North Carolina 811, Inc

NC 811 Annual Report

2018 Data and Field Study

NC 811 Annual Report – 2018

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811 Call Before You Dig

In the United States, excavation activities must be reported to notification centers (commonly known as one call centers) before work starts. This service was established to protect excavators and underground utilities from third-party damages. A one-call center may be defined as an entity that administers the system through which a person can notify owners/operators of lines or facilities in advance of proposed excavations. In North Carolina, employers/excavators are required by law to report planned excavation activities to North Carolina 811 (NC 811). NC 811 then notifies utility owners or operators who may have underground infrastructure within the proposed excavation area to mark them, if any. The following are laws that govern excavation activities:

1. North Carolina General Statutes (NC-GS), chapter 87 – Excavators

   Article 8A – Underground Utility Safety and Damage Prevention Act.

   Excavator responsibilities (87-122): "Before commencing any excavation or demolition operation, the person responsible for the excavation or demolition shall provide or cause to be provided notice to the Notification Center of his or her intent to excavate or demolish." Furthermore, NC-GS. 87 -120 (d) requires that any person that intends to excavate in the state of North Carolina to notify NC 811 at least three business days from the day of excavation.

2. North Carolina General Statutes (NC-GS), chapter 95 – Department of Labor and Labor Regulations

   Article 16 - Occupational Safety and Health Act of North Carolina (OSHA NC).

   1926.651 (b) (2): "Utility companies or owners shall be contacted within established local response times, advised of the proposed work, and asked to establish the location of the utility underground installations before the start

of actual excavation."

Accordingly, two of North Carolina's general statutes require at least a three working days notification before the proposed commencement of excavation. Otherwise, employers may be cited by OSHA NC or through a complaint process to the Underground Damage Prevention Review Board. When damage happens to underground utilities, North Carolina's Underground Utility Safety and Damage Prevention Act requires the excavator to immediately contact the Notification Center (i.e., NC 811) and the facility operator/owner, if known, to report the location and nature of the damage. Therefore, the employers of excavators must provide the required time and training to their excavators to ensure compliance. It is the employer's responsibility to provide all required resources to ensure both NC 811, and the facility operator, have been notified.

Number of Damages Reported in 2018

This report provides preliminary trends of collected damages in 2018 in the state of North Carolina. There were 12,024 reported damages in the state of North Carolina in 2018, which is higher than reported damages in 2017 (i.e., 11,160) and less than the reported damages in 2016 (i.e., 15,171). However, the number of damages reported by Common Ground Alliance (CGA) for 2018 in North Carolina is higher. CGA reported 24,931 damages in North Carolina. Figure 1 shows the number of damages reported to NC 811 and CGA, and the differences between them. It is clear that most of the difference occurred within Tele/CATV damages. The damage information is reported to CGA and NC811 by stakeholders (i.e., event source). Figure 2 summarizes 2018 damages by stakeholders for CGA and NC 811. It is obvious that locators represent the main source of information for CGA while excavators represent the main source of information for NC811. The findings in Figure1 and Figure 2 suggest that the difference in the

number of damages could be a result of the fact that Tele/CATV locators in North Carolina, who contribute more than 70% of the damage data to CGA DIRT, are not granted access to NC 811 when damages are reported. This difference in reported damages illustrates the fact that many excavators are failing to report the damages directly to NC 811 as required by North Carolina General Statutes (87-126), which as stated earlier.requires the excavators to notify NC 811 as soon as damages occur.

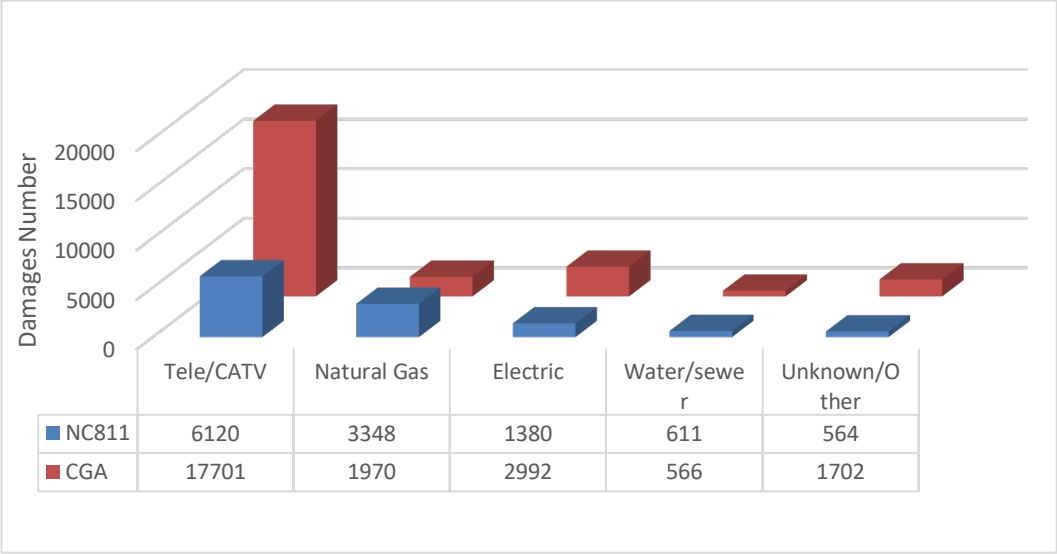


Fig.1. The Number of Damages Reported (NC 811 Vs. CGA)

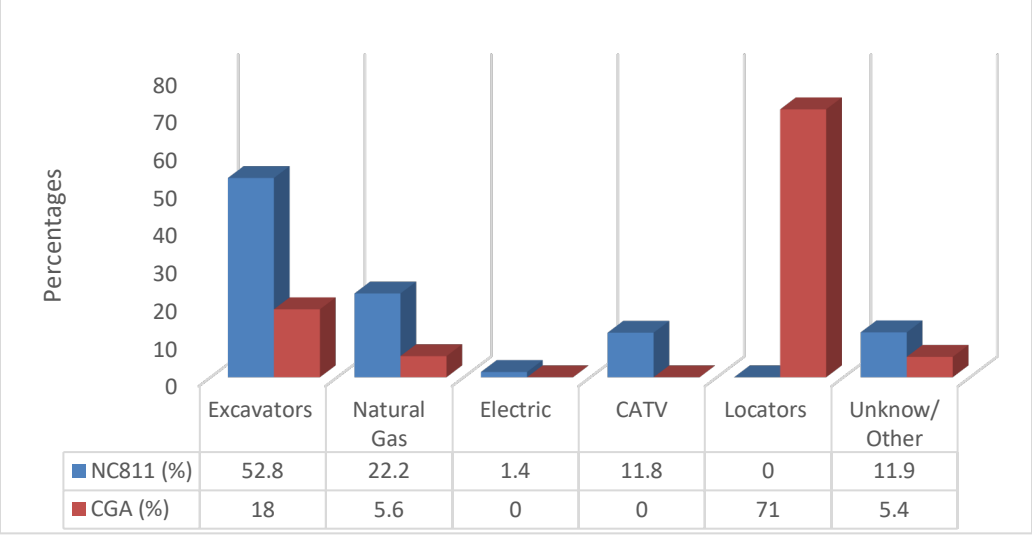


Fig. 2. Percentages of Damages Reported by Stakeholders

Root Causes

Trends among reports to NC 811 are discussed in this section. This report categorizes the primary causes of damages reported to NC 811 as follows:

- **Excavators Practices Insufficient**

  This category includes excavators practices that often lead to a utility damage, such as failure to use hand tools when needed, failure to maintain clearness, failure to protect/shore underground utilities, excavating before the legalisation valid time (i.e., 3 business days in North Carolina), excavating after the ticket expired, and improper backfilling practices. In addition, incorrect ticket information (e.g., describing the area incorrectly on the ticket) has been included in this category, since excavators are the source of the ticket information. The reader should be advised that some of these causes have been listed under **Other Notification Issue** in the DIRT 2018 report. Marks that have faded or have not been maintained are also included under this category since excavators should place a damaged mark ticket when marks have faded or were not properly maintained.

- **Locator Practices Insufficient**

  This category includes cases where underground utilities have not been located or were incorrectly marked due to a variety of causes such as broken tracer wire, abandoned facility, equipment limitation, lack of training, and inaccurate maps.

- **Notification Error**

  This category includes cases where no notification was made to the one-call center.

- **Other Causes**

  This category includes cases where damages that occurred were not a direct fault of any of involved parties, such as previously damaged utilities.

Figure 3 summarizes the causes of damages in 2018 based on information provided to NC811 without the unknown inputs. The data indicates that locator practices are the most frequent contributing factor to underground damages in North Carolina. However, readers should consider the fact that more than 50% of the data is based on the excavators' view, and the cause of 67.5% of reported damages are unknown. On the other hand, it impractical to compare the root causes in Figure 3 with CGA data because this report uses different categories. In addition, CGA data often provide locators' point of view since locators provide 71% of CGA data.

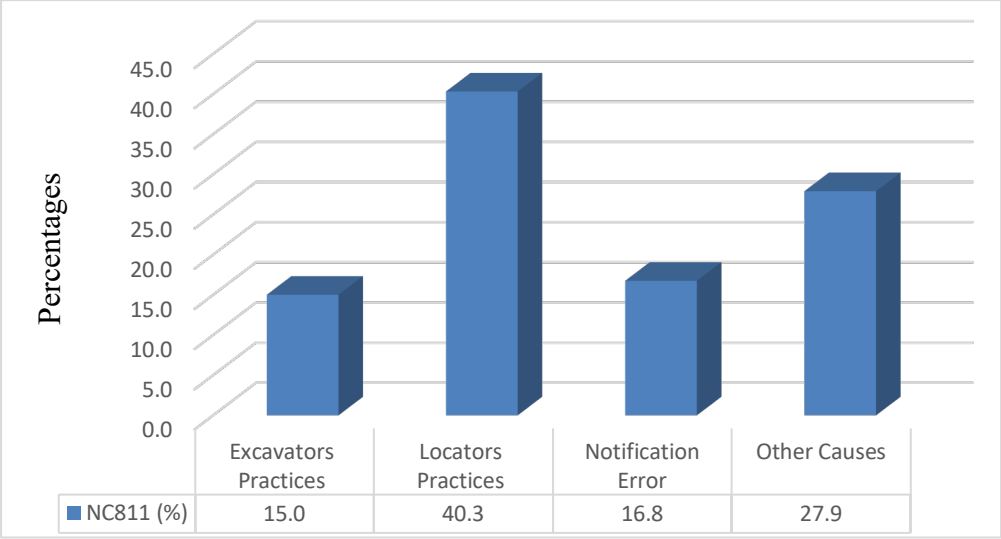


Fig.3. Root Causes Proportions

General Trends

For the remainder of this report, the discussion will deal exclusively with the NC 811's collected data and will not consider the difference reported by CGA. It is expected to obtain accurate trends of damages using NC 811 data, since a trend could be captured through a random representative sample.

No Locate Requests

One of NC811's goals is to ensure that all excavators call before they dig to mark underground utilities which could , in turn, help reduce damages. The 2018 dataset shows that 2408 damages

(i.e., 20%) were not associated with a locate request. This percentage is higher than data obtained in 2017, which was 19.4% (i.e., 2169 damages), and less than data obtained in 2016, which was 21.56 % (i.e., 3,271 damages). Furthermore, the examination of no locate requests indicates that most of the cases occurred in Mecklenburg (25.4.10%), followed by Wake County (9.96%), Guilford County (8.00%), and Durham County (3.69%), respectively. Comparing these percentages with 2016 and 2017 percentages shows an overall decrease in no locate requests among these counties, except Guilford, see Table 1. This finding suggests that NC 811's educational and outreach efforts should target these counties, especially Guilford. NC 811 education comes in a variety of methods such as advertisement (e.g., billboards and television advertisements), onsite training by NC 811 educators, and online (i.e., PIPES Plus). According to a study funded by NC 811 in 2017, media (which includes television, radio, and Internet advertisements) represents the most effective method of education, equaling 58.8%, followed by billboard (33.4%) and print (7.81%). Print includes magazines, phonebooks, and utility bills.

Table 1. No Locate Request by Major Counties between 2016 and 2018

County	Mecklenburg	Wake	Durham	Guilford
2018	25.40%	9.96%	3.70%	8.68%
2017	23.10%	17.38%	5.53%	4.52%
2016	28.12%	18.52%	6.14%	4.49%

Note: Counties with less than 3.7% of no locate requests in 2018 are not presented

Examining the no locate requests data by excavator type indicates that the higher percentage of no locate requests within known data was among contractors (45.2%) who mainly perform landscaping and waterworks. Accordingly, this finding highlights the specific sectors that NC 811 needs to target through educational and outreach efforts.

Damages Per County

The NC 811 damages per county show that higher percentages (i.e., more than 4%) of reported damages occurred in Mecklenburg County (21.94%), followed by Wake County (16.32%), Guilford County (5.82%), and Durham County (5.14%). The 2017 NC 811 report suggested that higher percentages of damages in these counties are expected since excavation work increased significantly in Mecklenburg, Wake, and Durham since 2015. Google and AT&T chose these counties to be outfitted with fiber Internet service. When comparing the 2018 percentages of damages per county with 2016 and 2017 percentages, a decrease occurred in most counties except Guilford County, which requires further investigation, see Table 2. The data also show an increase in no locate request in Guilford, see Table 1.

Table 2. Damages Percentages by Major Counties

County	Mecklenburg	Wake	Durham	Guilford
2018	21.94%	16.32%	5.14%	5.82%
2017	26.09%	19.87%	5.39%	4.36%
2016	33.35%	21.46%	6.62%	3.96%

Note: Counties with less than 4% of damages in 2017 are not presented

Employer Type

An excavator is a person engaged in excavation or demolition. There are also several types of employers, such as contractors and utility owners who hire excavators to perform an excavation. Contractors caused the most damage to underground utilities (75.4%), followed by municipalities (4.8%), and utility owners (2.7%). Employers who caused less than 3% of damages have been excluded for further discussion. Table 3 shows the number of damages per service type caused by

the major three employers. Figure 4 illustrates the percentage of damages to underground utilities per the major three employers who caused the most damages (i.e., 82.9%).

Table 3. Number of Damages per Employer and Service Type

	Contractors		Utility Owners		Municipalities	
	2017	2018	2017	2018	2017	2018
Tele/CATV	4,321	2,597	337	221	445	229
Electric	1,055	4,013	32	23	39	83
Water	611	518	10	7	6	10
Natural Gas	2,434	1,470	55	62	163	94
Sewer	48	65	4	0	3	3
Total	8,469 (78.8%)	9,062 (75.4%)	438 (4.07%)	325 (2.7%)	656 (6.33%)	527 (4.8%)

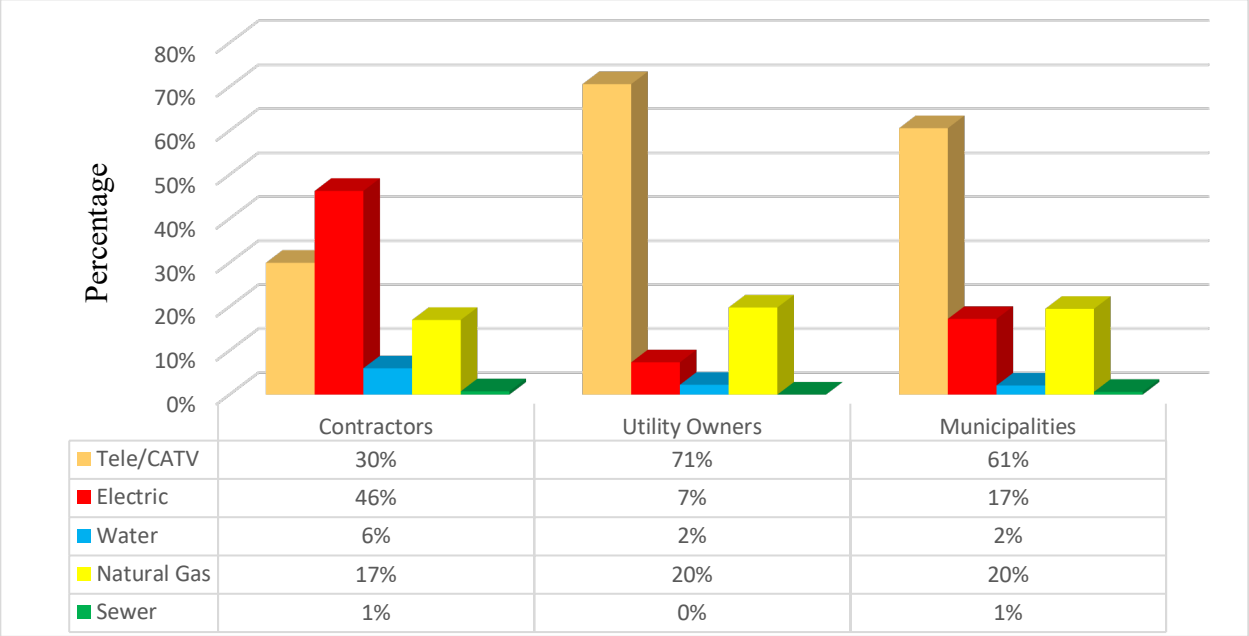
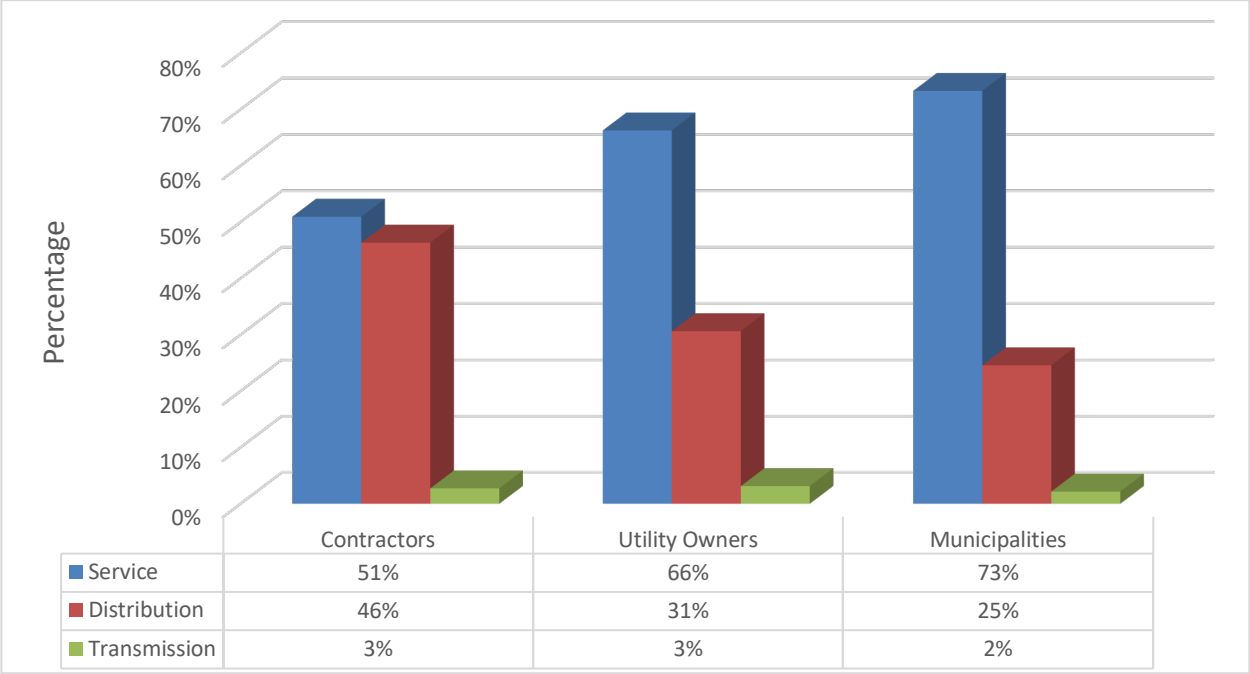


Fig.4. Damages to Underground Utilities per Employer Type

Finally, Figure 5 illustrates the services affected due to the damages. The service types are classified as transmission, distribution, and service lines. Transmission lines carry the service such as electricity, clean water, and natural gas to distribution lines that carry services to customers through the service lines. The overall data indicated consistency in affected service

types across major employers. It is also clear that damages to transmission lines represent a very small percentage. Transmission lines are deeper and well-marked in private rights-of-way (ROW). Furthermore, transmission lines that are not in private ROWs are usually along busy roads, not in neighborhoods. Also, Transmission Integrity Management has required pipeline personnel to be present during excavation to satisfy the Pipeline and Hazardous Materials Safety Administration (PHMSA). The higher risk of injury and potential cost of disruption to the transmission lines make these utilities a higher priority to the owners.



	Contractors	Utility Owners	Municipalities
Service	51%	66%	73%
Distribution	46%	31%	25%
Transmission	3%	3%	2%

Fig.5. The Affected Services per Type of Employer

Damages per Work Type

This section investigates damages per work type, within known data, to reveal if there is a type of work that contributes more than others to underground utility damages. The results suggest that most of the damages happened while conducting Tele/CATV work, followed by water/sewer work, electrical, and natural gas, see Table 4.

Figure 6 indicates that higher percentages of natural gas and water/sewer damages

happened while preforming Tele/CATV work. This finding is interesting since the depth of the Tele/CATV work should be less than other utilities. However, the increased use of horizontal directional drilling (HDD) could explain the high contribution of Tele/CATV. In recent years, HDD has become the method of choice for installing new underground utilities due to its minimal impact on the surface area and competitive cost. Thus, using HDD to install Tele/CATV may place them deeper than customarily expected which may lead to conflicts with existing lines and a higher rate of underground damages.

Table 4. Damaged Utilities per Work Type

Work Type	Damaged Utilities				
	CATV/Tele	Electric	Natural Gas	Water/Sewer	Total
Water/Sewer	1,662	342	220	15	2,239
Construction	537	80	132	28	777
Electric	814	135	155	57	1,161
Natural Gas	775	206	29	86	1,096
CATV/Tele	1,083	364	553	367	2,367
Other	633	97	142	15	887

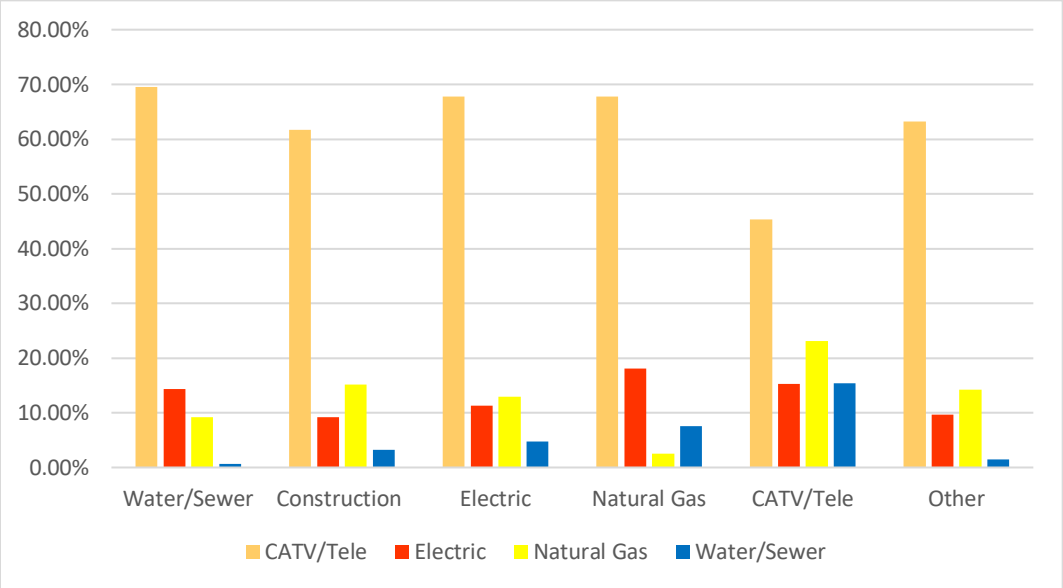


Figure 6. Damager per Work Type

Positive Response Trends

A ticket is created after each notification received by the NC 811notification center from an excavator. NC 811 transmits the received notification to the affected utility owners. Several transmissions are typically associated with each ticket, roughly a 5:1 ratio. Out of the 100 counties in the state of North Carolina, 51.7% (i.e., 5,716,009) of the 2018 transmissions were placed in the following counties: Mecklenburg (2,250,815), Wake (1,596,085), Guilford (593,202), Durham (489,725), Forsyth (449,797), and Buncombe (3365,385).

Positive responses are a requirement under the law, and a method for the members of NC811 to provide information to excavators regarding their ticket. The most frequent positive responses during 2018 were Code 10, followed by Code 20, Code 30, Code 999, Code 60, and Code 80, see Table 5. These six codes represent 97.38% of the total positive response codes. Figure 7 illustrates the percentages of the six codes per the major counties. The percentage of Code 999 in Durham County is the highest (10.85%) followed by Buncombe county (9.7%) and Mecklenburg (8.15%). These percentages suggest that a higher shortage of locators in these three counties, especially Durham county. Furthermore, the higher rate of Code 999 could be a result of low participation by utility owners in Durham County. Similarly, Forsyth seems to have higher rate of Code 30. Code 30 could be a reflection of locator shortage. The locators must put some code down even when they have not finished the job, so they use code 30. The data indicates that 58.5% of positive responses required more than the regulatory time, which is 3 business days in the state of North Carolina. This percentage is higher than the 2017 percentage by 10%. The numbers of business days (BDs) that were needed to provide a positive response in 2018 and 2017 are presented in Figure 8. The causes and remedies for this challenge are discussed later in the report.

Table 5. The Most Frequent Codes in 2018

Code	Number (%)	Code Meaning
Code 10	5,429,760 (39.7%)	No conflict, the utility is outside of the stated work area
Code 20	4,547,857 (33.2%)	Marked
Code 30	1,143,720 (8.36%)	Not complete
Code 999	1,003,417 (7.34%)	Member has not responded by the required time
Code 60	856,923 (6.27%)	Locator and excavator agreed and documented the marking schedule
Code 80	336,570 (2.46%)	Member's master contractor is responsible for locating facilities

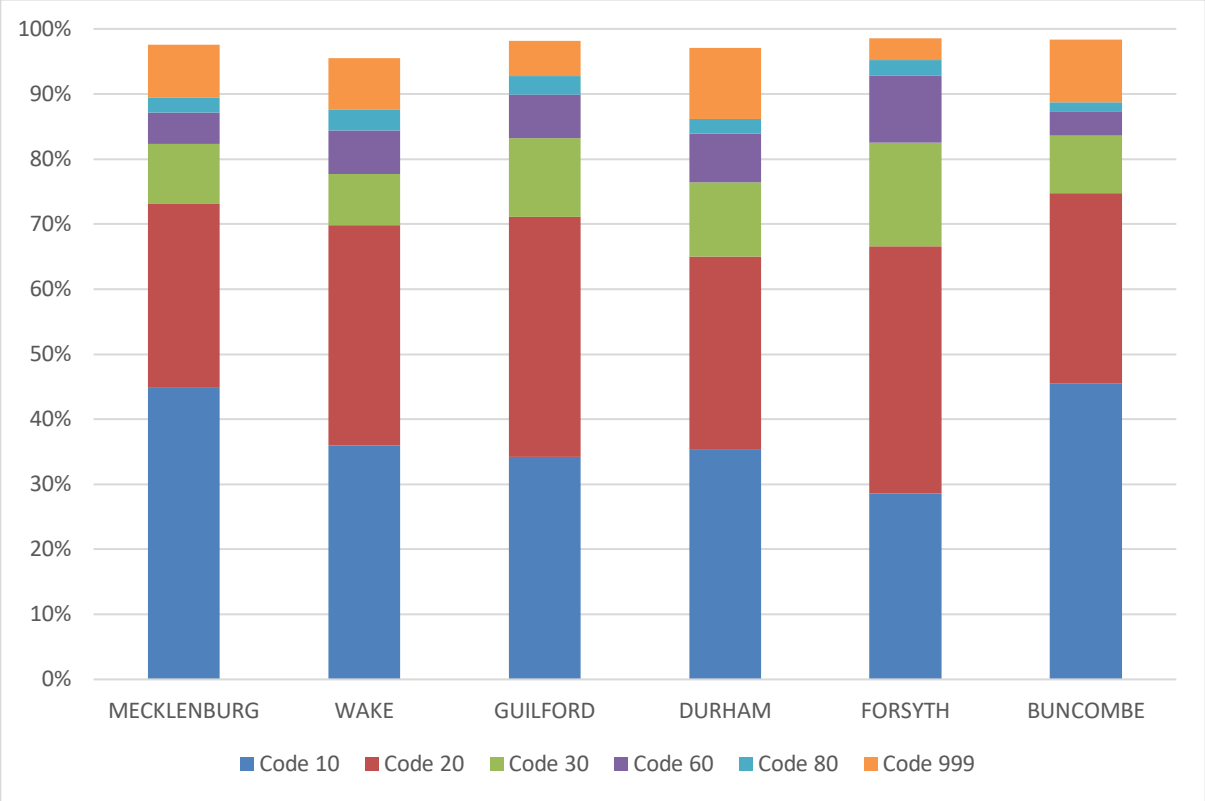


Fig. 7. Percentages of Major Codes

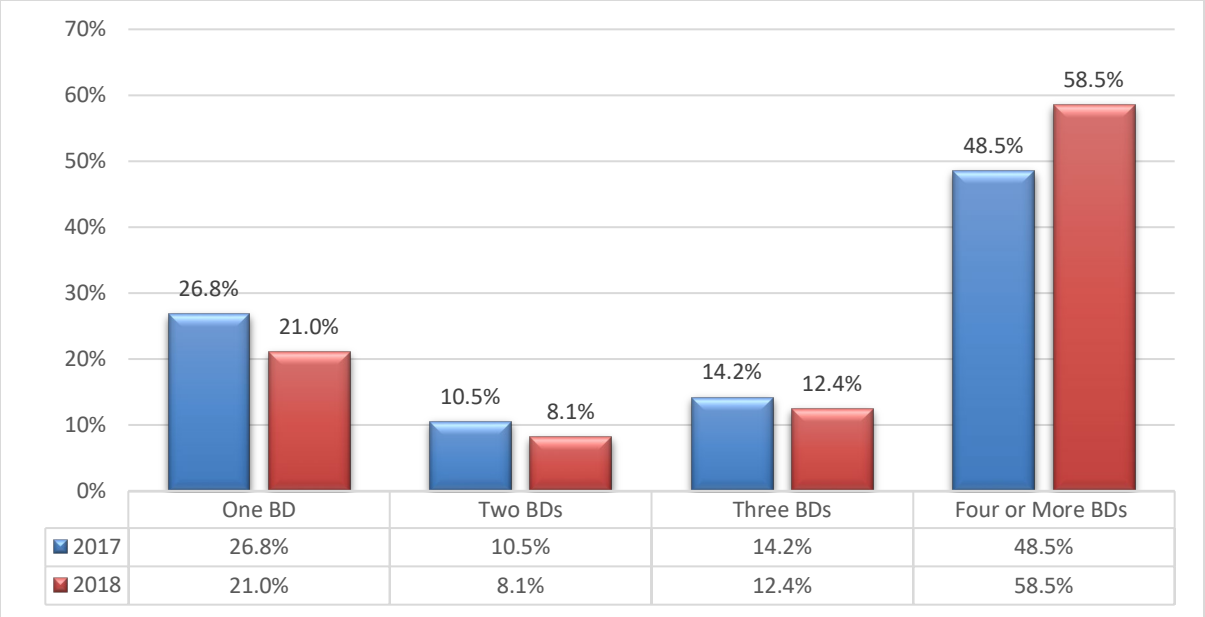
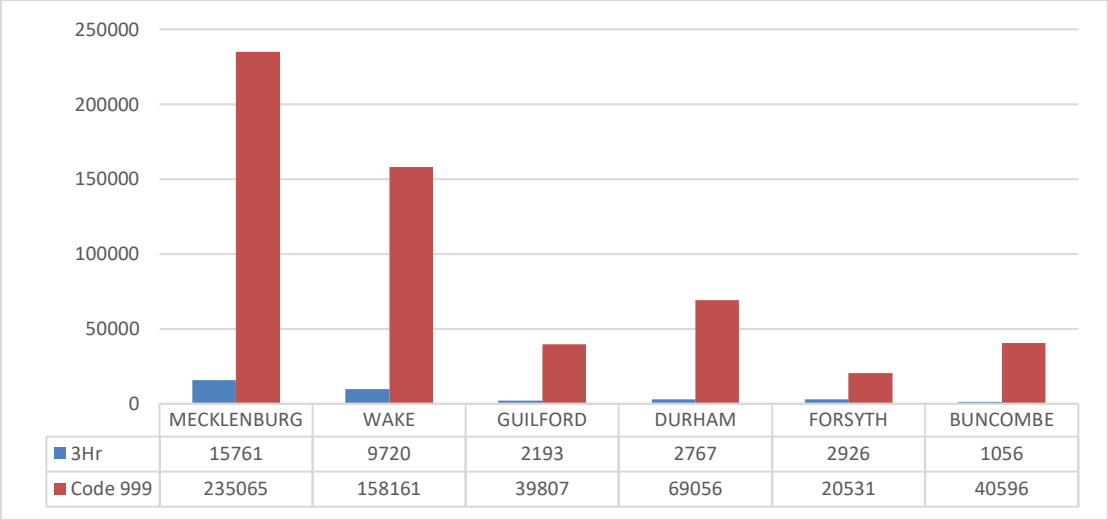


Fig. 8. The Number of Days Needed for Positive Responses

Three Hour Notice (3Hr) and Code 999

The utility owners must mark their utilities within 3 business days (BDs) according to the damage prevention act in the state of North Carolina. On the other hand, excavators shall not begin excavation until they placed 3Hr notice is when utility owners failed to mark their utilities within three BDs [87-122, (C) (2)]. Code 999 is assigned to a ticket when utility owners do not respond within the required time. In 2018, 51.7% (i.e., 5,716,009) of transmissions occurred in Mecklenburg, Wake, Guilford, Durham, Forsyth, and Buncombe. The percentages of the 3Hr notices and code 999 in these counties represent 62.9% and 56.1% of the total count, respectively. Comparing the overall number of 3Hr and Code 999 in these counties indicates that 3Hr notice is not fully utilized. For example, the number of 999 codes in Mecklenburg was 235,065, while the number of 3Hr notices was only 15,761, which leaves not enough explanation as how excavators often deal with Code 999, see Figure 9. Thus, educational and outreach efforts should clearly explain the importance of utilizing the 3Hr notice.



	MECKLENBURG	WAKE	GUILFORD	DURHAM	FORSYTH	BUNCOMBE
3Hr	15761	9720	2193	2767	2926	1056
Code 999	235065	158161	39807	69056	20531	40596

Fig.9. The Number of 3Hr Notices and Code 999

Field Perceptions

This section will discuss the findings of two field studies that have been funded by NC 811 and conducted through a collaboration with Construction and Safety Management, LLC (Dr. Al-Bayati), in order to improve the national damage prevention efforts.

Excavators Filed Study

The analyses presented in this section are the result of a survey completed by 477 excavators in October 2018. The goal is to improve the overall management of underground utilities by investigating current causes as well as best practices based on excavators' experiences. The key contributions of the study include, among others, recommendations to improve education material, tailoring construction firms' plans to address locating delay and inaccuracy and improving utility owners' locating efforts.

The job titles of the respondents fall within the following categories: Owner, Chief Executive Officer (CEO), and General Manager (46.9%), Project Manager, Superintendent, and Foreman (23.3%), Estimator, Scheduler, Engineer, and Geotechnical (6.9%), Subcontractor

(6.7%), and others (16.2%). The following are the areas of specialization of respondents' employers: 115 (24.1%) were residential contractors, 94 (19.7%) were public services departments, 48 (10.1%) were heavy construction contractors, 49 (10.3%) were special trades contractors, 28 (5.9%) were commercial contractors, 46 (9.6%) were utility contractors, and 97 (20.3%) represent other employers including homeowners, see Table 6. The percentages of employees were as follows: 249 (52.2%) had less than 10 employees, 114 (23.8%) between 10 and 50 employees, 38 (8%) between 50 and 100 employees, and 76 (16%) more than 100 employees, see Table 6. Most of the respondents represent establishments that hire less than 50 employees and could be classified as small construction firms. However, the revenue of respondents' employers varies. The revenue of 73 (15.3%) employers was less than $50,000 per year, 63 (13.2%) employers had between $50,000 and $100,000, 144 (31.2%) between $100,000 and $1,000,000, 98 (20.5%) between 1 and 5 million, and 99 (20.8%) more than 5 million, see Table 6.

The findings suggest that the locating service often takes more time than the statutory period (i.e., 3BD). Therefore, there is a need to continue monitoring the actual time required to complete locates and to issue positive responses across the United States. The visual inspection has been reported as one of the methods to verify positive responses. Besides being a violation of the law, the visual inspection method is not efficient because it does not ensure that all utilities have been marked. Therefore, excavators should utilize the methods that NC 811 provides to verify positive responses. Additionally, the findings suggest that firms with revenues under $50,000 annually and residential firms are more likely to utilize visual inspection. This outcome highlights an opportunity to redirect the educational efforts toward firms in need.

Table 6. The Study Sample Characteristics

Characteristics	Number (%)
Revenue	
Less than 50 K	73 (15.3%)
50K-100K	63 (13.2%)
100k - 1 Million	144 (31.2%)
1-5 Million	98 (20.5%)
More than 5 Million	99 (20.8%)
Number of Employees	
Less than 10	249 (52.2%)
10 -50	114 (23.8%)
50-100	38 (8%)
More than 100	76 (16%)
Establishment Type	
Residential	115 (16.2%)
Special Trades	49 (10.3%)
Civil and Heavy	48 (10.1%)
Commercial	28 (5.9%)
Private Utilities	46 (9.6%)
Public Services	94 (19.7%)
Construction - Other	97 (20.3%)

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The investigation of the damages' causes indicates that the lack of information about the depth of underground utilities is the most contributed factor. The legislation requires utility owners to mark the location of their utilities on the x-y plane, even though the current technology could provide the depth (i.e., z-axis) with some limitations. While inaccurate marking has been scored second, see Table 7. This deficiency will not be eliminated soon because of the following reasons:

- Underground utility maps are incomplete and out-of-date (i.e., as-planned vs. as-built) (Li et al. 2015; Talmaki 2013; Goodrum et al. 2008).
- The current shortage of skilled locators leads to locators being rushed or insufficiently trained.
- The possible interference of nearby utilities including abandoned utilities
- The easily defaced marking materials.
- The technical limitations of locating tools

The inaccurate marks could lead to underground utility damages by providing false confidence to excavators (Li et al. 2015). Therefore, excavators must be aware of the limitations of current locating practices to avoid false confidence. Also, the respondents suggested the accuracy of the marks of CATV/Tele utilities are lower than other underground utilities such as gas and electricity. This requires further investigation to uncover the reason behind it, which is crucial due to its potential contribution to the recorded higher rates of damages to telecommunication and TV utilities over the years. For example, 57% of damages to underground utilities in 2017 occurred to telecommunications and TV (DIRT Dashboard 2018). Therefore, further discussion will be carried in the locators' study section.

Participants placed "relying on general contractors to notify the one-call center" or "landowners' advice that it is safe to dig" as the third reason for damages to underground utilities.

Accordingly, this leads to a failure to notify the one-call center, and as a result, no locating is performed. It is the excavators' responsibility to verify and document that a notification has been placed, and a positive response has been issued before pursuing excavation. This challenge could be resolved by adopting a legislation approach similar to the Occupational Safety and Health Administration's (OSHA) multi-employer worksite policy. Excavators' commitment to damage prevention and work conditions (e.g., schedule obligations, budget limitations) have been placed as the fourth cause. Completing construction activities on time and budget is the core value of the construction industry. Therefore, construction practitioners often do their best to satisfy schedule and budget constraints. As a result, funding and scarce resources are significant obstacles to the implementation of technology to prevent damages (Quiroga and Anspach 2016). Therefore, schedule and budget constraints could contribute to overall damages, especially low-risk damages (e.g., telecommunication and cable tv). High-risk damages (e.g., gas and electricity) often lead to longer work interruptions, and as a result, construction practitioners may place a higher emphasis on compliance around potentially high-risk damages. Construction practitioners often try to avoid interruptions in their work (Hyari and Elrayes 2006). However, this is not the case with low-risk damages since their potential impacts on construction projects' schedules and budgets are minimal. The low penalty for non-compliance was also scored forth, see Table 7. Penalties are the primary method of enforcement required by regulations. Effective enforcement, not education, is most likely to succeed in improving site safety in the short-term (Mahalingam and Levitt 2007). Thus, a fair penalty is required to increase the influence of damage prevention efforts. However, effective enforcement itself can include education in addition to financial penalties.

Currently, penalties vary based on the state where the damage occurs. In North Carolina, penalties include training and a civil penalty not to exceed $2,500 (Al-Bayati and Panzer 2019).

However, there have been only three violations that resulted in a financial penalty recommendation since October 2014 in the state of North Carolina (Al-Bayati and Panzer 2019). Having rules or regulations that are not effectively enforced may send the wrong message to the excavators. Penalties are appropriate to modify both the excavator's and the utility owner's behavior. Thus, it may be reasonable to reevaluate the current enforcement processes, especially for repeat offenders.

Table 7. Root Causes based on Excavators' Experience

Group Number	Deficiency	M	SD
1	• Lack of depth information provided by locators	6.38	3.3
2	• Marks were too far from the utilities	5.8	3.0
	• Temporary nature of marking	5.7	3.2
3	• Excavators relied on the general contractors to notify one call center	5.18	3.3
	• Excavators relied on the landowner's advice it was safe to dig	4.96	3.5
4	• Excavators do not wait for three working days	4.28	3.1
	• Schedule Tight and cannot afford to hand dig within 2 ft of the marks	4.15	3.2
	• Penalties are too low	3.85	3.1
5	• It is less expensive for excavators to damage utilities than to excavate safely	2.98	2.89

Locators Field Study

In this study, utility locators' perspectives were collected, analyzed, and compared to excavators' perspectives and responses that were previously reported in this report. Surprisingly, the results suggest that stakeholders' behaviors (i.e., human factor), neither technology limitations nor

current policies, significantly contribute to a breakdown of the damage prevention process. Specifically, communication between stakeholders, excavators' behaviors, and locators' working conditions have been identified as crucial factors in the damage prevention process. There are few, if any, empirical studies that have recognized the human factor as a contributing factor to utility damages. The survey was administered between March and May 2019, and 98 responses were received. The job titles of the respondents fell within the following categories: Locate Technician 44 (44.9%), locate Manager 30 (30.6%), and locate supervisor 24 (24.5%). The answers to the question about the participants' experience indicate that 81 (82.6%) respondents have more than three years of experience, 14 (14.3%) respondents have between 1-3 years of experience, and 3 (3.1%) respondents have less than 1 year of experience. The educational background of respondents mostly falls within US high school 26 (26.5%) and some college or beyond 68 (69.4%). The age of participants falls between 20 years and 66 years (M = 43.24, SD = 11.1). Finally, the respondents came from North Carolina 43 (43.9%), New Jersey 10 (10.2%), California 8 (8.2%), South Carolina 6 (6.1%), and other states such as Texas, Virginia, and Maryland 31 (31.6%). The respondents were also asked to provide information about their working conditions. Table 7 shows the working conditions of locators, including the number of working days per week and the number of locates, working hours, and driven miles per day. Most locators (i.e., more than 50%) work up to 10 hours and drive more than 75 miles every day. Comparing the number of locates per day presented in Table 1 with the years of experience reveals that more experienced locators can complete a higher number of locates per day, see Figure 10.

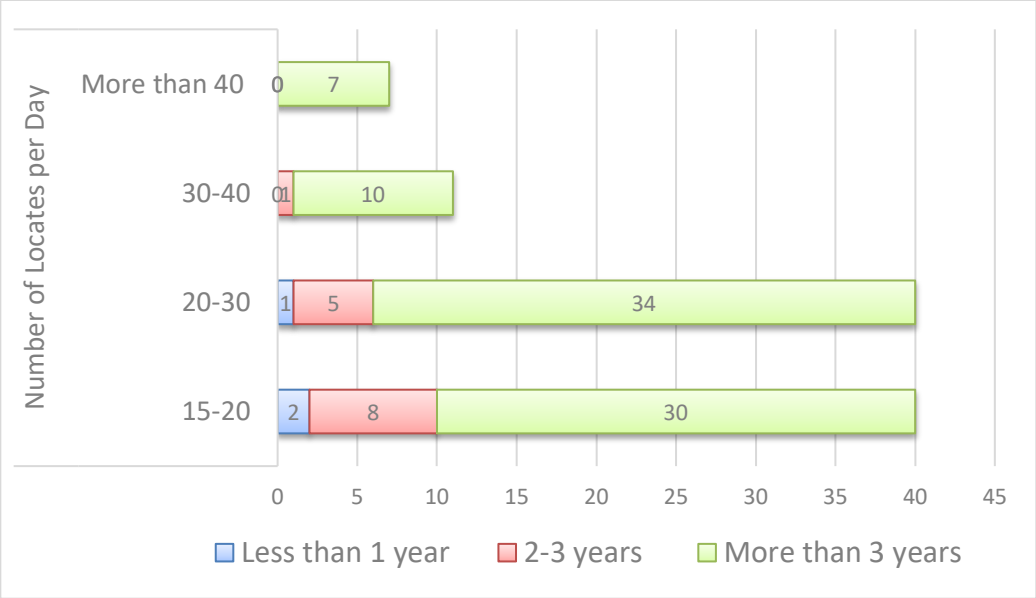

Fig. 10. Number of Locates per Locators' Experience

Table 8. Locators Working Conditions

Characteristics	Number (%)
Locates per Day	
15-20	40 (40.8 %)
20-30	40 (40.8 %)
30-40	11 (11.3%)
More than 40	7 (7.1%)
Working Days per Week	
1-4	4 (4.1%)
5	56 (57.1%)
6	32 (32.7%)
7	6 (6.1%)
Hours per Day	
6-8	12 (12.2 %)
8-10	60 (61.3 %)
More than 10	26 (26.5%)
Miles Driven per Day	
Less than 25 miles	6 (6.1%)
25-50	22 (22.4%)
50-75	29 (29.6%)
More than 75	41 (41.8%)

Al-Bayati and Panzer (2019b) have suggested eight causes of locates inaccuracy. Accordingly, participants were asked to score the eight suggested causes of locates inaccuracy from 1-10, where 1 means totally disagree, and 10 means totally agree. The suggested causes are:

1. The locators being in a rush due to the workforce shortage
2. The locators do not get enough training
3. Inaccurate maps
4. Some utilities were installed with looped lines that were not marked
5. The utility location gets obscured due to material interference
6. The utility location is unlocatable due to a broken tracer wire
7. The utility location gets obscured due to vegetation growth
8. The locating equipment limitations

A factorial ANOVA was conducted to determine if there is a statistically significant difference between the suggested causes based on participants' experiences. The results indicate a statistically significant difference in the score of causes (F= 131.3; df =7, 776; $p < 0.001$). Follow-up tests were conducted to evaluate the pairwise differences among the accuracy scores of utilities. Accordingly, Tukey's Honestly Significant Difference (HSD) tests were conducted on all possible pairwise contrasts. The results revealed that "the locators being in a rush due to workforce shortage" is statistically significantly the most contributing cause to locate inaccuracy (i.e., score average is 7.04) followed by "Inaccurate maps" and "The utility location is unlocatable due to a broken tracer wire." Table 8 illustrates the groups that were found to be significantly different ($p < 0.05$). The scores of causes based on locators' perspectives are different than those based on excavators' perspectives, as was reported in Al-Bayati and Panzer (2019b). However, both excavators and locators scored the "locators being in a rush" as the most contributor to inaccurate locates and the accuracy of utility mapping second, see Table 9.

Broken tracer wire contributes significantly to inaccurate locates according to locators' perspectives (i.e., 2nd group), while this issue contributes less according to excavators' perspectives (i.e., 4th group), see Table 8. Locators also suggest that the training quality is the third contributing factor, not the first as excavators suggest. The research team believes that comparing the perspectives of locators and excavators is crucial to identifying areas of misunderstanding, which in turn will help to improve education and damage prevention efforts. In addition, it is anticipated that the locators' perspectives towards inaccuracy causes are more valid due to their work experience.

Table 9. Homogeneous groups of causes from the most to the less contributing Cause

Group #	Group # (Al-Bayati and Panzer 2019b)	Cause	Score Average
1	1	The locators being in a rush due to the workforce shortage	7.04
2	4	Broken tracer wire	6.67
	2	Inaccurate maps	6.42
3	1	The locators do not get enough training	5.83
	4	The utility location gets obscured due to material interference	5.27
4	4	The utility location gets obscured due to vegetation growth	4.54
	3	Utilities were installed with looped lines that were not marked	4.20
	N/A	The locating equipment limitations	4.09

On the other hand, Al-Bayati et al. (2019) suggested that the time to complete locates is often more than the legislated time (e.g., 3 BDs). However, the factors that contribute to late locates

have not been previously identified. Therefore, the participants were asked about several potential factors that have been suggested by stakeholders during the survey pre-test as well as based on the experience of the Executive Director of NC 811. The suggested factors are workforce shortage, inaccurate maps, tickets that should be survey/design, no white lining, and wrong update tickets. Workforce shortage seems to be a significant challenge that contributes to late locate, see Table 10. The responses suggest that inaccurate maps are an issue locators face on a regular basis (26.6%), or at least from time to time (59.2%), see Table 10. A design/survey ticket should be created by firms or individuals during the design phase. Design/survey tickets are intended to be used when excavation is not taking place. The legislated time to respond to a design/survey ticket is 10 business days instead of the 3 full business days. In addition, a response to a design/survey ticket could be either a physical locate, provision of maps, or access to the maps provided by the utility. A large portion of the study sample indicates that excavation tickets are being requested instead of design/survey tickets on a regular basis (30.6%) or from time to time (44.9%), see Table 10. This is could be a result of the fact that architectural/ engineering firms want a physical locate and they understand that a locate is not an automatic guarantee with a design/survey request or they do not want to wait 10 days to get a response. This misidentification places an unnecessary load on locators. The white lining around the proposed excavation area should be made by contractors when the area cannot be adequately described in the ticket. The white lining must be made with soluble white paint, white flags, or white stakes. The white lining is very important to accurately locate the utilities within an acceptable time. Unfortunately, white lining seems not to be a practice that is performed consistently as needed by the excavators, see Table 10.

Table 10. Factors that Increase locating time

Factor	Never	Rarely	Sometimes	Often
Workforce Shortage *	8 (8.2%)	16 (16.3%)	53 (54.1%)	21 (21.4%)
Inaccurate maps *	1 (1%)	13 (13.3%)	58 (59.2%)	26 (26.5%)
Tickets that should be Survey/Design	7 (7.1 %)	17 (17.3 %)	44 (44.9%)	30 (30.6%)
No White Lining	1 (1%)	6 (6.1%)	32 (32.7%)	59 (60.2%)
Update Tickets - works have not begun	(1%)	8 (8.2%)	37(37.8%)	52 (53.1%)
Update Tickets - works have completed	0 (0%)	15 (15.3%)	47(48%)	36 (36.7%)

* This factor contributes to inaccurate locate as well, see Table 9

The current literature often focuses on damage prevention technology and the physical conditions of underground infrastructure. Accordingly, the main contribution of this study is highlighting the human factor that contributes to underground infrastructure management in the United States. Specifically, understanding and identifying the required and desired behaviors of the stakeholders will certainly improve the process efficiency. At the same time, it is critical to understand how deviations (i.e., undesirable actions) from the desired behavior of stakeholders can compound issues such as delayed and incomplete locates. Undesirable actions can quickly create a snowball effect that compromises the damage prevention efforts. For example, the study reveals that abusing the one-call notification system by placing false emergency tickets or incorrect ticket types (e.g., placing 3Hr ticket instead of marks damaged ticket and update ticket when the work has not started yet) is a common practice that significantly increases the locators' workload. This unnecessary amount of notifications creates system noise. The effect of the system noise would not be limited to longer locating the time, but rather could create a compounding effect that leads to many undesirable scenarios such as:

- Excavators may decide that it makes sense to place tickets weeks in advance of when the actual work starts.

- Excavators may lose confidence that the locates will be completed on time. In this case, the excavator may place a series of tickets with the hope that some of the work will be located within time, and those will be the jobs they move the crews to work on.

On the other hand, locators can also contribute to system noise. For example, locators had used positive response codes such as code 60 (i.e., the locator has spoken to an excavator and arranged a schedule) and code 32 (i.e., the locator was unable to reach the excavator, and there is need to speak with them), when in fact those actions did not take place. As a result, the process must be built on a foundation of trust among stakeholders that each party handles their portion of the responsibility. Table 5 shows the desired behavior of the stakeholders (i.e., utility owners, locators, excavators, and one-call centers). When a party does not feel that they can trust the other, or abuses the system with his/her undesirable actions, the potential for the creation of noise occurs.

The size of the area that the locator needs to mark has been identified as a challenge for locators. An excavator may call both sides of the road for a possible road bore. In this case, the excavator should be white lining the specific area of boring. Otherwise, locators have to locate the whole area, which requires a considerable amount unnecessary time and effort. Thus, white lining is crucial for the prevention damage process. The white lining has been recommended as one of the best practices in CGA's best practices guide (CGA 2019). Based on the study findings, the authors believe the white lining should be a mandatory practice. Similarly, it is a common practice that excavators request a whole property to be marked when the excavation is taking place in a small portion (e.g., front easement or left side of the home). Thus, the excavators should be specific regarding the ticket area. Similarly, the law should be specific and reasonable regarding the ticket area. For example, the existing law in North Carolina requires that the size area not exceed a quarter-mile or five contiguous addresses. The intent was that the smaller of these two criteria

would guide the creation of a manageably-sized ticket. However, the language did not clearly mandate whichever is lesser. Therefore, any request could default to a quarter-mile. Accordingly, The North Carolina law taking effect on October 1, 2019, provides new language requiring the lesser of five adjacent parcels or a quarter-mile to be used when creating a single locate request. Overall, the law should ensure that the proposed area satisfies the stakeholders' needs and limitations, especially the locators. As a result, the shared responsibility among stakeholders, including one-call centers, is a critical factor in ensuring the system's reliability and workability. Shared responsibility calls for teamwork among stakeholders, which creates a smoother work process, as has been suggested by Farnsworth et al. (2017). Beyond the human factor role, the inaccuracy of locates will always present a possibility that construction firms should consider. The inaccuracy could be a result of a wide range of issues such as the coupling effect and abandoned utilities (Metje et al. 2015, Al-Bayati and Panzer 2019b). The abandoned utilities are not just compromising the locate accuracy; they also confuse excavators by giving them false confidence that they have uncovered the marked underground utility and they are fine to use a mechanical excavator. Abandoned utilities are caused by utility owners removing them from the services as well as the maps. There have been proposals that abandoned utilities must be marked. However, this has been recognized as an impossible task if the records no longer exist.

Locate Services Costs - Segra Case Study

In early 2019, Segra, a telecommunications provider, began to take steps to reduce escalating locate services costs. An analysis of 811 portal reporting and contractor invoicing was performed, and among the more notable cost categories to surface, were update tickets generated by Segra fiber construction projects. Segra was generating 1100 update tickets per month, on average. Further analysis revealed that the majority of these update tickets were carried forward over a period of months and were entered on the same date, indicating potential procedural problems. It was quickly determined that Segra contractors were entering tickets for multiple project miles, far

exceeding the rate that would be necessary to accommodate standard construction intervals and production rates for those projects. In other words, quantities of tickets submitted to 811 exceeded fiber build production rates by a large degree. As a result of this practice, these tickets would approach expiration, and subsequently get updated in 811, generating unnecessary costs both in terms of locate contracting services, and 811 fees. In addition to this, Segra was able to find a correlation between excess update tickets and late ticket notices and missed locates.

As a result of these findings, A series of conference calls and in person meetings were held was initiated to educate and train Segra contractors on proper ticket submission procedures in an attempt to reduce update ticket volumes. Segra utilized 811 portal data to identify high volume contractors in terms of update tickets. Accordingly, Segra found that two contractors, out of a field of 20 who were contributing more than 90% of all update ticket traffic. As a result, update ticket volumes began to decline sharply within one month of this approach, see Figure 11. Furthermore, a follow up revealed that new contractors coming on board also needed to be introduced to the utility's commitment to better process management.

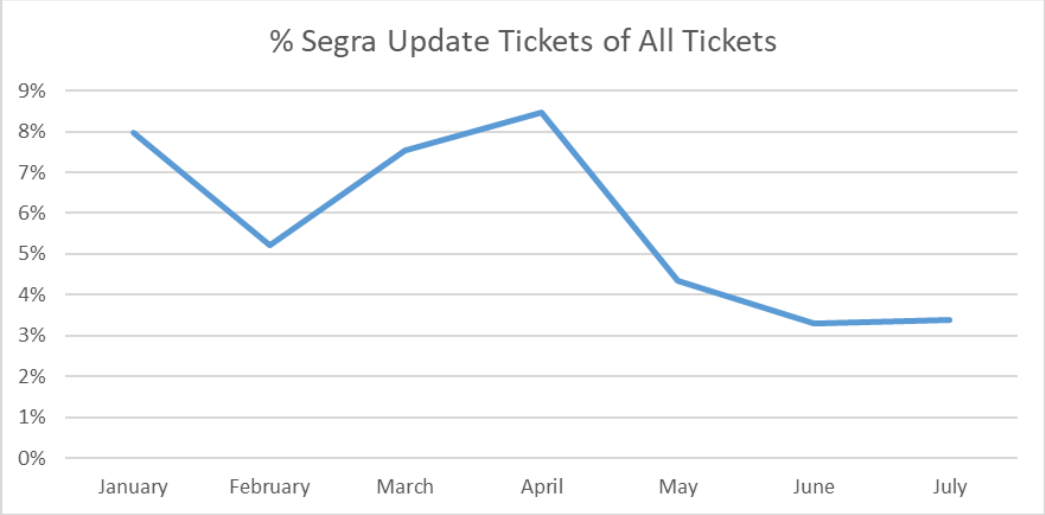

Fig. 11. The Reduction of Updated Tickets

Recommendations

Vital services like clean water, sewer, and electricity utilize underground infrastructure. Unfortunately, many damages to underground utilities are happing because of construction activities. Therefore, there is a need for greater understanding of damage causes to better manage

risks to underground utilities. The two field studies provide a detailed description of the process and deficiencies of damage prevention efforts. The study reveals several opportunities that could help improve underground damage prevention practices across the United States. Accordingly, one of the main recommendations of this study is to ensure that the education material includes the following topics:

- Excavators awareness training: The awareness should include information about the process of damage prevention, the type of tickets that excavators can utilize, the consequences of placing incorrect or false tickets, and the limitation of the current process (e.g., coupling effect, abandon lines, broken tracers, and weather impact). The importance of clear communication (e.g., contractor representative (CR) and white lining) with locators and the one-call center should be the core of awareness and educational efforts. The excavator should fully understand the process and the possible negative impact of placing an incorrect ticket type. For example, while locators indicate that broken tracers contribute significantly to inaccurate locates, many excavators seem not to be aware of the tracer wires. Thus, it is expected that they will not report the damaged tracers, even though there are no financial penalties for breaking a tracer, and utility owners fix the tracer wirers for free. Furthermore, the suggested definition of utility damage does not include tracer damage. For example, Makana (2018) stated that utility damage happens when any element of the utility network get damage during excavation. Similarly, Bernold (2003) defines the utility damage as the disruptions that occur to subsurface services such as telecommunications and electricity. In addition the following components should include:

- The legal requirements and acceptable methods to verify the positive response.
- Excavators' responsibility to notify the one-call center or verify that general contractors or landowners have already notified the one-call center must be emphasized to reduce notification error.
- The temporary nature of marks and best practices to sustain them against weather and work conditions.
- The importance of photographic documentation of the job sites before, during, and after excavation.

- Locators awareness training: The awareness should include information about the process of damage prevention, the meaning of the codes used for positive responses, the consequences of incorrect positive responses, the limitation of the current process and how to reduce its impact, and the importance of clear communication with field personnel and utility owners. For example, the study revealed that inaccurate maps negatively impact the accuracy of locates. Similarly, locators indicate they often deal with inaccurate maps. Thus, it is crucial to open a communication channel between locators and utility owners to report inaccurate maps in order to update them.

Also, it is recommended to direct education toward residential construction firms and construction firms with revenues under $50,000 annually since the data shows a lack of compliance among these types of construction firms. In addition, construction firms must consider the fact that locating time may take more than legislated time. Thus, construction firms should tailor their project scheduling to address this deficiency in current practices. Furthermore, the following best

practices should be utilized:

- The excavators' study indicates that the lack of utility depth information provided with locating marks is the most contributing factor to damages to underground utilities, despite the fact that some of locating equipment could provide the depth. Thus, construction firms could invest in locating equipment to double-check the locating marks and to provide the depth information.
- Improving the marks' visibility and response time should be on the utility owners' agenda. Currently, the main obstruction against improving the locating visibility and response time is the cost to utility owners. Therefore, incentives to the utility owners are necessary.
- A utility agreement plan between construction firms and utility owners should be utilized for large projects (Sweeney 2010). Also, the agreement between construction firms and utility owners supersedes the state prevention act. As a result, it benefits construction firms that have projects across the United States to have a unified management method for addressing existing underground utilities.
- For small projects, a plan identifies who should notify one call center must be created and communicated so that the responsible party bearing responsibility notifies the one-call center. This is needed to manage the relationship between homeowners and excavators properly. However, it should be realized that utility owners will not locate the homeowners' and landowners' private facilities. Thus, excavators should rely on the homeowner/landowner or a private locator, and if they are in error, it is not the excavator's fault.
- Subsurface Utility Engineering (SUE) should also be utilized when applicable. The SUE method outlines the steps that the American Society of Civil Engineers (ASCE) has

suggested to mitigate the risk related to underground utilities (ASCE 2003). The method suggests four levels of quality regarding the management of the underground utility. The quality level is determined by the means and methods used to gather the information.

The current working conditions of locators seem to be an important factor in damage prevention. Lack of time seems to be the first contributing factor to inaccurate locates. Al-Bayati and Panzer (2019b) suggested hiring more locators to overcome the lack of time. However, the locators' study reveals that the lack of time could be a result of insufficient communication or incorrect information provided by excavators. Thus, it is important to improve overall communication between locators and excavators to reduce the overall locating time. Excavators should visit the site before placing the ticket to ensure that the site is accessible as well as to white line the excavation area. In addition, it is vital to have an active enforcement process to reduce abuses of the system. Additionally, further requirements should be enforced to better manage broken tracers and abandoned utilities.

The identified best practices and undesirable actions should also be incorporated into states' damage prevention acts (i.e., one-call state statutes). Although one call statutes vary from state to state, there are common themes. In 1998, PHMSA convened a meeting of 16 industry stakeholders from underground utility safety and damage prevention industries that resulted in CGA's best practices guide (CGA 2019b). Thus, Thus it is hoped that the CGA Best Practices Committee consider the findings of this research as a potential inspiration for future recommended best practices.

Finally, ASCE 38-02 provides a standard for defining four quality levels of utility locates through Subsurface Utility Engineering (SUE), which is a branch of engineering practice (ASCE

2002). While these four levels are mostly based on an engineer's involvement, the standard does not clearly highlight the importance of the cooperation needed to provide higher quality performance. According to Anspach and Scott (2019), civil engineers are responsible for managing associated risks while working around underground utilities. Thus, there is also a need to incorporate the findings of this study into the ASCE 38 to improve the performance of civil engineers who are responsible for managing underground utilities.

Finally, while the field research has identified the challenges with excavation and with locating, the most significant stakeholder that can serve as a change agent is the utilities themselves. When reviewing the top excavators contributing to system noise it becomes evident that the majority are working either directly for or as contractors to the utilities (e.g., Segra case study). Maintenance activities and new service installation contribute heavily to the workload generated by the Notification Center. Therefore, educating the utility companies as to the impact of work process is a critical component to the success of any reduction in "system noise" such as excessive updates that has been discussed in Segra case study. In an effort to support communication, sharing of field photos from locators with excavators could significantly enhanced positive response. Thus, the utility owner, who also own the field photos taken by the locators, should agree to make them available to the excavators. Furthermore, the locators indicate that improved, up to date maps would help with accuracy when identifying facilities. The key to making process changes occur is to educate about:

- The direct and indirect cost benefits to the utilities in establishing and enforcing notification process improvement.
- The provision of locate information (such as pictures and videos) to excavators through use of enhanced positive response.

- The importance of providing the most current, detailed maps to locators working to protect their facilities.
- The importance of the provision of damage data for the purpose of developing proactive, damage prevention predictive tools.

Conclusion and Ongoing Field Research

The responsibility of protecting infrastructure from third party damage falls on all parties involved in the process. The success of each element of the safe digging process is predicated by the action taken in the previous step. Therefore, all parties should review their contribution to the overall system and make corrections that can prevent unnecessary noise in a process that is understood by everyone to help protect life, health and property. The authors hope this research can help others to follow suit in identifying the stress points within their own jurisdictions to affect meaningful industry change.

Finally, A follow-up survey is currently ongoing to evaluate the overall improvement in NC 811's performance between 2018 and 2019 which would help improving the overall performance. The follow-up survey will be conducted during September 2019.

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