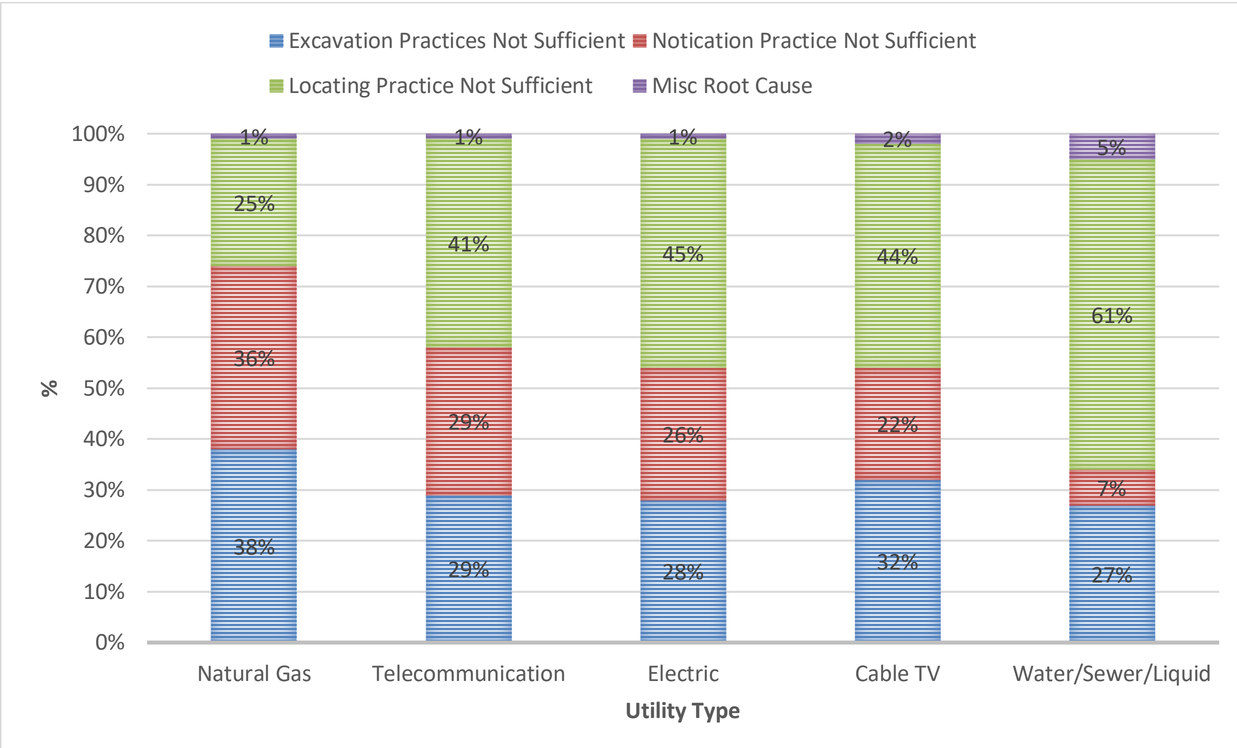


Figure 6 demonstrates the relationship between utility type damaged and root cause groups in 2021. Excavation practices root cause group accounts for about one-third of all reports for each utility type. The only exception is natural gas, which has improper excavation practices as the root cause for 38% of the reports. These levels have remained consistent over the years.

Figure 6

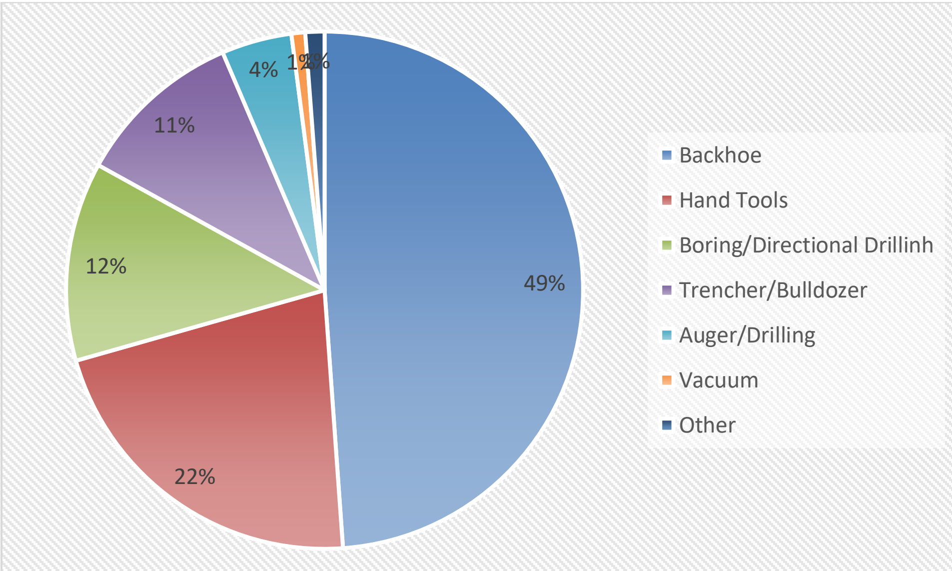
Root Causes By Utility Type



Additional data has been collected on the type of equipment in operation when a utility is damaged. Equipment types include backhoes, hand tools, boring/directional drilling, trencher/bulldozer, auger/driller, vacuum, and others. Figure 7 shows the number of reports by equipment type. Backhoes account for almost half of the reported damage, and hand tools account for almost a quarter. Boring/drilling is also a large contributor to utility damage and has been trending upwards over the last several years. Horizontal directional drilling is expected to have increased use in the future as a less invasive means of installing utility infrastructure. However, the key problem with this method is that there is no way to confirm that the drill has successfully avoided all underground utilities.

Figure 7

Reports By Equipment Type



Notification Practice Not Sufficient

Improper notification practices are a large root cause of utility damage and is the first step in the process to perform work around a live utility. Of the 25 root causes made by DIRT, five fall into the improper notification root cause category. This includes: (1) no notification made, (2) excavator dug prior to valid start date/time, (3) excavator dug after valid ticket was expired, (4) excavator dug outside of area described on the dig ticket, and (5) excavator provided incorrect notification information. Figure 8 displays a bar diagram of the improper notification root causes between 2018 and 2021. No notification made is the leading cause every year both in the improper notification category and across all other root cause subcategories. Since 2018, no notifications have accounted for nearly a third of all reports submitted to DIRT. Notification being the first step in the process to work around a utility, it should be a focal point to reduce utility damages. Digging before valid start date/time was a significant number of reports in 2018 and 2019, accounting for nearly 10% of all reports. However, this number significantly dropped to around 2% in 2020 and 2021. The remaining three root causes in the improper notification category have accounted for less than 2% of all reports each year during the study.

Figure 8

Notification Root Causes By Year

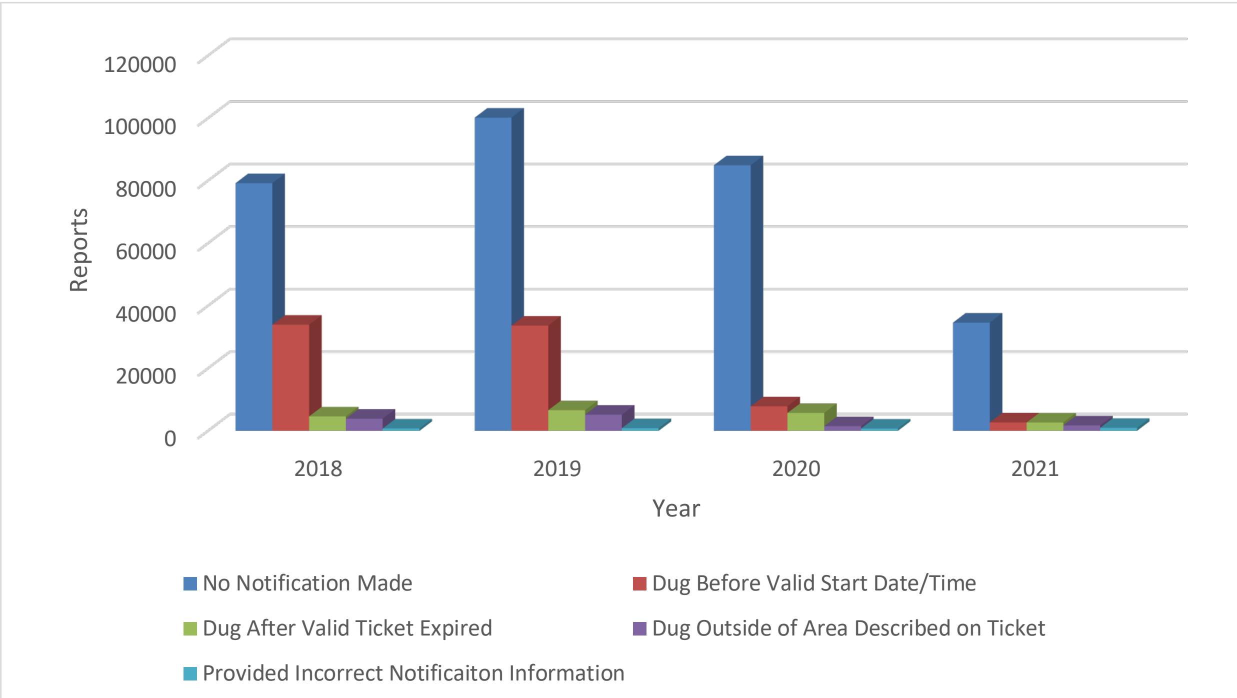


Figure 6 demonstrates the relationship between utility type damaged and root cause groups in 2021. All the various utilities show between a quarter and a third of all strikes due to improper notification root cause. However, water/sewer shows very minimal reports for improper notification.

Locating Practice Not Sufficient

Insufficient locating practices have accounted for around 20% or less of total DIRT reports from 2012 to 2018, however, these numbers have been steadily increasing. Locating practices have accounted for nearly a third of all reports between 2019 and 2021. Of the 25 known root causes classified by DIRT, 12 fall into the locating practices category. The list of these root causes can be seen in orange in Table 1. The 12 root causes were combined into five groups, based on similarities, to examine as a data set. This includes: (1) locator error, (2) not marked or incomplete marks, (3) maps or records incorrect, (4) unlocatable or trace wire issue, and (5) abandoned utilities. A comparable data set from 2015 to 2020 showing locating practice root causes can be seen in Figure 9. Locator errors have remained the leading cause in this category over the span of this study. Abandoned facilities and incomplete marks combined accounts for 40-50% of the yearly reports in the locator practices root cause category.

Figure 9

Locator Root Causes By Year

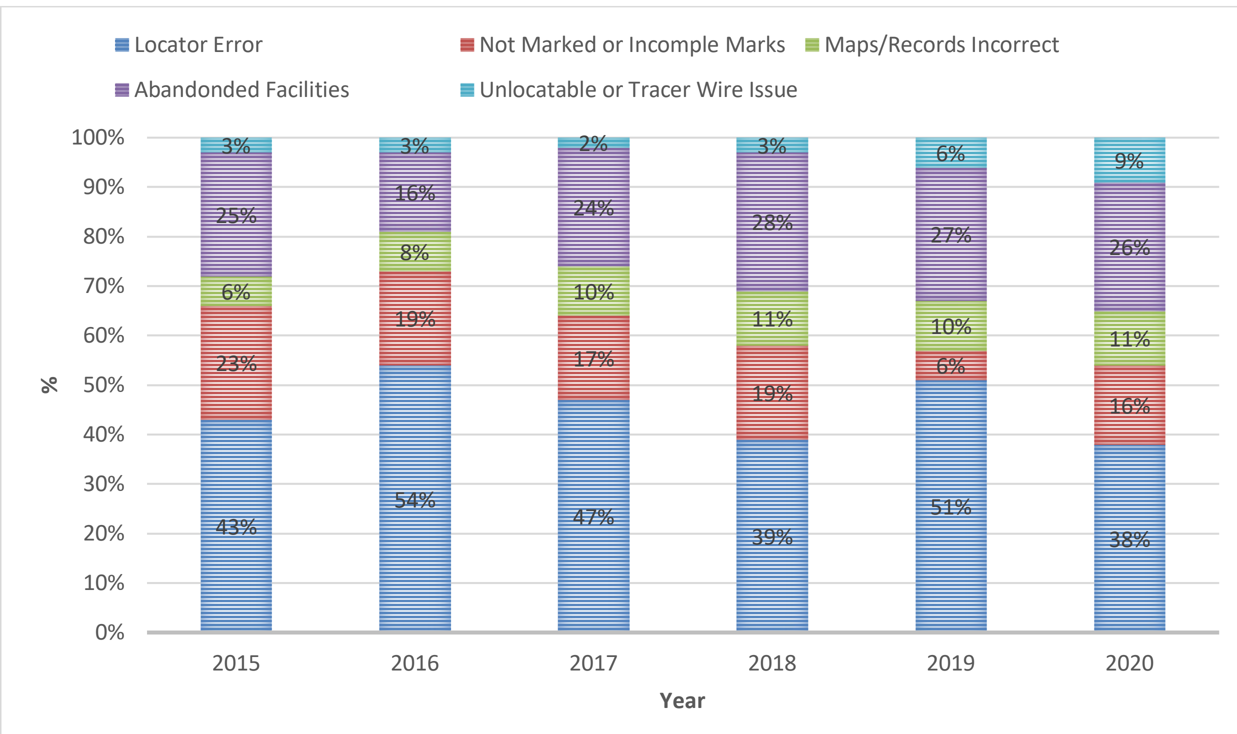


Figure 6 demonstrates the relationship between utility type damaged and root cause groups in 2021. Locating practices were the root cause for utility damage to telecommunication, electric, and cable TV between 40-45% of all reports. However, this percentage was much higher for water/sewer and much lower for natural gas. Water/sewer utility damage reports showed that locating errors were the root cause of damages 61% of the time, which was over double that of any other root cause for water/sewer damages. Natural gas utility damage reports showed that locating errors were the root cause 25% of the time, which is significantly less than all other utility types.

Miscellaneous Root Cause

The miscellaneous root cause group is the smallest and consists of the reports that could not be classified into the locating, excavating, or notification root cause categories. Of the 25 known root causes classified by DIRT, three fall into the miscellaneous root cause category. These include: (1) utility showed previous damage, (2) deteriorating utility, and (3) call center error. These three categories combined account for less than 1% of the yearly reports submitted to DIRT. Therefore, this category will not be a prime focus for this study.

Chapter V: Discussion, Conclusion and Recommendations

The purpose of this study is to establish a company-wide UUMP that will effectively manage the risk of damage to underground utilities during construction or maintenance activities. Primary goal of the UUMP is to develop a plan for verifying the presence of underground utilities on construction sites to minimize the risk of injuries, property damage, financial lost, and environmental damages. The UUMP will be developed by 1) identifying existing practices for underground utility management based on literature review, 2) exploring best practices and new technologies adopted by comparable companies performing subsurface work, and 3) evaluating DIRT report data to identify the leading cause for utility strikes during construction activities.

Discussion

Notification practices, locating practices, and excavation practices are the root cause for utility strikes in over 90% of the reported incidents by DIRT. Therefore, the UUMP for Company XYZ should focus on these three main root cause categories in order to significantly reduce the risks posed by work around underground utilities. Trends over the last 10 years have shown that all three categories account for nearly one third of reports to DIRT. Therefore, equal focus on each category is essential for minimizing risk. A particular focus will be on the six leading unique root causes, which account for slightly over 76% of reports in 2021.

Notification Practices

No notification made to call centers is the leading cause for all reports to DIRT, accounts for 25% of all reported incidents. This is the first and most important step in reducing the risk of working around underground utilities. One call center generally operates seven days a week, and it is encouraged to provide 10 days advanced noticed prior to any earthwork activities. In some instances, it may be necessary to contact private utilities directly to ensure all utilities have been notified. Additional focus should be placed on notifying natural gas companies, as natural gas lines have been the leading utility damaged from no notification. Focus on electrical utilities should not be ignored, as these provide a great risk to workers' safety. On projects of a larger scale, it is recommended (and sometime required) that the project team schedules a utility locate meeting with all involved parties. Utility locate meetings help ensure that all parties are aware and up to date regarding any work around subsurface utilities.

The other unique root causes in the notification category account for a minimal percentage of the total reports to DIRT. However, these root causes should still be considered to effectively minimize risk. The key focus should be on assuring all information on the notification ticket is accurate, and assuring all work adheres to the information on the ticket. This includes following any start and end times/dates, digging within ticket boundaries, and correcting any misinformation on the ticket.

Locating Practices

The leading two unique root causes in the locating category are facilities not marked and facilities inaccurately marked due to locator error. Best practice to reduce risk in this category is for site managers to double check all plan sets and historical records. It is also recommended to walk the site with all locators to ensure all utilities have been marked. In order to preserve marks, refresh paint regularly, or take adequate site photos and records for later use. It may be necessary for utility locates to come out more than once on an extended project. These will not reduce all risk with locating practices, because in some situations a utility may be inaccurately recorded/mapped. Therefore, it is recommended that precautions are taken within a 10' tolerance zone of all utilities. It is also recommended that all utilities are treated as live until further verifications measures are taken. As a further verification practice, it may be necessary to provide additional means of locating utilities. Some contractors own a locating wand, which can help narrow down the location of an unknown utility. In some situations, contractors can hook onto a utility in a known/exposed location, and more accurately trace out the utility with their locating wand. In some situations, it may be necessary to pothole or vacuum excavate around utilities to confirm locations prior to commencing any construction activities. Any additional means and methods to locate potential underground utilities is encouraged.

When constructing, maintaining, or exposing utilities, steps can be taken to ease locating practices in the future. A key step is to accurately record the locations and conditions of all utilities. This includes observations, notes, and survey data. This should be collected, compiled, and sent to any governing agencies. Additionally, contractors can ensure all tracer wirer and warning tapes are installed properly and not damaged during backfill activities. These steps will greatly aid the locating process in the future.

Excavation Practices

Excavation practices have been the leading root cause of utility strikes over the last 10 years. However, the last four years have shown a more even distribution of root causes, and a reduction in excavation root causes. There are five unique root causes in the excavation category, and all five falls into the top eight root causes for all reports to DIRT. The top two unique root causes in this category are failing to maintain clearance and improper excavation techniques. Both of these root causes can be significantly reduced by the proper use of a spotter. It is highly encouraged to always use a spotter when digging around underground utilities.

Another major contributor to the excavation practices category is failing to verify marks by potholing. It is recommended that all utility locations are confirmed prior to digging. This can be done by hand digging or vacuum excavating. However, these techniques have also seen a rise in utility strikes over the last five years, so correct use of these techniques is essential. Another contributor to this category is failure to maintain marks. All utility locates should be regularly refreshed, and it is highly encouraged that photos are taken to help guide the refresher process. The final unique root cause in the excavation category is failure of shoring, supports, and backfill. Therefore, even once a utility is exposed, proper techniques are needed to maintain the utilities integrity. All shoring and utility supports should follow project design requirements. In many situations, utility supports and shoring are approved by a licensed structural engineer. Additionally, proper backfill and compaction techniques must be followed. Many utilities require a specific backfill material and dimensions for minimal clearance. Adhere to project specifications when determining backfill requirements. In some situations, it is necessary to use a followable fill concrete mix underneath a utility to ensure the utility rests on a solid base.

Additional considerations should be made based on the type of equipment used for excavations. Excavators have been the leading equipment type used during utility strikes. The use of excavators can be useful as long as proper potholing, locating, and verifying has been done prior to use of excavators. Boring and directional drilling has seen a rise in utility strikes over the last several years. This is considered a less invasive activity than excavating, however, locating and potholing are crucial during these operations. When drilling, it may be difficult to know if, where, and when a utility has been damaged. Therefore, it is imperative to have an experienced driller, and to have extensive knowledge of utility infrastructure prior to drilling.

Conclusions

Company XYZ has seen a rise in utility damages during construction and maintenance activities across the United States. Damage to underground utilities can cause injuries, loss of life, schedule delays, and financial losses. In order to minimize these risks, this study aimed to develop a companywide UUMP. This UUMP was developed through a comprehensive literature review of best practices across the industry, and through analysis of DIRT reports over a 10-year span. The UUMP provides a guideline through the three major steps of working around underground utilities: notification, location, and excavation. Recommendations for each step were determined by leading root causes and best practices across the industry. Continued development of the UUMP should continue to develop and adapt to new data, technologies, and industry trends. This UUMP is intended as the most effective way to minimize risk of potential damage to underground utilities and should be applied to the health and safety program across all projects performed by Company XYZ.

Recommendations

The following are recommendations by the author to continue the enhancement of the UUMP and to improve work practices around underground utilities in the future.

- It is recommended that the development of the UUMP be an on-going process. The UUMP should adapt to emerging trends in DIRT reports and should include the latest best practices throughout the industry.
- The best practices outlined in this UUMP can be included in project planning across Company XYZ. However, the best practices may change depending on the work area and situation.
- This UUMP is intended for Company XYZ. However, the UUMP can be applied to companies that perform similar work to Company XYZ. Before applying this UUMP, any company should consult their corporate health and safety program.

- Continue to report all utility damages to DIRT in order to improve data quality in the industry. Greater emphasis on quality data will help narrow down the areas of focus to reduce risks when working around underground utilities.
- Emphasize the importance of quality survey and as-builds during utility installation. This will improve the accuracy and quality of utility records and information moving forward.
- A UUMP safety checklist was created to guide project managers while in the field. The checklist is included in the Appendix and is intended to be used as a field verification guide during construction activities around underground utilities. This document should be amended moving forward as new and better work practices are developed.

The listed recommendations will help reduce the risks posed by construction and maintenance activities around underground utilities. Additionally, the recommendations will help assure that the UUMP is an evolving document over time.

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Appendix

Company XYZ – UUMP Safety Checklist

General Information	Comments
Project Name:	
Project Number:	
Date:	
Work Location:	
Contractor:	
Submitted By:	
Additional Information:	

Notification Procedures Checklist

Checklist Item	Yes	No	N/A	Comments
Has the One Call Center (or local equivalent) been contacted?				
Was the One-Call Center notified 48-hours in advance?				
Were private utilities notified?				
Is the work location information on the notification ticket accurate?				
Is the date and time on the notification ticket valid?				
Was there a joint utility meeting held? If yes, note date/time in comments & list participants below.				

Utility/Company:	Primary Contact:	Phone Number:	Email:

Location Procedures Checklist

Checklist Item	Yes	No	N/A	Comments
Did locator mark all utilities? If yes, note date/time in comments.				
Was onsite representative present during locating?				

Were the project plans and historical documents referenced and cross checked during locating?				
Were field notes and photos taken?				
Can utilities be verified by a tracer wire?				
Were utility locations verified by the contractor performing work? If yes, note verification method in comments.				
During verification, were the utilities surveyed?				
If yes to the last question, is a model being used to map utilities?				
Excavation Procedures Checklist				
Checklist Item	**Yes**	**No**	**N/A**	**Comments**
Is the Notification ticket active and accurate?				
Are utility locate marks still visible?				
Have utilities been verified prior to excavation?				
Are there any special considerations while excavating? If yes, note in comments.				
Will utility supports, shoring, or any other means of stabilization be needed during excavation. If yes, note in comments.				
If yes to previous question, were the supports and/or shoring approved by a licensed engineer?				
Were the approved utility supports or shoring drawings followed during excavation?				
What type of machine is being used for excavation?				
Is a spotter available during digging operations?				