North Carolina 811, Inc

2021 NC 811 Annual Report

NC 811 Annual Report – 2021

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TABLE OF CONTENTS

Suggested Citations

Al-Bayati, A. J., and Panzer, L. (2019) "Reducing Damages to Underground Utilities: Lessons Learned from Damage Data and Excavators in North Carolina." Journal of Construction Engineering and Management, American Society of Civil Engineers. 145 (12), DOI:10.1061/(ASCE)CO.1943-7862.0001724

Al-Bayati, A. J., and Panzer, L. (2020). "Reducing Damages to Underground Utilities: Importance of Stakeholders' Behaviors." *J. Constr. Eng. Manage.*, American Society of Civil Engineers, 146(9), 04020107

Number of Damages Reported in 2020

There were 37,127 reported underground utility damages incidents in the state of North Carolina in 2020. However, there was an anticipation that in some cases, multiple reports of the same damages were duplicated. Accordingly, several steps have been followed to remove the potential multiple reports of a single incident by different reporting entities, including but not limited to:

- Comparing the addresses in the NC 811 database with the database of registered North Carolina addresses (i.e., 4,900,000) utilizing fuzzy string matching.
- Creating a list of addresses that consolidated existing and corrected addresses via Fuzzy and manual verification.
- An assumption that no more than one damage per the same type of facility had occurred within 7 days at the same address. If these were identified in the data, they were treated as one unique incident.

This methodology reveals 5361 potential duplicates, see Figure 1. Accordingly, the potential true number of reported damages is 31,766 in North Carolina in 2020. Readers must be aware that this number differs from the reported damages in North Carolina by the Common Ground Alliance's Damage Information Reporting Tool (DIRT) report. The estimated number of damages based on the DIRT report is 26,778.

Overall, the potential number of damages based on the NC 811's duplication removal method indicates a higher number of reported damages than in the previous years, as shown in Table 1. It must be noted that, prior to 2020, reported damages from a particular locate contractor were not shared with NC 811 and were therefore not included in the 2016 – 2019 damages represented in Table 1. The inclusion of damages reported by this particular locate contractor is reflected in the much higher number in the 2020.

Table 1. The Number of Reported Damages to NC 811

Year	2020	2019	2018	2017	2016
Damages Number	31,766	15,621	12,024	11,160	15,171

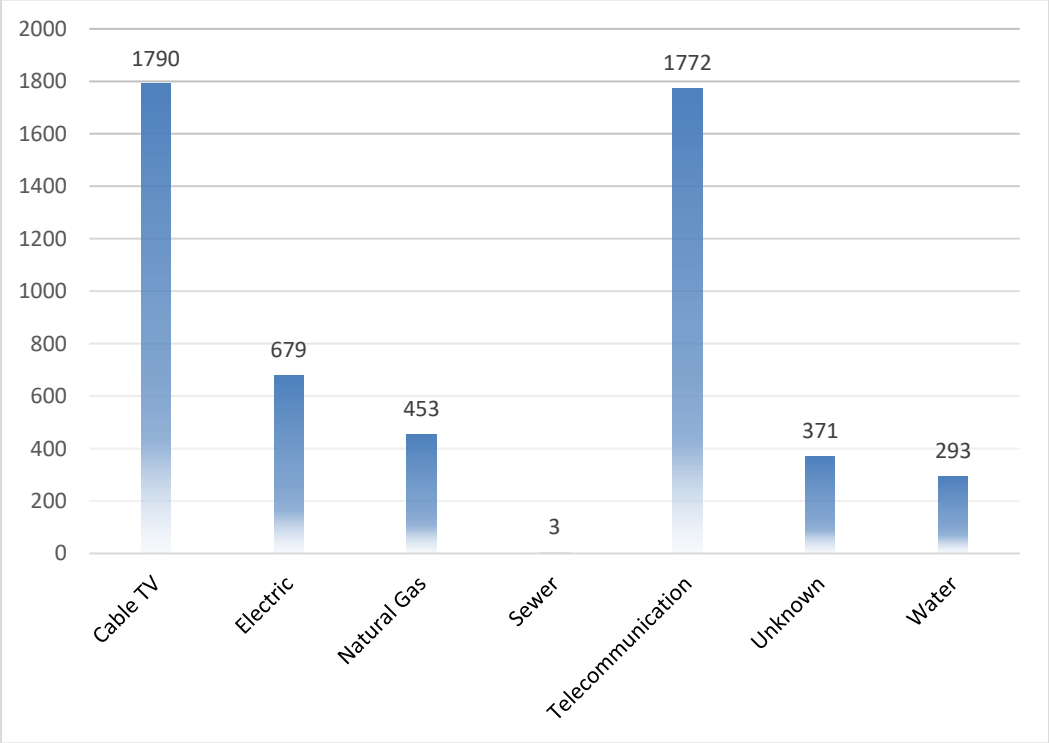


Fig. 1. The Potential Number of Duplicates in NC 811 Data Per Facility Type

The Cause of Damages

Third-party damages to the subsurface infrastructure seem to a persistent issue that negatively influences the integrity of underground utilities and its vital services to citizens of North Carolina. North Carolina 811 (NC 811) has been conducting research studies to identify causes and remedies of third-party damages. The studies solicited stakeholders' (i.e., excavators, locators, and utility owners) perceptions about the topic. Clearly, there are several factors contributing to third party damages which reinforces the industry understanding that preventing damages is a shared responsibility. Overall, the direct causes of third-party damages could be grouped into four categories:

1) excavators' insufficient practices,

2) locators' insufficient practices,

3) utility owners' insufficient practices, and

4) General industry practices.

- Excavators' insufficient practices (EIP) include damages resulting from no locate requests, invalid use of a locate request (e.g., wrong area was excavated), and failure to use hand tools to uncover subsurface utilities. In North Carolina, the following direct causes fall under this category:
    - No notification made to the one call center/811
    - Excavator dug prior to valid start date/time
    - Excavator failed to maintain clearance after verifying marks
    - Excavator dug prior to verifying marks by test hole (pothole)
    - Excavator provided incorrect notification information
    - Excavator failed to protect/shore/support utilities
    - Excavator dug outside area described on ticket
- Locators' insufficient practices (LIP) include inaccurate marks and the absence of marks. In North Carolina, the following direct causes fall under this category:
    - Unmarked or inaccurately marked due to locator error
    - Incomplete locates
- Utility owners' insufficient practices (UOIP) include the following:
    - Inaccurate utility record/maps
    - No response from operator/contract locator
    - Unlocatable facilities

- General industry practices that may be a result of common industry practice or work conditions. In North Carolina, the following direct causes fall under this category:
    - Abandoned facilities
        - Abandoned facilities do not belong to any utility owners/operators; they contribute to less accurate marks and more damages. They are not a result of a particular stakeholder practice. Rather, they are a result of a general industry lack of sustainable processes to keep records of abandoned facilities. Thus, this challenge should be addressed by a national effort to better manage these facilities.
    - Temporary nature of marks
        - The temporary nature of marks was ranked second in the causes of damages as suggested by excavators (Al-Bayati and Panzer 2019). Marks can be faded or lost due to weather and work conditions, and marks are removed as soon the excavation starts.
    - Previous damage
    - Deteriorated facility
    - Tracer wire issue
        - Utility owners/operators often apply tracer wire to plastic facilities to help locate them. Damages to tracer wire could be perceived as low-risk damages by excavators (Al-Bayati and Panzer 2019). Largely, low-risk damages (e.g., telecommunication and television damages) have lower potential monetary impact on construction project schedules and budgets, unless they involve fiber-

optic telecommunication lines. Therefore, low-risk damages are often not reported. Broken tracers contribute significantly to inaccurate locates.

These insufficient practices not only cause damages but also compromise the entire one call system, as has been discussed in a recently published article by Mr. Panzer and Dr. Al-Bayati, entitled "Reducing Damages to Underground Utilities: Importance of Stakeholders' Behaviors."

The Direct Cause of Damages

It must be noted that this cause categorization differs from the CGA's categorization in two ways:

- The DIRT report's cause categories include excavation practices, invalid use of request by excavator, locating practices, miscellaneous, no locate request, and unknown/other. As previously discussed, the NC 811's categorization classifies no locate requests and invalid use of request by excavator under excavators' practices. Furthermore, the NC 811 categorization utilizes utility owner practice and general industry practice categories. Finally, the NC 811 categorization only handles known data and totally ignores the unknow/other category. For more information about the NC 811 categorization, see Al-Bayati and Panzer's book Underground Utilities for Construction Practitioners and Homeowners or other published reviewed articles by Al-Bayati and Panzer.
- The NC 811 research team considers these causes direct causes, whereas CGA's DIRT report considers them root causes. According to Al-Bayati et al. (2021), direct causes consist of unsafe acts (e.g., digging prior to a valid start date) and unsafe conditions (e.g., failing to protect/shore/support utilities), whereas root causes, which lead to direct causes, consist of human factors and workplace factors, such as inadequate training and lack of knowledge or skill. Al-Bayati and Panzer (2020) suggest several root causes of damages based on locators' and excavators' observations and comments, such as workforce shortages, broken tracer wires, and inaccurate maps. See Table 2 for more details about the identified causes and their rankings. A closer look of the

direct causes will be discussed in the damage data analysis section.

Table 2. Inaccurate Locate Causes

Locator Ranking	Excavator Ranking	Cause
1	1	Locators rushing due to workforce shortages
2	4	Broken tracer wires
	2	Inaccurate maps
3	1	Insufficient locator training
	4	Utility location obscured due to material interference
4	4	Utility location obscured due to vegetation
	3	Utility installed with unmarked looped lines
	N/A	Locating equipment limitations

Most of damages were reported by locators 20,952 (66.0%) followed by excavators 7,214 (22.7%) and utility operators/owners such as natural gas and telecommunications 3,600 (11.3%). However, almost all excavators have indicated that the cause is not reported (i.e., Unknow/Other). This report categorizes the primary cause of damages as follows: excavators' practices, locators' practices, utility owners' practices, and general industry practices. The direct cause has been reported in only 16,937 (53.3%) reports mostly by locators. The proportions of each case category are presented in Figure 2 based on the known inputs.

The data indicates that excavators' practices contribute to 68.96% of underground damages in North Carolina. To better understand the nature of the insufficient practices of locators and excavators, the actions of each category have been determined, see Table 3. Within the excavators' insufficient practices, failing to place a locate request through NC 811 contributed to 6,296 (53.9%) of the damages. The next two contributing factors are: (1) not verifying marks by test-holes 2,561 (21.9%), and (2) failing to maintain clearance 772 (6.6%). According to North Carolina damage prevention law, excavators must not use mechanized equipment until visually

verifying the location of marked utilities [87-122 (C) (9) (a)]. Excavating prior to verifying the marks seems to be a wide-spread issue that represents the second cause of damages due to excavators' insufficient practices. In addition, maintaining clearance between a facility and the point of any mechanized equipment is required to reasonably avoid damages [87-122 (C) (9) (C) and (10)]. failing to maintain the needed clearance was the third contributed factor to the damages in North Carolina. Thus, NC 811 education efforts should focus on these issues. Finally, digging prior to start data or after the ticket expiration represents the third and fourth causes within excavators' practices. It is anticipated that marks will be in place when digging within these circumstances.

Finally, abandoned facilities represents 85% of the general industry practices category. Damage prevention training programs must address this issue carefully. However, the challenge remains that abandoned facilities are not present in the maps provided to the locators and therefore the locator does not have knowledge of the presence of these abandoned lines.

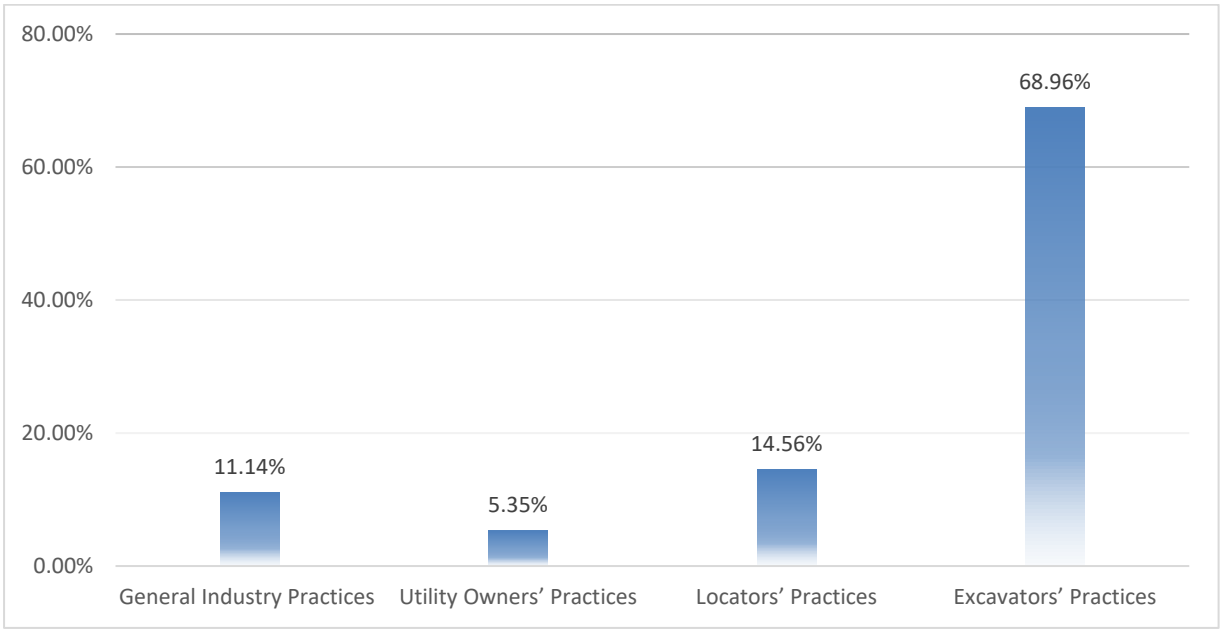


Fig. 2. Direct Cause Proportions -2020

Table 3. Direct Causes Nature and Proportions – Within Known Data

Cause	Nature Marked inaccurately due to abandoned facility	Number (%)
EIP	Falling to notify One-Call Center / 811	6,296 (53.9)
	Digging prior to verifying marks by test-hole	2,561 (21.9)
	Failing to maintain clearance	772 (6.6)
	Digging prior to valid start date	772(6.6)
	Digging after valid ticket expired	543 (4.6)
	Others such as providing incorrect ticket information and falling to support uncovered activities.	735 (6.3)
LIP	Marked inaccurately due to Locator error	975 (39.5)
	Incomplete locates	931 (37.8)
	Not marked due to Locator error	560 (22.7)
UOIP	No response from operator/contract locator	446 (49.2)
	Marked inaccurately due to incorrect facility record/maps	287 (31.7)
	Unlocatable facilities	153 (16.9)
	Not marked due to Incorrect facility records/maps	20 (2.2)
General	Abandoned facility	1608 (85.2)
Industry	Tracer wire issue	154 (8.2)
Practices	Marks faded, lost or not maintained	112 (5.9)
	Previous damage	12 (0.6)

No Locate Request

NC 811 was created to ensure that all active underground utilities are marked before the excavation starts. This process can only begin when excavators notify NC 811. The 2020 dataset suggests that 6,296 (19.8%) of all damages were not associated with a locate request within reported causes. This percentage is lower than those obtained in 2019 (22.8%, 3,561 damages), 2018 (20%, 2,408 damages), and 2016 (21.56 %, 3,271 damages). It is roughly higher than 2017 percentages which was 19.4% (2,169 damages). However, this should be reviewed based on the fact that the causes of 14,829 damages have not been reported in the collected data.

The examination of no locate request indicates that most of the cases occurred in Mecklenburg County (19.8%), followed by Wake County (17.38%), Durham County (4.67%), and Guilford County (4.49%). Comparing these percentages with previous years' percentages shows an overall increase in no locate requests in Wake and Durham and noticeable reduction in Mecklenburg and Guilford, see Table 4. The percentages from Wake County show a concerning increase, which requires special attention.

Table 4. No Locate Requests by Major County between 2016 and 2020

County	Mecklenburg	Wake	Durham	Guilford
2020	19.8%	17.38%	4.67%	4.49%
2019	33.4%	7.2%	2.4%	13.5%
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%

Examining the data of "no locate requests" by excavator type reveals that the highest percentage of no locate requests within the known data was among contractors (77.81%) which is similar to

last year's percentage (79.8%). Similar to the previous reports, the firms that did not place a locate request were mainly perform landscaping, water, and sewer install/maintenance works. 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 49%) of reported damages occurred in Mecklenburg County (22.4%; 7,317), followed by Wake County (17.48%; 5554), Guilford County (4.94%; 1570), and Durham County (4.49%; 1,450). When comparing the 2020 percentages of damages per county with percentages from previous years, a constant trend could be captured, see Table 5.

Table 5. Damages Percentages by Major County

County	Mecklenburg	Wake	Durham	Guilford
2020	23.03%	17.5%	4.49%	4.94%
2019	21.79%	15.45%	5.19%	7.26%
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%

Damages Trends

Figure 3 shows the proportion of damages per utility type. Clearly, most of damages (57%) occurred to telecommunication and cable TV subsurface utilities (Telecommunication 40.38% and Cable TV 16.12%). Al-Bayati and Panzer (2021) suggest a few unique factors that contribute to the damages of telecommunication and cable TV including shallow depth and their low-risk impact on overall project. Furthermore, telecommunication and cable TV subsurface utilities are considered low-risk damages which are acceptable by most contractors (Al-Bayati and Panzer, 2020). Low-risk damages have no monetary potential impacts on construction projects' schedule and budget unless they damage fiber-optic telecommunication lines. Damages to electrical utilities scored second (16%) which is an issue that requires further investigation and monitoring. Coupling effect (the influence of nearby cables and metallic pipes) is one of main causes of electrical utility inaccurate locates (Al-Bayati and Panzer 2021).

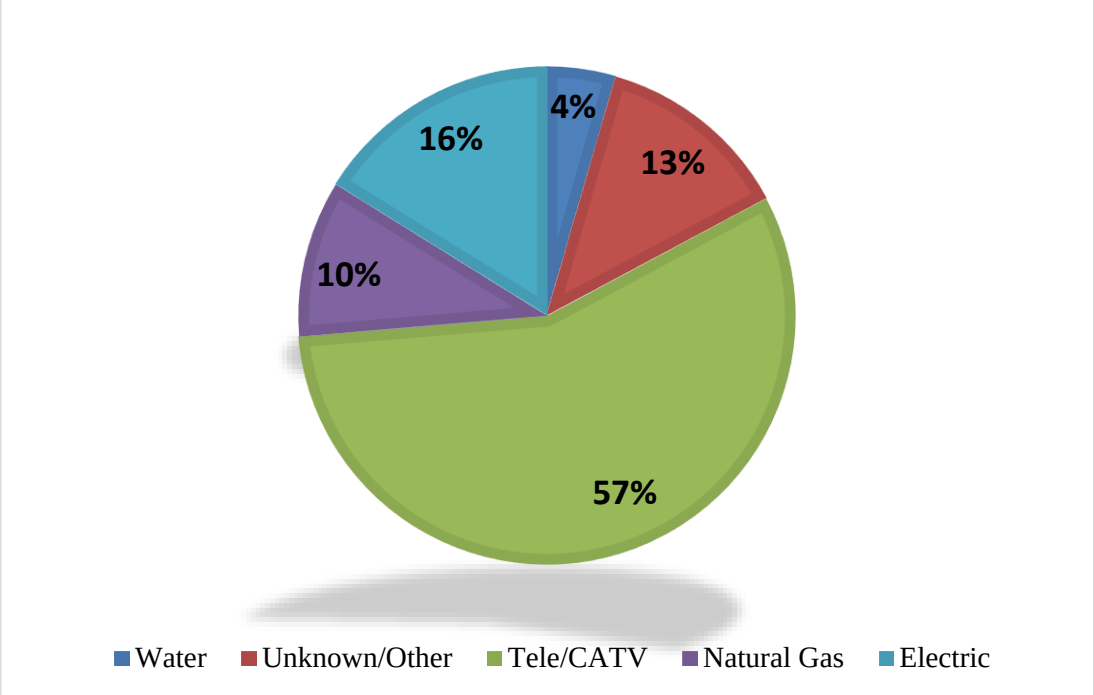


Fig. 3. Damage Proportion per Utility Type

An excavator is a person engaged in excavation or demolition. There are several types of employers who hire excavators to perform an excavation (e.g., contractors and utility owners). Within the known data, contractors caused the most damage to underground utilities in 2019, accounting for 83.9% (9,963) of damages and municipalities (5.65%, 671 damages). These rates are similar to those reported in previous years. The service types are classified to 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. It is clear that damages to transmission lines represent a small percentage of the overall damages reported as can been seen in Figure 4. Transmission lines are deeper and better marked in private rights-of-way (ROW) with permanent above ground marks. Furthermore, transmission lines that are not in private ROWs are usually along busy roads, not in neighborhoods. The Gas Transmission Integrity Management (GTIM) 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 the potential cost of disruption to the transmission lines make these utilities a higher priority to the owners.

The risk factor of these three affected services is inversely proportional to the percentages. The highest risk potential to injury or widespread outages lies in the transmission category. Therefore, the greatest emphasis from a safety perspective is placed on transmission lines (i.e., high risk utilities) even though the focus of damage prevention needs to address all three types. For example, in April 2019, a natural gas service line was struck during a horizontal boring operation resulting om two fatalities, several injuries, and damaged and destroyed buildings in Durham, North Carolina.

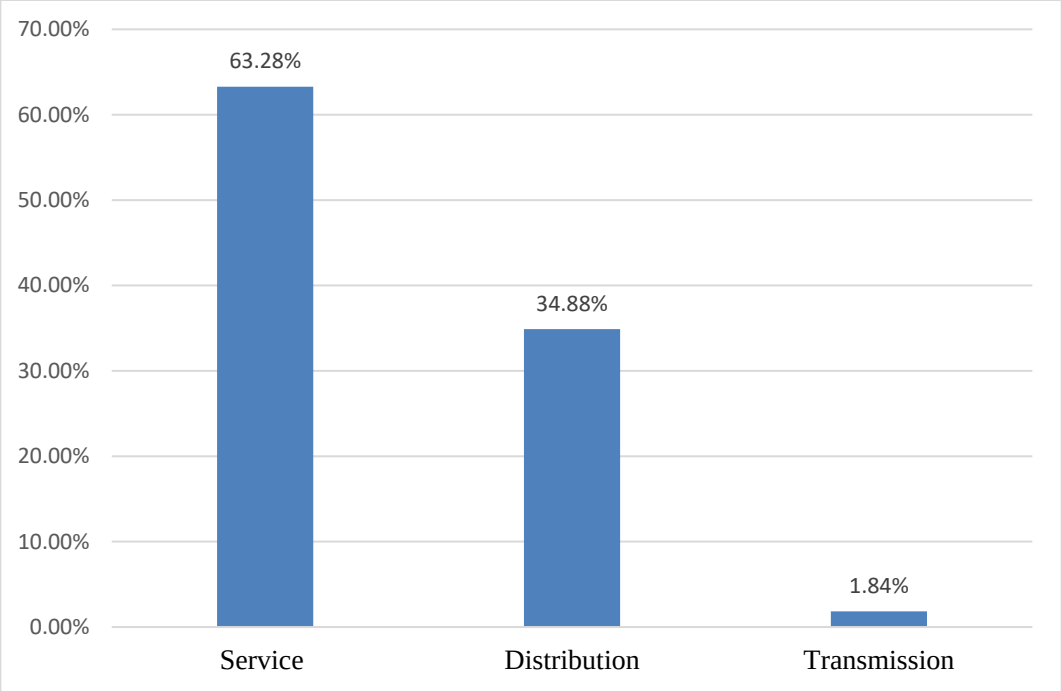


Fig. 4. The Affected Service

Damages per Work Performed

This section investigates damages per work type, within known data, to reveal whether there is a type of work that contributes more than others to underground utility damages. The results suggest that most of the damage incidents occurred while conducting tele/CATV work, followed by water/sewer work, electrical, and natural gas, see Figure 5. On the other hand, Figure 6 between damages reported in 2018 and 2019 in terms of work type. Clearly, electrical work contributed more to damages in 2019 than in 2018. Furthermore, Table 6 explores the relationship between work performed and utility damages. Clearly, water/sewer work contributes to higher percentage of damages (36.3%) than others, specially tele/CATV damages (20.5%).

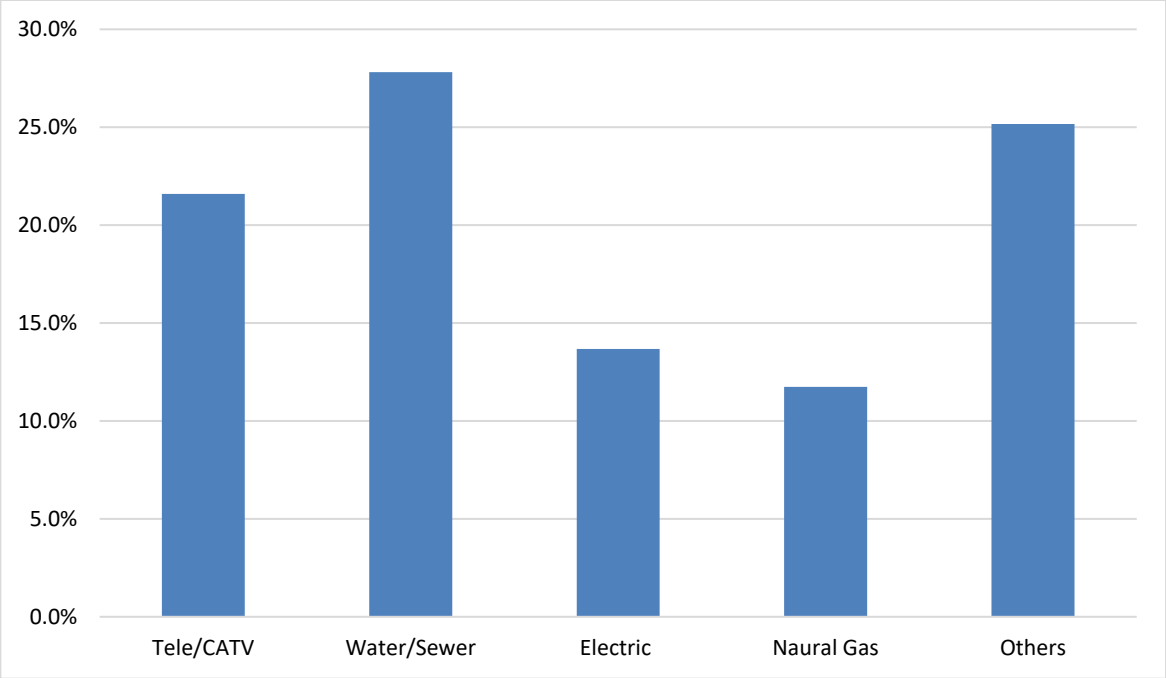
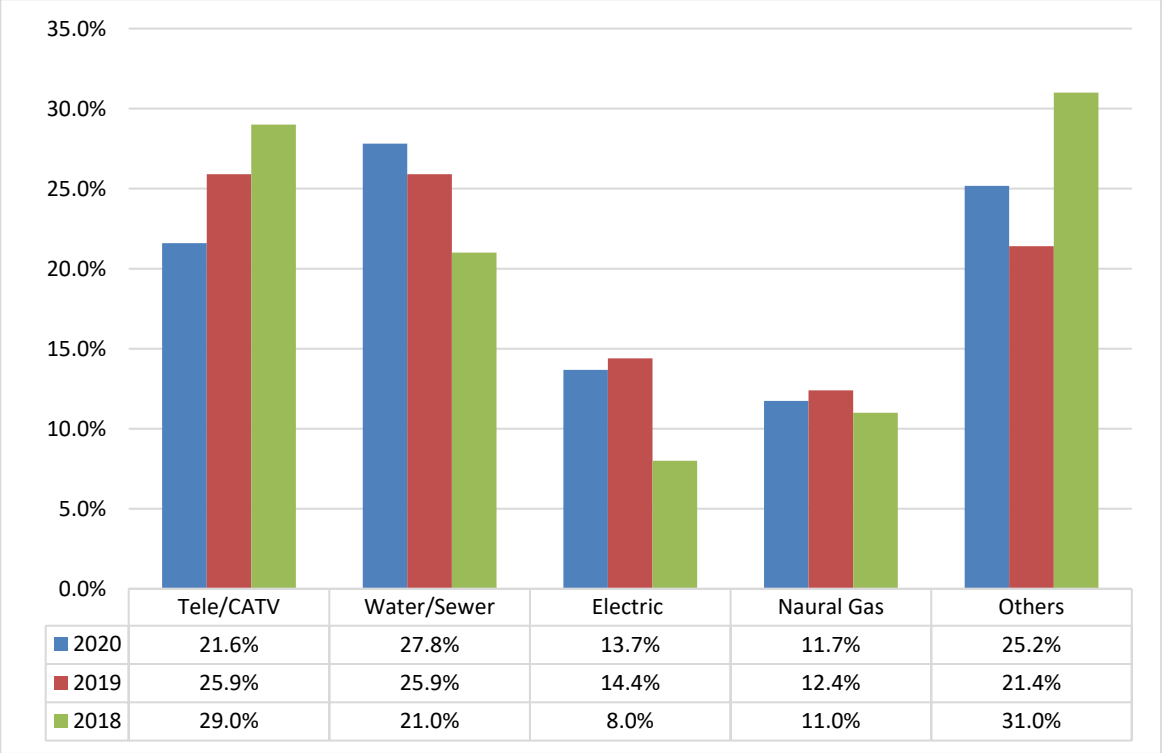


Fig. 5. Damages per Work Performed



	Tele/CATV	Water/Sewer	Electric	Naural Gas	Others
2020	21.6%	27.8%	13.7%	11.7%	25.2%
2019	25.9%	25.9%	14.4%	12.4%	21.4%
2018	29.0%	21.0%	8.0%	11.0%	31.0%

Fig. 6. A Work Performed Comparison 2018- 2020

Table 6. The Percentages of Work Performed per Damaged Facility 2020

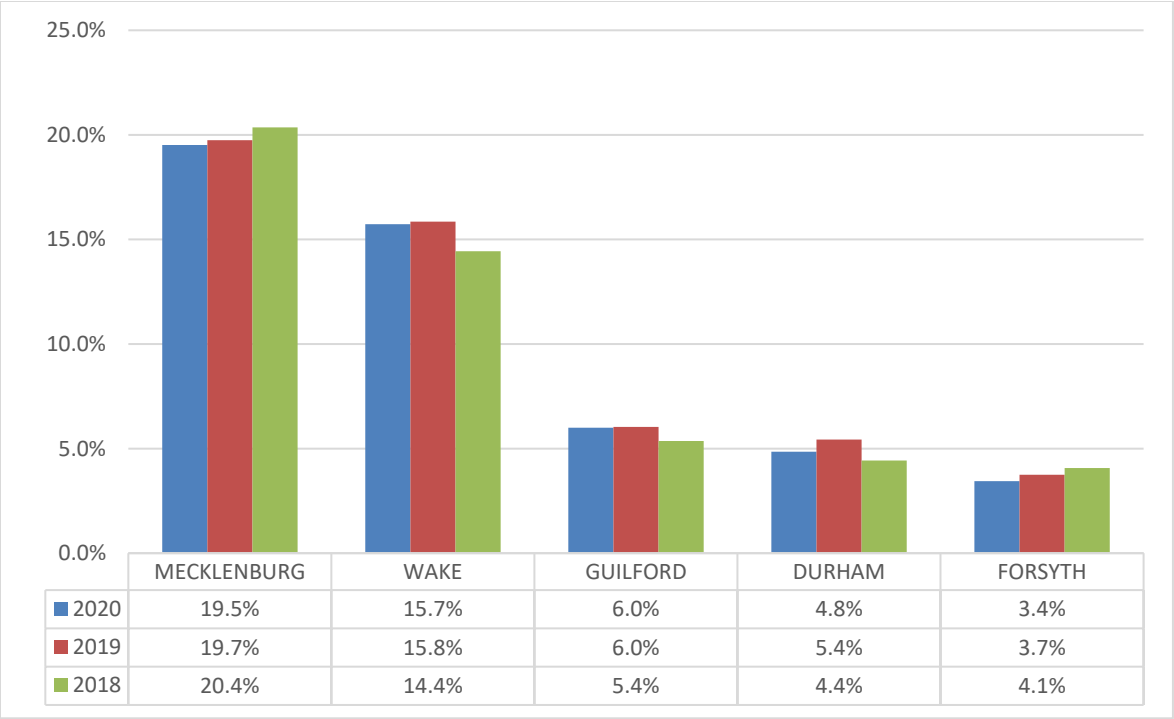
Damaged Utility	Tele/CATV	Electric	Gas	Water/Sewer	Total
Work Performed					
Tele/CATV	14.2%	3.7%	7.6%	4.0%	29.5%
Water/Sewer	20.5%	4.2%	11.2%	0.4%	36.3%
Electrical	12.6%	1.7%	3.4%	0.8%	18.6%
Natural Gas	10.7%	2.4%	1.5%	1.1%	15.7%
Total	58.0%	12.1%	23.6%	6.2%	

Positive Response Trends

Tickets are created after each notification received by the NC 811 notification 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 6:1 ratio of transmissions to tickets). There were 2,146,810 tickets and 12,421,473 transmissions in the state of North Carolina in 2020. Out of the 100 counties in the state of North Carolina, 49.5% (i.e., 6,152,685) of the 2020 transmissions were placed in the following counties: Mecklenburg (2,423,777), Wake (1,953,788), Guilford (745,002), Durham (602,252), Forsyth (427,866). Figure 7 shows the proportions of transmissions in these counties between 2018 and 2020.

Positive responses are a requirement under the law and a method for the members of NC 811 to provide information to excavators regarding their ticket. The most frequent positive responses during 2020 were Code 10, followed by Code 20, Code 60, Code 999, Code 30, and Code 80, see Table 7. It seems that Code 60 has been utilized slightly more in 2020. On the other hand, the use of code 30 (i.e., Not complete) scored the lowest percentage since 2018 which may indicate better management of locate request by utility owners. Figure 8 shows the major codes per the top five counties.

The data indicate that 55.4% of positive responses required more than the regulatory time, which is three business days in the state of North Carolina. This percentage is higher by roughly 8% than 2019 percentage. The numbers of business days (BDs) that were needed to provide a positive response between 2017 and 2020 are presented in Figure 9.



	MECKLENBURG	WAKE	GUILFORD	DURHAM	FORSYTH
2020	19.5%	15.7%	6.0%	4.8%	3.4%
2019	19.7%	15.8%	6.0%	5.4%	3.7%
2018	20.4%	14.4%	5.4%	4.4%	4.1%

Fig. 7. Transmission Proportions Comparison 2018- 2020

Table 7. The Most Frequent Codes in 2018 - 2020

Code	Number (%)			Code Meaning
	2018	2019	2020	
10	5,429,760 (39.7%)	6,318,607 (40.3%)	5,849,385 (42.3%)	No conflict, the utility is outside of the stated work area
20	4,547,857 (33.2%)	5,001,258 (31.9%)	4,812,998 (34.8%)	Marked
60	856,923 (6.27%)	223,167 (1.4%)	945,636 (6.8%)	Locator and excavator agreed and documented the marking schedule
999	1,003,417 (7.34%)	1,616,907 (10.3%)	897,957 (6.5%)	Member has not responded by the required time
30	1,143,720 (8.36%)	1,843,619 (11.8%)	685,087 (5.0%)	Not complete
80	336,570 (2.46%)	334,547 (2.1%)	307,100 (2.2%)	Member's master contractor is responsible for locating facilities

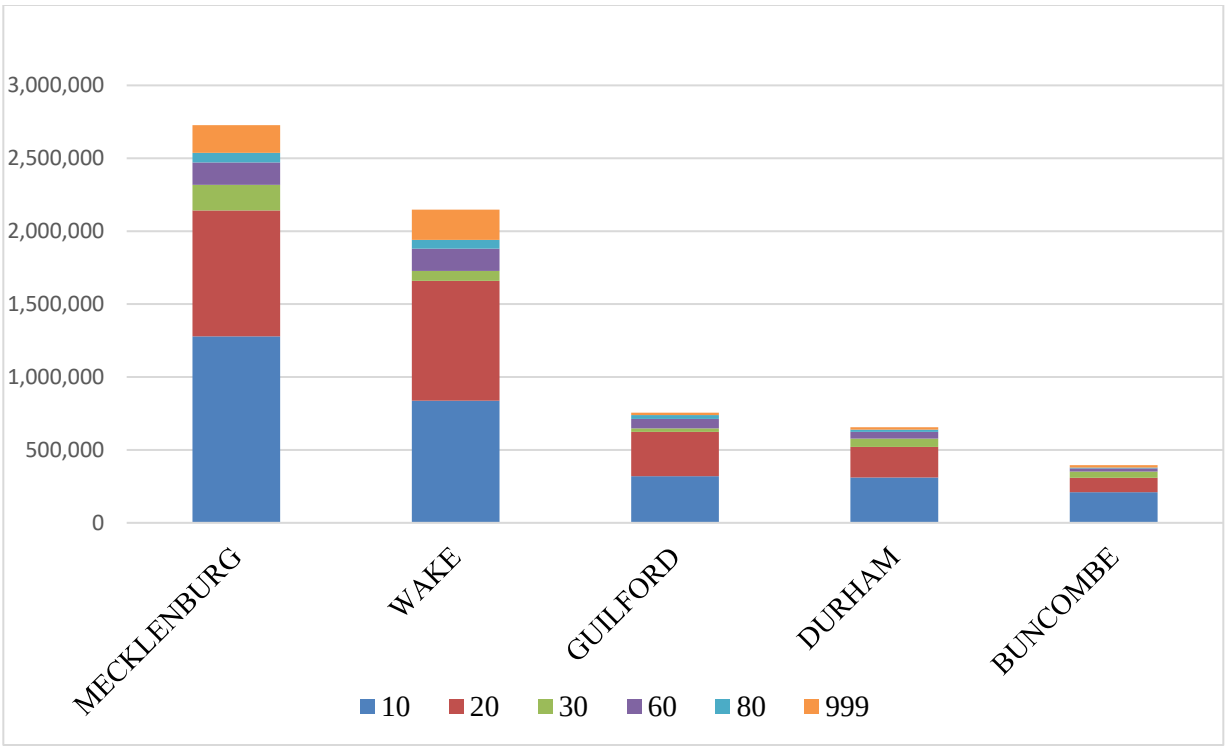
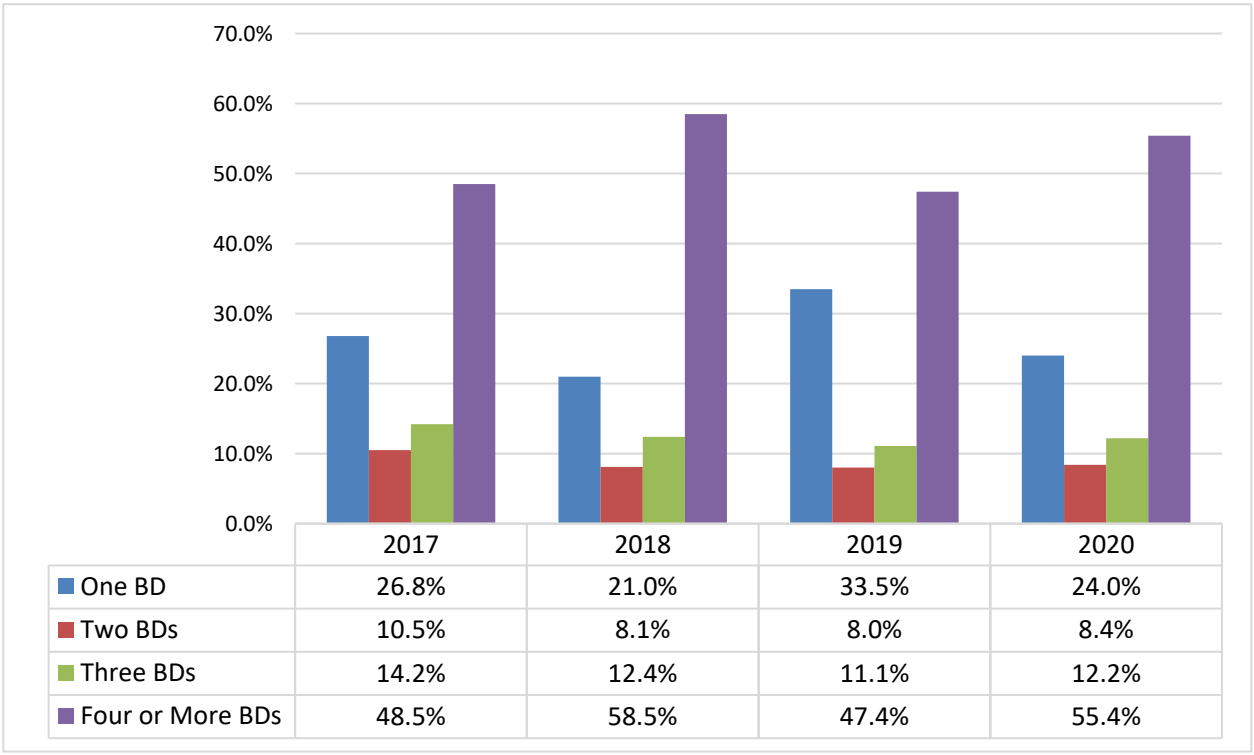


Fig. 8. Percentages of Major Codes by County



	2017	2018	2019	2020
One BD	26.8%	21.0%	33.5%	24.0%
Two BDs	10.5%	8.1%	8.0%	8.4%
Three BDs	14.2%	12.4%	11.1%	12.2%
Four or More BDs	48.5%	58.5%	47.4%	55.4%

Fig. 9. The Number of Days Needed for a Positive Response

Three-Hour Notice (3Hr) and Code 999

The utility owners must mark their utilities within three business days (BDs) according to the damage prevention act in the state of North Carolina. Excavators shall place a three-hour notice (3Hr notice) when utility owners fail 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 2020, 49.5% (i.e., 6,152,685) of transmissions were placed in Mecklenburg, Wake, Guilford, Durham, and Forsyth. The percentages of the 3Hr notices and Code 999 in these counties represent 52.9% and 48.8% of the total count, respectively.

Comparing the overall number of 3Hr and 999 Codes in these counties indicates that the 3Hr notice is not fully utilized in 2020. For example, the number of 999 Codes in Mecklenburg was 189,787, whereas the number of 3Hr notices was only 16,702, which suggests failure to use the 3Hr notice and/or invalid use of the Code 999, see Table 8. Thus, educational and outreach efforts should clearly explain the importance of utilizing the 3Hr notice.

Table 8. The Number of 3Hr Notices and Code 999

County	**2018**		**2019**		**2020**	
	3Hr	Code 999	3Hr	Code 999	3Hr	Code 999
Mecklenburg	15,761	235,065	20,906	322,987	16,702	189,787
Wake	9,720	158,161	18,777	290,714	13,992	208,085
Guilford	2,193	39,807	4,570	57,046	2,391	16,326
Durham	2,767	69,056	5,323	120,266	3,186	16,862

The Sources of Damage

The damage sources section is a new addition to NC 811 yearly report. It could be defined as the object or substance motion that directly produced the damages. Within the known data, Backhoe and Trackhoe (6092; 54.4%) contribute the most to damages to subsurface utilities, followed by Hand Tools (2190; 19.5%), Boring (1031; 9.2%), Trencher (470; 4.2%), Directional Drilling (449; 4%), and Drilling (398;3.6%). However, it is difficult to justify the high proportion of hand tools without a third-party damage investigation.

2021 Follow-up Survey

The 2021 follow-up survey to assess the experiences of NC 811 customers was administered during May 2021. The survey targets callers who contacted NC 811 between January and April 2021; a total of 61,856 individuals called NC 811 during this period. This year's follow-up survey adopted a simple probability sample; that is, a small, random portion of the entire population was selected, ensuring that each member of said population had an equal probability of being chosen. A simple probability sample allows for generalization of the findings since it reflects the characteristics of the targeted population. To ensure the validity and reliability of the sample size, the following criteria were employed:

- An alpha level of 0.05 to reduce the probability of making type I errors (i.e., false positives, or seeing relationships that are not present). This level helps reduce the probability that differences identified between groups are due to chance rather than the quality of service. In other words, this alpha level reduces the chances of making a type I error by 95%.
- A statistical power of 90% to reduce the probability of making type II errors (i.e., false negatives, or failing to see relationships that are present). A statistical power of 90% reduces the chances of making a type II error to only 10%.
- A high effect size (R=0.40) to ensure the statistical significance of observed differences between groups in the study population. This effect size is considered large by Cohen (1988). The effect size is used to ensure the findings represent a widespread opinion about the investigation services within the study population.

Based on the criteria above, a sample size of sixty-one (n=61) is recommended by Ellis (2010). However, high nonresponse rates are a prevalent issue within survey research studies, and they often compromise the reliability and validity of survey study findings. For example, a response

rate of 30% means the study suffers from a nonresponse bias of 70%. Based on the prior follow-up surveys, a response rate of 2.5% was the roughly response rate. Thus, the probability sample was increased by 40 times (n=40 X 61=2,440) to overcome the anticipated response rate. Thus, 2,440 email addresses were randomly selected from the target population of 61,856. Responses were received from 86 individuals, 41.9% of whom were first-time users of the NC 811 system. Figure 10 shows the number of participants in the NC 811 follow-up surveys, including the 2021 survey. It is worth noting that a convenience sample was adopted to evaluate the data from the 3 years prior to 2021. Convenience sample is a non-probability sample and should not be used to reflect the characteristics of the targeted population.

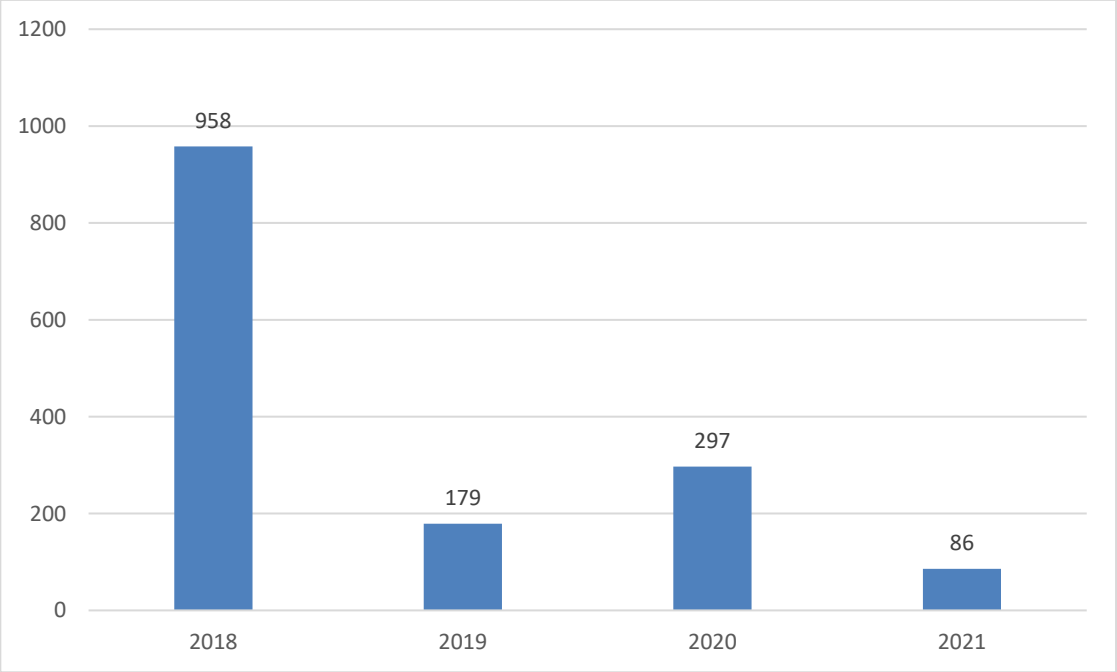


Fig. 10. The Sample Size Over the Last Four Years

Most of the participants were homeowners (62; 72.1%), followed by construction practitioners (13; 15.1%), city or county staff (5; 5.8%), and others, including private locate firms, agriculture firms, and utility owners (6; 7%). Figure 11 illustrates the method used by participants to place a locate

ticket. Calling NC 811 via phone was the most frequently used method reported by the study sample.

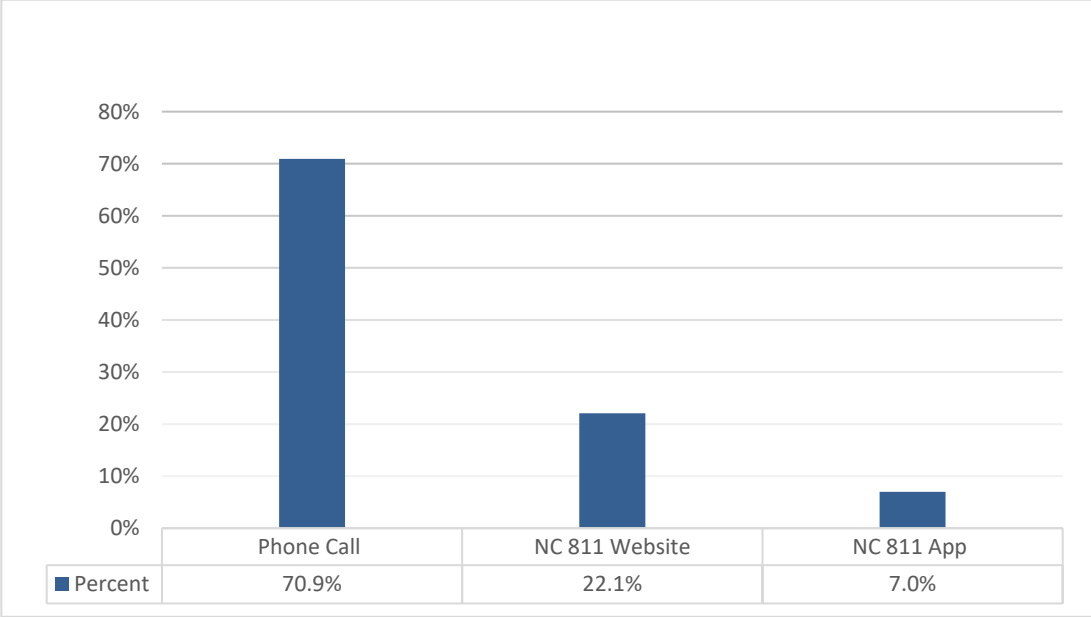


Fig. 11. NC 811 Contact Methods – 2021

The participants were asked about the ease of placing a locate ticket through NC 811. The collected data suggests that 94.2% of participants believed it was easy to place a locate ticket. This percentage was 96.1% in 2020, which does not differ from the 2021 data to a statistically significant degree. Table 9 lists a sample of reasons why 5.8% of the study sample believed it was not easy to place a locate ticket.

Table 9. Sample of Participant Feedback – Ticket Information

• I wanted subdivision located, and they wanted to create a ticket for all 10 lots.
• A little difficult to get personnel to understand the requirement.
• The single address ticket works sometimes, and sometimes it doesn't.

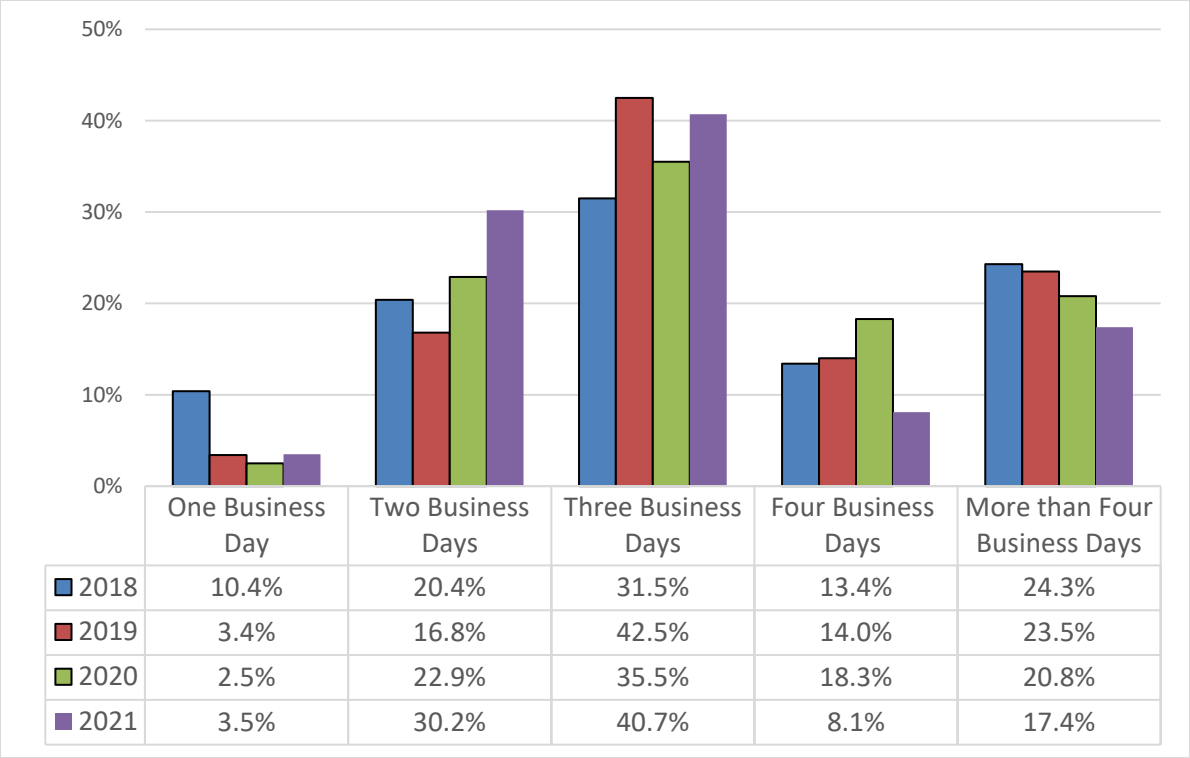
The Survey Findings

The locate accuracy provided by NC 811 seemed to satisfy the individuals who participated in the study; 82.6% of them stated that the locate marks were accurate to them. This percentage was 82.1% in 2020 and 87.9% in the 2018 survey, which arguably does not represent a significant variation. nonetheless, this variation should be further monitored. According to those who indicated that the locates were inaccurate, the inaccurate locates were mostly associated with tele/TV underground utilities (9; 60%), followed by gas utilities (4; 26.7%). Accordingly, 5 damages to underground utilities were reported (4 damages to tele/TV utilities and 1 to a gas utility).

Locate time

The legally required timeframe to locate underground utilities is 3 business days in North Carolina. The collected data suggests that utility locators were unable to clear 25.5% of locate requests within the legally required timeframe in 2021, see Figure 12. This percentage is considerably lower than the percentages found in the 2018, 2019, and 2021 follow-up surveys, which were 37.7%, 37.5%, and 39.1%, respectively. Excavators must give a 3-hour notice when locators fail to mark their utilities within the legally required timeframe [NC Gen Stat §87-122, (C) (2)].

Al-Bayati and Panzer (2021) suggest several causes for late locates, including workforce shortages, inaccurate maps, use of the wrong ticket type by excavators or designers, absence of white lining, and improper update tickets. According to the locators who participated in the study, workforce shortages were the greatest contributor to late locates, see Table 10.



	One Business Day	Two Business Days	Three Business Days	Four Business Days	More than Four Business Days
2018	10.4%	20.4%	31.5%	13.4%	24.3%
2019	3.4%	16.8%	42.5%	14.0%	23.5%
2020	2.5%	22.9%	35.5%	18.3%	20.8%
2021	3.5%	30.2%	40.7%	8.1%	17.4%

Fig. 12. Number of Days Needed to Locate Underground Utilities

The second greatest contributor was inaccurate maps, which is a challenge that locators face on a regular basis (26.6%) or at least from time to time (59.2%). The use of normal locate ticket for design/survey work, can also cause locate delay. The legally required timeframe to respond to a design/survey ticket is 10 business days instead of the usual 3 full business days. In addition, the response to a design/survey ticket could be a physical locate, the provision of maps, or access to the maps provided by the utility. Locators who participated in Al-Bayati and Panzer's (2021) study reported that excavation tickets were requested instead of design/survey tickets on a regular basis (30.6%) or from time to time (44.9%), see Table 3. This could be because designers often want a physical locate, which is not guaranteed with a design/survey request, or they do not want to wait 10 days to get a response. The response to a design/survey ticket could be a physical locate, the provision of maps, or access to the maps provided by the utility. This inappropriate utilization of 811 tickets places an unnecessary burden on locators.

Locators also reported white lining as a major challenge that increases the required time to complete a locate. White lining is vital to define the area to be excavated, and it facilitates accurate locates of utilities within an acceptable timeframe. In North Carolina, the law requires excavators to place white lining around the proposed excavation area when the area cannot be adequately described in the ticket.

Furthermore, zeroing in on the root causes of late locates revealed that a shortage in skilled locators, along with other factors, have led to long working hours 6 days a week, with long driving times to perform an average of 20–30 locates per day, see Figure 13.

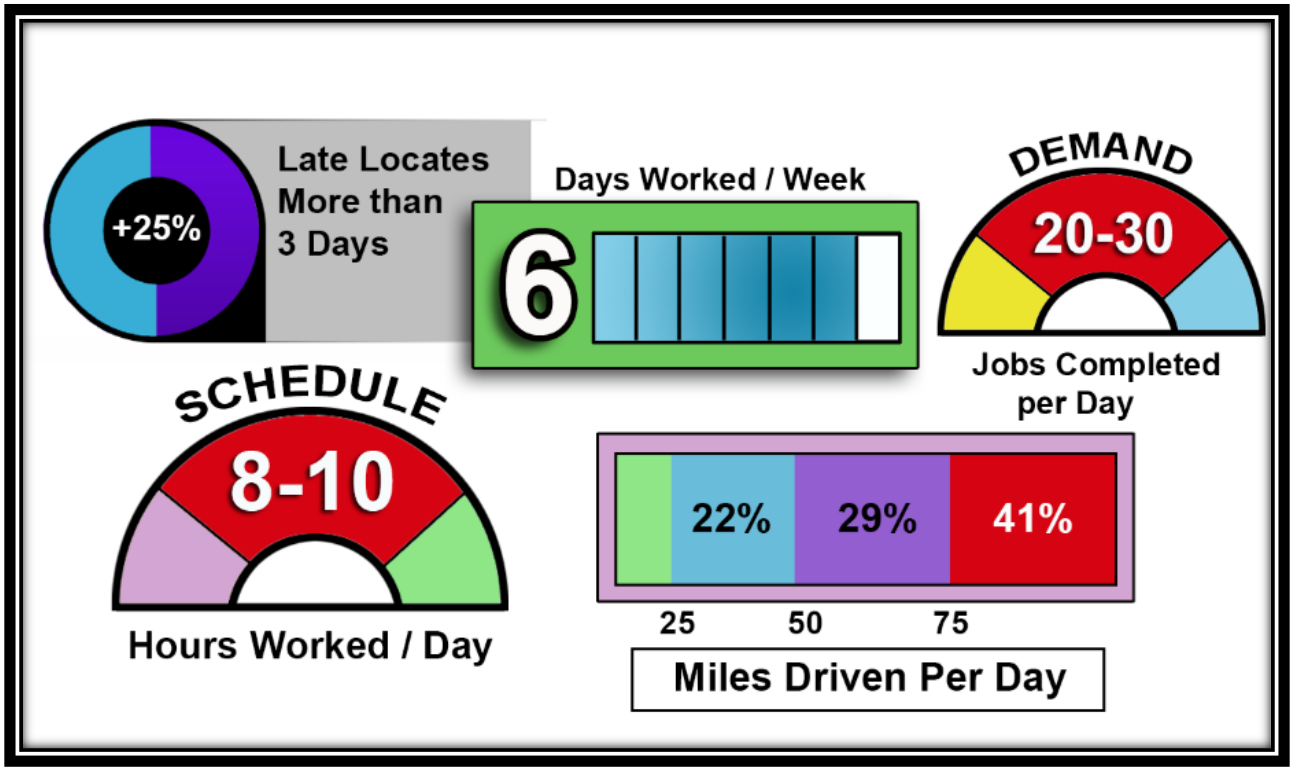


Fig. 13. The Working Conditions of Locators

Table 10. Factors that Increase Locate Times

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 when the work has not begun	1 (1%)	8 (8.2%)	37 (37.8%)	52 (53.1%)
Update tickets when the work has been completed	0 (0%)	15 (15.3%)	47 (48%)	36 (36.7%)

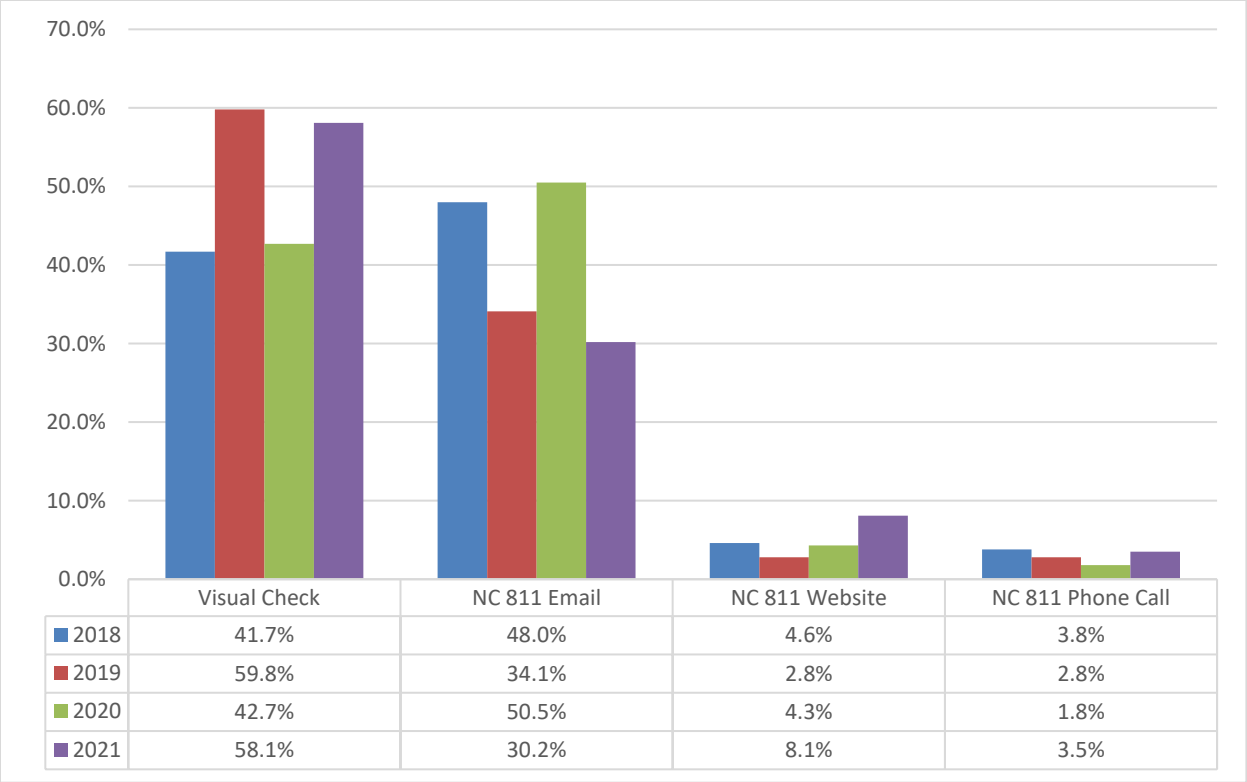
*This factor contributes to inaccurate locates as well (see Table 2).

These daily challenges that contribute to late and inaccurate locates create system noise and a compounding effect leads to many undesirable scenarios, as suggested by Al-Bayati and Panzer (2021). For example:

- When excavators believe that they will not receive a response in the required timeframe, they may place locate tickets weeks in advance, hoping to obtain marks when they are planning to dig.
- 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 on time, and those will be the jobs they move the crews to work on.

Positive Response Verification

Article §87-122. (a) (2) of the Damage Prevention Act in North Carolina requires excavators to ensure that all underground utilities have been marked (i.e., positive response) by checking with NC 811 via phone, email, or through NC 811's website. However, the results indicate that 58.1% of participants only visually checked the excavation areas to verify the status of their locate request, and 30.2% verified the status of their locate request via receipt of an email from NC 811. Figure 14 suggests that the issue of using an inappropriate method to check for a positive response has been reported frequently over the period from 2018 to 2021. Checking the excavation area alone is not sufficient to verify a positive response. Thus, it is crucial to increase efforts to educate excavators about the correct methods for verifying a positive response. It is particularly important to educate homeowners, who represent 72.1% of 2021's follow-up survey sample, see Figure 5. NC 811 has produced an educational video that aims to educate excavators and homeowners about how to verify a positive response (https://www.youtube.com/watch?v=ujKnBWcKmfw). However, this video should be distributed via email or text message after a locate ticket is placed to ensure excavators learn how to verify a positive response in the correct way.



	Visual Check	NC 811 Email	NC 811 Website	NC 811 Phone Call
2018	41.7%	48.0%	4.6%	3.8%
2019	59.8%	34.1%	2.8%	2.8%
2020	42.7%	50.5%	4.3%	1.8%
2021	58.1%	30.2%	8.1%	3.5%

Fig. 14. Positive Response Verification Methods

The Quality of Services Provided

This section assesses the perceptions of the study sample about the following items using a 1 to 10 scale: the professionalism of NC 811, the overall process of NC 811, the accuracy and completion time of locate requests, and the professionalism of locators. Similar to those found in previous years, the results suggest that NC 811 personnel scored higher in professionalism than in other aspects, see Figure 15. NC 811 personnel also scored higher in professionalism and process than in previous years, with average scores of 9 and 8.51, respectively. However, the scores for locate accuracy and completion time are still straggling behind other measured aspects, regardless the slight improvements. As discussed earlier, there are several factors associated with this performance deficiency, some of which are beyond the control of utility owners and locators.

When asked "What is needed to improve the overall NC 811 process?", 50 participants (58.1%) indicated that the system works fine for them, and there is no need for improvement. However, 6 participants (6.9%) expressed a desire for better communication, and 7 (8.1%) participants reported a need to improve the timeliness and accuracy of locates. The timeliness and accuracy of locates are influenced by multiple variables that should be clearly communicated to NC 811 customers to better manage their expectations. Participants also reported a need to improve locate mark resilience and correct usage of ticket types as seen in Table 4. Improvements to NC 811's website and phone system were requested by 5 (5.8%) participants. Finally, other improvements were requested by 16 (18.6%) participants. Table 11 lists important feedback and recommendations provided by the study sample.

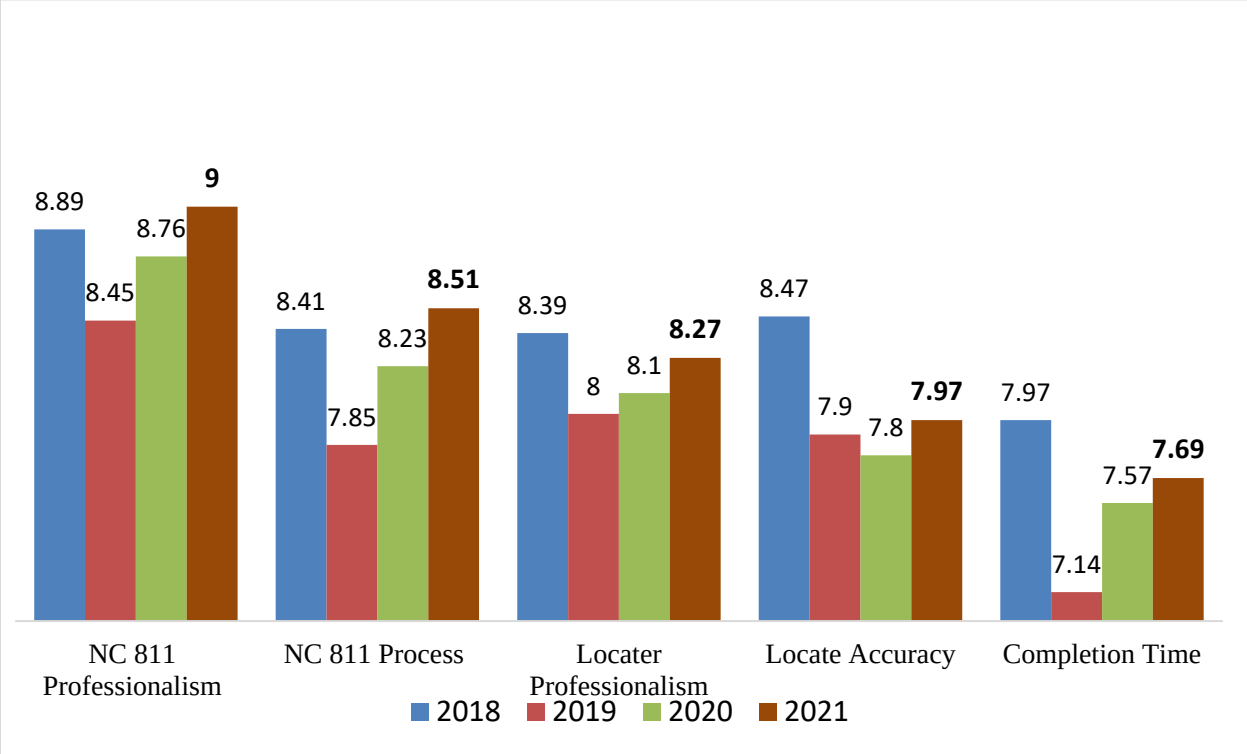


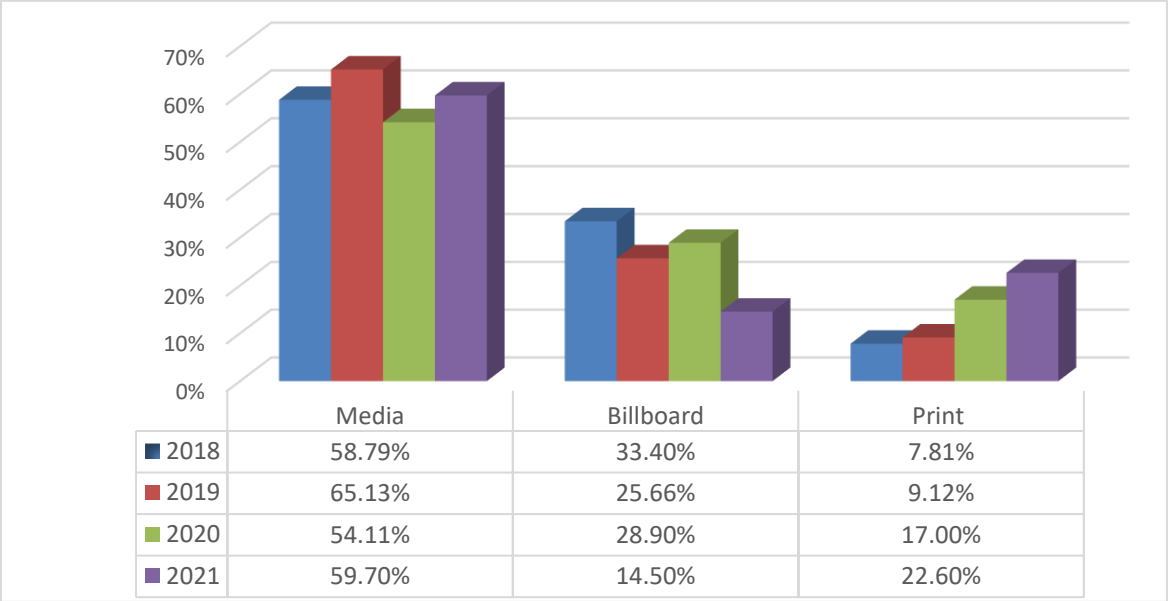
Fig. 15. Average Quality of NC 811 Service Based on Participants' Experiences

Table 11. Improvements Suggested by the Study Sample

Suggestion	Suggestion Example
Better communication	My dogs almost ate the person marking the wires because I didn't know when they were coming.
	Perhaps better communication on when techs are coming out via the website.
	Some method of indicating on site that a utility that isn't present (and thus unmarked).
Improving website or phone system	Add an option to attach photos or documents.
	Website user ability needs improvement. Was not able to get everything marked when scheduling online in the past, so I only use the phone for scheduling.
	Better automated system, too often cannot find street.
Locate mark resilience and correct usage of ticket types	Don't send utility locators to mark in paint during a rainstorm. Use flags if raining.
	I'm satisfied with the service, but I was just wanting to plant some small trees. Maybe have an area geared more towards residential small garden types of things instead of major construction.
Others	Place fines on locate companies who lie to complete tickets.
	That it can coordinate all even private.
	All operators get on the same page.

NC 811 Outreach Efforts

North Carolina 811 works hard to educate the citizens of North Carolina about its services. The education efforts come in different formats, such as billboard, TV, and radio advertisements. Of the 2021 follow-up survey participants, 72.2% indicated that they have seen an NC 811 advertisement. Figure 7 illustrates effective methods of education based on participant feedback. According to this feedback, media (e.g., television, radio, and internet advertisements) represents the most effective method of outreach, accounting for 59.70% of reported views, followed by billboard (22.6%) and print (14.5%) advertisements. Print advertisements (i.e., in magazines, phonebooks, and utility bills) seem to have gained more influence over the years, see Figure 16. These overall findings should contribute to shaping future outreach efforts as well as funding. However, these findings should be understood based on the characteristics of the survey participants, the majority of whom are homeowners.



	Media	Billboard	Print
2018	58.79%	33.40%	7.81%
2019	65.13%	25.66%	9.12%
2020	54.11%	28.90%	17.00%
2021	59.70%	14.50%	22.60%

Fig. 16. Effectiveness of Outreach Methods

Demographics and Practices of Professional Participants

Twenty-four businesses participated in the survey. Of these businesses, 12 (14%) had fewer than 10 employees, 4 (4.7%) had between 10 and 50 employees, 6 (7%) had between 50 and 250 employees, and 2 (2.3%) had more than 100 employees. Thus, most of the respondents represented establishments that hire fewer than 10 employees and could be classified as small construction firms. Similarly, the revenues of the participant businesses were as follows: 10 (11.6%) earned less than $100K per year, 4 (4.7%) earned between $100K and $500K, 3 (3.5%) earned between $500k and $5 million, and 7 (8.2%) earned more than $5 million. Eight respondents (9.3%) indicated that they utilized private locate firms to help them locate underground utilities, mostly to locate private utilities or to use advanced technology (e.g., ground penetrating radar [GPR]) to locate underground utilities. Only 10 (11.6%) participating businesses had a written damage prevention program with recommended practices to manage work around subsurface utilities.

The Emerging Need for Private Locating Firms

The North Carolina 811 aims to better understand the services provided by private locate firms. A clear understanding of private locating services will help provide better guidance regarding the services that they can be received by hiring a private locator in order to reduce damages to subsurface utilities. Therefore, it is crucial to provide accurate responses to the survey questions to ensure a better representation of your services. Locating underground utilities during the design phase and before excavation starts is the first line of defense against utility damages. Identifying utility conflicts and correlating utility-related information between construction stakeholders can reduce unexpected delays and cost overruns (Lee et al., 2016; Al-Bayati and Panzer, 2019).

Two methods can be utilized to locate underground utilities before excavation starts or during the design phase: utilizing the one call system (i.e., call before you dig) and hiring a private locating firm. It is important to realize that the one call system does not locate private and abandoned subsurface utilities, which makes the use of private locating firms a necessity in some projects. Figure 17 shows a sample of private utilities that have been marked by a private locating firm. The one call system includes design or related tickets that designers often use to help avoid utility conflicts during the construction phase. In a recent study by North Carolina 811 (NC 811), excavators indicated that they would continue to use NC 811 despite its limitations to satisfy the state legal requirements and double check the acquired information regarding subsurface utilities.

This indicates the need to utilize private locating firms as well as a one call center during the early stages of the project.

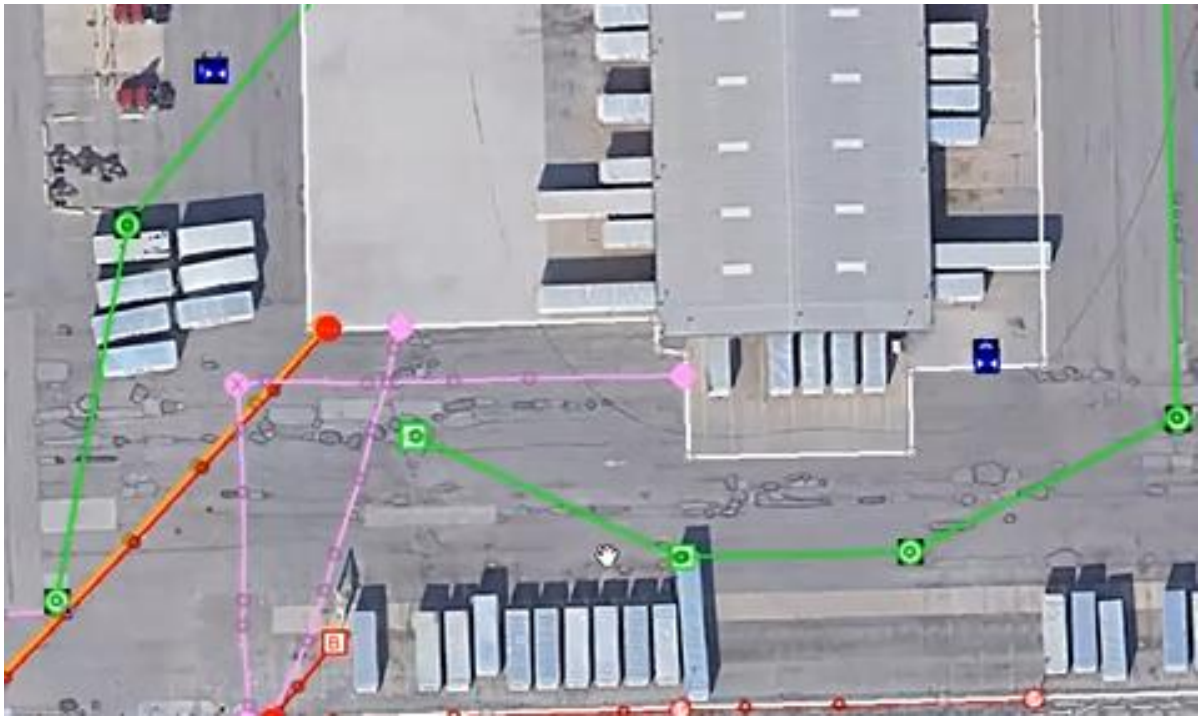


Fig. 17. Private Utilities Located by a Private Locating Firm

Research Methodology

A survey was prepared to solicit the private locating firms' opinions regarding the market need for their services. Accordingly, the responses were analyzed, and scores were generated for participants' responses. The research question was:

- Based on your experience, why is your customer utilizing your services instead of or along with the one call system? Please list no more than three reasons in bullet points.

The survey was administered during 2021, and 25 responses were received. The job titles of the respondents fell within the following categories: firm president, locate manager, and project engineer or manager. Most of the participants had more than 10 years of experience. The findings suggest that the most frequently stated reason (n = 12) for using a private locating firm is that such

firms locate private utilities—a service that is not within the scope of work of one call centers—followed by the locate accuracy of the service provided (n = 11), faster service (n = 10), and overall quality of service, including reliability, flexibility, and more advanced technology being used to locate underground utilities, such as ground penetrating radar (n = 8). Other reasons were also provided, such as the need to obtain a certain SUE level (n = 6) and the need to meet standards of care and safety and/or resolve legal or permitting issues.

Discussion and Recommendations

The market need for private locating firms seems to be growing to satisfy the need to locate private underground utilities and deliver faster, more accurate services. The findings of this study suggest that the need to locate private utilities is the contributing factor to this need. The second and third most commonly referenced reasons were locate accuracy and timeliness. This report discussed in depth the lower accuracy and longer than anticipated response time of locates within the one call system and their potential remedies.

Having better knowledge about the location of underground utilities during the design phase is crucial to reduce the probability of increased costs and expanded construction project timelines and to prevent damages to subsurface utilities. As a project progresses, the costs of design changes increase, whereas the ability to avoid utility relocation without change orders decreases. Knowing the location of subsurface utilities during the design phase forces project stakeholders to make critical decisions in the early stages of the project, during which the costs and risks associated with changes are lower. Otherwise, if a large part of the design stage has been carried out with minimal information about substance utilities, many costly changes are anticipated during the construction phase due to design conflicts with underground utilities. In other words, during the design phase, the use of available resources to locate underground utilities

can optimize the project as well as infrastructure damage prevention by providing an improved ability to manage potential utility conflicts. The project stakeholders, including the design team, can collaboratively introduce efficient plans to mitigate utility conflicts before they become high-cost impacts during construction.

Subsurface Utility Engendering (SUE) utilization was the fourth most stated reason for hiring a private locating firm within the study sample. This is an important finding that could reflect the following:

- The industry is still not familiar with the SUE standard. According to Jeong et al. (2004), the limited education about SUE is one of the greatest obstacles to utilizing it. The lack of education leads to many clients confusing the concept of SUE with the one call system and failing to use SUE private locating services.
- Not all private utility firms can provide SUE quality levels to their customers because it is not one of their major selling products. Not all private utility firms have a registered professional in their staff and have acquired the necessary knowledge to deliver SUE quality levels. Thus, it is important to hire a SUE firm to obtain the necessary SUE quality level, not just a private utility firm.

Finally, it is within the designers' duty of care to consider subsurface utilities. A duty of care can be defined as a requirement that a person act toward others and the public with the watchfulness, attention, caution, and prudence that a reasonable person would use under the circumstances. There is no excuse to ignore the potential influence of underground utilities on the overall project, especially during the design phase. Negligence claims could occur if financial damages arise from the architectural engineering firm failing in their duty of care by neglecting the influence of

underground utilities. Accordingly, project owners could sue designers for negligence in fulfilling their duty of care if a utility conflict causes significant damage during the construction phase. Utility conflicts are a major risk driver of cost contingencies (Diab et al., 2017). However, it is important to note that a duty of care arises from a statute, a contractual relationship, or by operation of the common law. As a result, considering subsurface utilities should be included in the contract between owners and architectural engineering firms. However, the owners should be aware of the added costs associated with design firms hiring a private locating firm. According to Jeong et al. (2004), more than ten times the funds invested in investigating underground utilities will be returned to the project owners in terms of fewer utility conflicts and relocations. There are four potential contributing cost saving categories from acquiring reliable information pertaining to the locations of underground utilities:

- Reduced number of utility relocations
- Reduced contractor claims and change orders
- Reduced incidents and injuries
- Reduced project delays due to utility relocates

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