



# Resilience of Infrastructure Damage Prevention: Vital Role of One Call Centers in the United States

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**Abstract:** The management of subsurface utilities contributes significantly to the resilience of modern cities. Damage to subsurface utilities greatly impacts daily life and has severe consequences, including property damage, scheduling delays, and fatal and nonfatal injuries. One call centers are the cornerstone for preventing subsurface utility damage in the United States. Construction contractors and subcontractors rely on one call centers to notify utility owners about their excavation plans. The shared responsibility approach, which calls for teamwork between excavators and utility owners, is a crucial element of the one call system. This study aims to benchmark one call centers' current practices to improve the overall communication among stakeholders and enhance damage prevention efforts. The provided benchmarking suggests the dire need for better strategies to collect and analyze the data from damage events. In addition, the practical outcomes of the North Carolina Locate Resolution Partnership Committee (NC Resolution Committee) were assessed. The assessment suggests that using data from one call centers could lead to a resilient damage prevention process. Thus, this study delivers a better understanding of the current practices of one call centers and a new approach to improving damage prevention efforts beyond the traditional role of one call centers. DOI: 10.1061/(ASCE)SC.1943-5576.0000674. © 2022 American Society of Civil Engineers.

## Introduction

Subsurface utilities are vital in all modern cities; they provide necessary services such as electricity, water, telecommunications, gas, and drainage to millions of citizens (Zhang et al. 2020). Furthermore, subsurface infrastructure continues to grow with the population (ASCE 2002). Unfortunately, the number of damage events to subsurface utilities continues to increase in the United States. The 2019 Damage Information Reporting Tool (DIRT) report suggests that accidental damage to subsurface utilities rose in 2019 for the fifth straight year (DIRT 2019). Fig. 1 shows the total estimated damage events to underground utilities between 2016 and 2019. The estimated economic impact of these events was \$30 billion in 2019 alone (DIRT 2019). Damage to subsurface infrastructure negatively impacts public services (e.g., water, electricity, and sewer), construction projects' schedule and budget, the environment, and fatal and nonfatal injuries (Al-Bayati and Panzer 2019; Tanoli et al. 2019). There were 362 fatalities due to excavation accidents from 1993 to 2013, along with 1,397 injuries and \$6.6 billion in property damage in the United States (Zhang et al. 2020).

One call centers have been established to provide a communication channel between excavators and utility owners to reduce damage, mainly by marking underground utilities before excavation starts. Fig. 2 illustrates one call centers' role in linking the locating efforts between excavators and utility owners in a simplified way. According to Bernold (2003), damage to subsurface utilities is extensive despite the successful implementation of the one call system.

Bernold's statement remains valid after 18 years of evolution in damage prevention. Clearly, there is a dire need to explore new approaches to improving the resilience of the one call system. According to the International Organization for Standardization (ISO), resilience can be defined as the ability to absorb and adapt to a changing environment (ISO 2018). Within this study context, resilience could be described as the one call system's ability to quickly and efficiently accommodate and enhance the handling of daily challenges and disruptions that may hinder damage prevention efforts. The fundamental idea is to provide techniques that reduce infrastructure damage and increase the overall system's resilience.

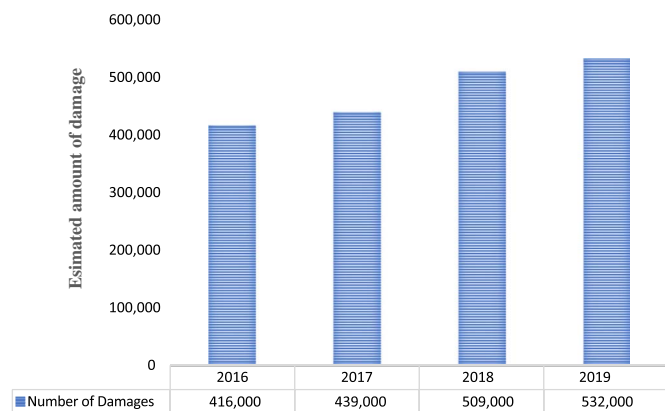
It is essential to realize that a damage prevention process does not occur in a vacuum. Communication among stakeholders is a core value of the one call system's operation, making it a significant contributor to the United States' damage prevention process. Thus, the shared responsibility approach is vital to reducing damage to underground utilities. Shared responsibility calls for teamwork among stakeholders to create a smoother work process. Shared responsibility among the involved parties is crucial to successfully reducing damage (Al-Bayati and Panzer 2019). There are three leading causes of underground utility damages: excavators' practices, locators' practices, and utility owners' practices (e.g., incorrect utility records/maps). Utility owners often hire locating subcontractors to mark their underground utilities when they receive a ticket from a one call center (Al-Bayati and Panzer 2020). Failing to notify the one call center, which could be included under excavators' practices, is the single largest individual root cause. DIRT (2019) suggested that no-locate damage represented 29.1% of damage events in 2019.

Several types of locate tickets can be placed by excavators through one call centers, such as update tickets, emergency tickets, and 3-h tickets. Table 1 shows the ticket types used by North Carolina One Call System (i.e., NC 811) and their definitions. In general, damage prevention acts require that a positive response be issued within a specific window, which is three working days in most states. A positive response could be defined as an automated notification that allows excavators, locators, operators, and other interested parties to determine a locate request's status. The current

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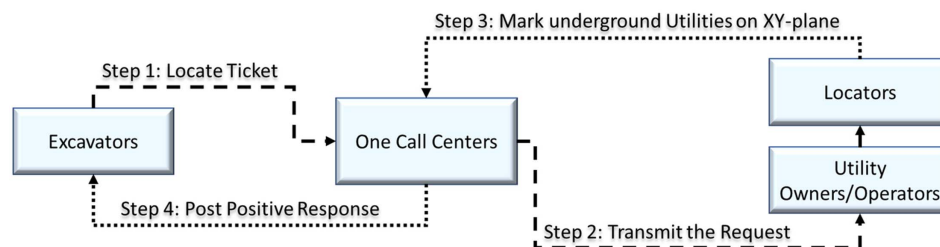
**Fig. 1.** Estimated damage in United States.

process to preserve underground utilities depends on timely, accurate locates, both areas in which current systems fall short to a slight degree (Al-Bayati and Panzer 2020). The data indicate that locate requests often take longer than the regulatory window to fulfill (Al-Bayati and Panzer 2019). On the other hand, the accuracy of locates is often compromised by several factors, such as the coupling effect, poor ground, inaccurate maps, and abandoned lines

(Siu and Lai 2019; Al-Bayati and Panzer 2020). The limitations in the current process compromise its effectiveness.

The unnecessary load (i.e., system noise) contributes to late, inaccurate locates, which increase the risk of damage to underground utilities (Al-Bayati and Panzer 2020). For example, excavators who submit update ticket requests when the work has not started yet cause an unnecessary load. Similarly, locators can contribute to excessive load using positive response codes, such as Code 60 (i.e., the locator has spoken to an excavator and arranged a schedule), for actions that have not taken place. A lack of communication between excavators and locators can also easily lead to system noise. The main form of communication between locators and excavators is white lining (Al-Bayati and Panzer 2020). White lining is a method used by excavators to mark a proposed excavation using soluble white paint, white flags, or white stakes.

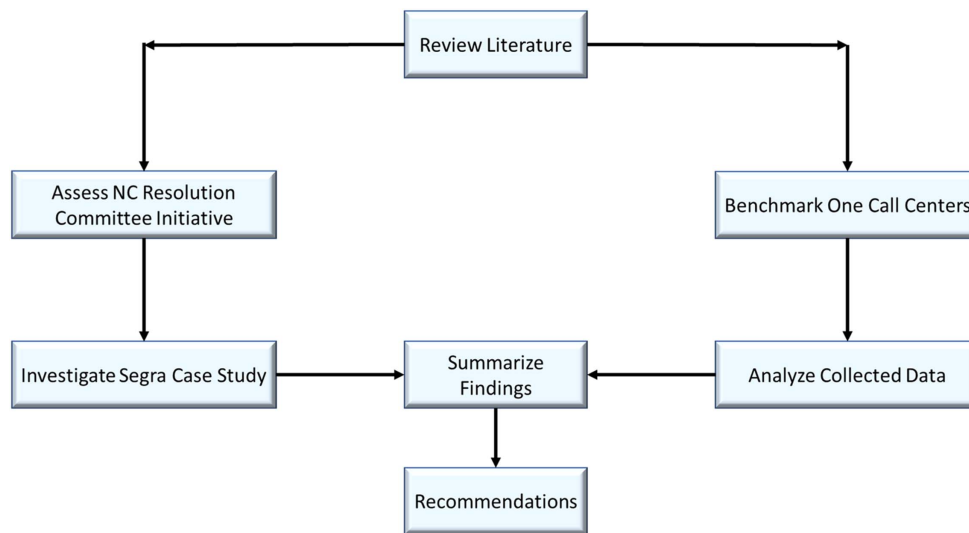
The effects of system noise are not limited to longer locate times; they can also lead to a compounding effect that could compromise the overall one call process. For example, locators have noticed that 3-h (i.e., 3Hr) notices, rather than the destroyed marks tickets, increase after bad weather affects already marked utilities. Excavators may request the 3Hr notice ticket instead of a destroyed marks ticket for a faster response (the response time for a destroyed marks ticket is the same as that for a regular ticket). Submitting incorrect tickets overloads the system and may also influence the contract locators' compensation (contract locators often do not get



**Fig. 2.** Simplified illustration of role of one call centers.

**Table 1.** Ticket types used by NC 811

Ticket type	Description
Normal	Requested when any excavation or demolition is planned. This is the standard type of ticket used and requires a full three working days' notice.
Update	In the event the excavation or demolition activities continue beyond the 15 full working days (life of the notice), the excavator will need to update the notice per NC general statutes. Updates can be requested by the 12th full working day. Changes cannot be made to an update notification. If changes occur, a new notice must be processed.
Emergency	An emergency ticket can be placed by excavators when an excavation involves a clear imminent danger to life, health, or property and must be completed as soon as possible. In addition, emergency tickets can be used when working on essential utility services or a blockage of transportation facilities, such as highways and railways. The law does not address the time frame in which a utility owner must deliver a positive response.
Destroyed marks	In the event the locate markings have been destroyed or defaced, the excavator may request a destroyed marks notice if the original notice is active and has not expired. This notice is sent to all or specific members to request a remark of the area requested on the original notice. Markings can be destroyed due to weather, grading, or heavy traffic, for example.
Design/survey	A design or survey ticket is requested for those responsible for designing underground facilities or those who require a general description and location of existing underground facilities in an area. Because there will be no digging, and therefore no risk to the underground utilities, the utility owners or their contract locators have 10 full working days to respond to a design/survey ticket instead of the usual 3 full working days.
3-h	If a utility owner fails to provide a positive response, the excavator may proceed with the excavation if there are no visible indications of a facility at the proposed excavation or demolition area, such as a pole, marker, pedestal, meter, or valve. However, if the excavator is aware of or observes indications of an unmarked facility at the proposed excavation or demolition site, the excavator shall not begin excavation or demolition until a 3-h notice is made. A 3-h notice must be addressed by the utility owner within 3 h.



**Fig. 3.** The research methodology.

paid for 3Hr notices). Therefore, this study investigates current efforts to improve communication among all involved parties in the damage prevention process by assessing one call centers' current practices to reduce system noise. In addition, the outcomes of the North Carolina Locate Resolution Partnership Committee (NC Resolution Committee) will be discussed. The NC Resolution Committee was created based on the shared responsibility concept to improve communication among stakeholders and to reduce damage.

## Methodology

To achieve the study objectives, the method illustrated in Fig. 3 was followed. This method is twofold: (1) evaluate the initiative of the NC Resolution Committee; and (2) benchmark the one call centers' current practices that aim to improve communication among stakeholders. A case study from the NC Resolution Committee will be presented to clearly illustrate the potential contributions of the NC Resolution Committee to overall damage reduction. In addition, an online survey targeting one call centers was designed and administered to assess the current practices of one call centers. Finally, findings and recommendations are presented.

## Outcomes of NC Resolution Committee

The NC Resolution Committee uses data analysis and educational outreach to improve the resilience of NC 811. The members of the NC Resolution Committee include individuals from utility companies, excavators, locators, and NC 811 staff. The group convened in the summer of 2018, and the committee began creating a mission statement to guide the direction and establish the ground rules. The NC Resolution Committee uses data to propose actions, which makes this effort unique and promising. Data, often considered the raw material of knowledge, require careful analysis to deliver meaningful recommendations and corrective actions. Therefore, the use of data to improve the resilience of damage prevention processes makes the NC Resolution Committee worth monitoring and assessing. When the NC Resolution Committee was originally discussed among stakeholders, the decision was made to create two separate NC Resolution Committees in North Carolina's two most

populous counties: Wake County and Mecklenburg County. Each committee took independent ownership over its own work. For example, the NC Resolution Committee of Mecklenburg County decided to create a white lining video to assist excavators in understanding the importance of white lining and to provide guidance on the best ways to perform that activity to help locators better identify where excavations are to take place. After several months of having two NC Resolution Committees work independently, it was determined that it would be more effective to combine the two and expand the group to include people across the entire state of North Carolina.

In early 2019, NC Resolution Committee members noted an increase in the number of update tickets based on the data provided by NC 811. Update tickets allow excavators to provide coverage and legal compliance for an excavation that is not completed within 15 working days. As stated earlier in this paper, excavators, who place update tickets when the work has not yet started, contribute to system noise. Although submitting an update ticket is perfectly acceptable as part of the process, it was discovered that roughly 30% of all tickets were updates of original requests. Excessive updates hinder timely locates due to the excessive amount of work being requested either before the actual work takes place or after the work is concluded. It also adds considerable costs to utility owners, who must pay the expenses required for each locate. In addition, unnecessary updates increase the membership fees that must be paid to NC 811 by utility owners.

Accordingly, the NC Resolution Committee further investigated instances of updated tickets in which the work duration, as provided by the excavator, was 1 day or less. The investigation indicated that a considerable number of update tickets are updated at least twice. This means that an excavation task that could be completed in a single day has often been located at least three times over a 45-day period. As NC Resolution Committee members explored this further, they found that many of the excavators who were creating excessive updates were working directly for the utility owners themselves. As a result, the identified utility owners were notified to start monitoring their subcontractors to reduce system noise. The utility owners were encouraged to initiate this effort to improve their overall financial performance as well. That is, the NC 811 membership fee for utility owners is based on their share of overall ticket volume, including update tickets. Furthermore, utility owners pay their locating contractors to mark the proposed excavation area

after each request is placed through NC 811, which includes update tickets. Highlighting the economic impact of such noise on utility owners is a critical stepping stone to optimizing the management of the damage prevention process by utility owners. Utility owners should increase outreach and education funds to reduce system noise, which will deliver an acceptable return on investment by reducing locate expenses and fees for one call center membership. Among the utility owners who responded to the NC Resolution Committee is Segra, one of the largest independent fiber bandwidth companies in the US and a member of the NC Resolution Committee.

## Segra Case Study

Segra has effectively utilized the data provided by NC 811 through the NC Resolution Committee to reduce system noise and decrease locate and membership expenses. As a result, this case study could be used to achieve the study objectives by reducing system noise if the practice is adopted by other one call centers. In early 2019, Segra began to notice an escalation of update locate requests, which consequently creates significant system noise. An analysis of NC 811 portal reporting and contractor invoicing was performed, and among the more notable cost categories were update tickets generated by Segra tied to its fiber construction projects. As a result, detailed information about the Segra subcontractors linked to the issue was gathered. At the outset of the initiative, Segra, through its subcontractors, was generating 1,100 update tickets per month on average (Table 2). Further analysis revealed that most of these update tickets were carried forward over months and were entered on the same date, indicating a potential procedural practice. It was quickly determined that Segra's subcontractors were entering tickets for multiple project miles, far exceeding the rate that would be necessary to accommodate the standard construction schedule and productivity rate. In other words, the number of tickets submitted to NC 811 exceeded the possible construction productivity rate. Most of these tickets approached expiration and were updated because the excavation could not be completed within the regular schedule. This practice significantly increases the locate time of legitimate locate requests. Furthermore, the practice generates unnecessary costs for Segra in terms of locating expenses and NC 811 membership fees.

To address this concern, Segra was able to access NC 811 portal data to rank contractors based on their number of tickets. Segra found that 2 out of its 20 contractors contributed more than 90% of all update tickets. As a result, an effort was initiated to educate and train Segra contractors on proper ticket submission procedures. A series of conference calls and onsite meetings were held with Segra's subcontractors to discuss this undesirable locating practice and its unwanted influence. This undesirable locating practice increases operational expenses, which in turn negatively influences investment plans. Explaining this to Segra's subcontractors was a game changer because their actions could impact their future

business opportunities. As a result, update ticket volumes began to decline sharply within 2 months after this effort started (Table 2). The update tickets' share of all tickets was reduced from 8% to 3% (i.e., from 1,140 tickets to 571). This reduction reduced Segra's monthly operational costs by roughly \$7,000. The estimated reduction is based on \$12 per locate to cover the expenses needed to send a locator to the field, not including the NC 811 membership fee. Furthermore, Segra has noted fewer damage events, resulting from the fact that Segra's locators have more time to locate the legitimate locate requests, which reduces late and missed locates. As a result, the return on investment is anticipated to be much higher than the reduction in locate expenses. However, it must be noted that these changes were not permanent and that over time behaviors began to return to the initially identified ones. Therefore, Segra has decided to hold biweekly meetings with its subcontractors to keep the message fresh, realizing that this is an ongoing affair.

The Segra case study illustrates the desirable impact of better communication and data utilization on improving overall damage prevention efforts. The achievement of this improvement via education and outreach efforts was shared with the NC Resolution Committee, and a decision was made to follow Segra's steps to reduce system noise. Accordingly, letters were sent to the excavators who contributed the most to system noise and the entities that contracted them in November 2019. The identification of the top 20 contributors was based on the number of tickets updated 2 or more times with a work duration of no more than 1 day, that is, work that should take 1 day or less had not been completed within 45 working days of the original ticket. Table 3 shows the percentages of tickets that met this identification criterion. The letter points out the undesirable effects of system noise and the resulting costs to the utilities. The letters were purposely written to offer education to those firms by NC 811 and the NC Resolution Committee about the issue without proposing enforcement actions. As a result, several onsite meetings were conducted to clarify the processes, understand the challenges of the companies creating the tickets, and educate professionals about the impact of tickets that, if not directly tied to work being conducted, could be considered in violation of NC law. Continued review of data during and after these onsite efforts demonstrated that they were effective in reducing the

**Table 2.** Segra data before and after educational efforts—2019

Month	Segra update tickets	Percentage of update tickets (out of all tickets) (%)	Estimated costs (\$12/locate)
March	1,176	8	14,112
April	1,379	8	16,548
May	711	4	8,532
June	488	3	5,856
July	571	3	6,852

**Table 3.** Percentages of tickets of top 20 excavators—December 2019

Firm code	Concernment updates	Total updates	Concernment tickets (%)
1	332	4,076	8.1
2	326	2,822	11.6
3	319	2,042	15.6
4	216	4,927	4.4
5	185	1,035	17.9
6	184	271	67.9
7	168	947	17.7
8	98	586	16.7
9	97	544	17.8
10	94	189	49.7
11	87	188	46.3
12	76	306	24.8
13	62	163	38.0
14	58	259	22.4
15	57	61	93.4
16	50	204	24.5
17	46	236	19.5
18	43	265	16.2
19	42	100	42.0
20	39	104	37.5



occurrence of update tickets over the short term. For example, the excavator with the fifth highest occurrence in December (Table 3) was provided with specific onsite training. This training was delivered by the utility that contracted the company and a representative of NC 811. The training stresses the costs of these and their influence on overall damage prevention efforts. When the report was issued in January, the company was no longer in the top 20.

## One Call Center Benchmarking

Benchmarking is a systematic method of measuring an organization's performance to establish a baseline and detect necessary improvements at the organizational level (Al-Bayati and Panzer 2020; Love and Smith 2003). Accordingly, an online survey was administered during August 2020 utilizing a convenience sample to benchmark one call centers. A total of 14 one call centers participated in the survey. However, not all responses were usable due to duplicate answers from the same one call center. The duplicate answers from the same one call center were counted as one response. If two different answers from the same one call center were found, further investigation was carried with that one call center to ensure the provided information's quality and correctness. As a result, the data from 12 one call centers were determined to be suitable for the data

analysis process. The 12 one call centers were those in Virginia, Tennessee, Oklahoma, North Carolina, Mississippi, Michigan, Louisiana, Connecticut, Indiana, Colorado, California, and Arizona. The description of the analysis results avoids specifying an individual one call center's answers to maintain confidentiality. All respondents' job titles were one of the following: executive director, president, director, vice president, and education specialist.

## Benchmarking Findings

Knowing the importance of system noise reduction, the first section of the survey aims to identify current data collection practices regarding emergency tickets, update tickets, and damaged marks tickets. The results indicated that most one call centers that participated in the study collected information about update and emergency tickets but not damaged marks tickets. This finding could have resulted from the fact that damaged marks tickets are not available in all states. The participants were asked if they noticed that some of these tickets were illegitimate. All participating one call centers answered *yes* to this question (Table 4). The participants were asked about the actions they take to reduce illegitimate tickets. Table 4 shows some of the steps used by one call centers. For example, one of the responses suggested that there was nothing to be done

**Table 4.** One call center benchmarking—qualitative data

Aspect	Feedback/reported
Have you noticed that some of the emergency, update, or damaged mark tickets are illegitimate?	We do not audit the reporting of data provided by the excavator or the facility owner and operator for illegitimate purposes. There are times when the system is misused for the benefit of the excavator when they fail to properly plan and place their requests within the guidelines. It's obvious that some emergency locate requests aren't legitimate. Members find that a lot of tickets submitted as emergency tickets are not true emergencies. We affirm that the emergency ticket is, in fact, an emergency ticket by reading the definition of an emergency ticket and asking the caller to agree.
What actions, if any, does your center take to reduce illegitimate tickets?	Nothing really because the more complicated you make the process, the less it will be used. We do not have any enforcement authority, so we engage the underground facility operators to write letters instructing the excavators about the illegitimate tickets to stop the behavior. We have a committee to discuss overall trends, and this committee offers education to those who might be using the system in a way that is unintended.
Does your center reach out to the top contributors of illegitimate tickets?	We have not identified the type of extensive problem with "illegitimate" tickets that would necessitate a full-blown program to eradicate them. We have, but they tell us they are legit tickets. Operators/locators are in a better position than we are to determine whether these are legitimate requests or not.
How does your center handle data?	We do. When an abuse of any kind comes to our attention, we send a liaison to talk face to face to the abuser. Facility owners are required to report damage to the state public service commission. These data are calculated, and the weighted average determines the areas on which to focus the education/marketing budget to include billboards, online marketing, and social media. We use a fully automated software program that allows all facility operators to report/input "incident" information.
Does your center analyze damage data?	Excavator data are collected through a ticketing system, and that is uploaded into DIRT. We do not collect damage data at this time. Our law does not require that damage be reported to a one call center; however, we do create a "damage ticket" if we receive a call to report damage.
How does your center focus on outreach efforts?	We do not collect damage data but receive them from our state regulators. We look at trends on overall damage, root causes, and responsible parties as well as geographic location. We do emphasize white lining, even though it is not mandatory. We stress that contacting a one call system is only the start of the communication process between the two parties and that every resource—from employing white lining at the job site to using positive responses through the one call system to directing communication in the field between excavator and plant owner—should be used to ensure safe digging and damage prevention. Training emphasizes the importance of accurate phone and other contact information.

to reduce them; another indicated that there was a system in place to flag such tickets, warn the excavators who place them, and even require the excavators to attend mandatory training. Furthermore, the participants were asked about the methods they often used to share the collected data. Educational efforts seem to be the main action used to reduce illegitimate tickets. However, legal consequences and active enforcement may be necessary to reduce noise and improve the overall system's resilience. In addition, the study asked participants whether they contacted the top contributors of illegitimate tickets. Most received responses suggested difficulty in pursuing this route. Table 4 shows a sample of the reported obstacles. The absence of an objective method of analysis to identify the major contributors to system noise is troubling.

The participants were also asked about the damage reporting requirements. The damage prevention law in only two states within the study sample requires utility owners, locators, and excavators to report damage to a one call center. This finding is problematic because the USDOT's Pipeline and Hazardous Materials Safety Administration (PHMSA) assesses the effectiveness of damage prevention laws based on nine factors, one of which is data analysis of reported damage. PHMSA's most recent evaluation report suggests that damage reporting is the method least commonly used by one call centers (PHMSA 2020). Furthermore, participants were asked about the methods they use to analyze collected data on different types of tickets. The one call centers in the study use various methods to analyze collected data, including consulting firms, Common Ground Alliance (CGA's) Damage Information Reporting Tool (DIRT), state public commissions, and automated software programs. Five call centers indicated that they did not analyze damage data (Table 5). The NC Resolution Committee shows the importance of sharing data to improve damage prevention resilience and reduce system noise. However, to avoid overwhelming stakeholders with information, it is not recommended to share raw data unaccompanied by careful, detailed analysis of those data. Accordingly, the sharing of data by one call centers without detailed analysis is questionable.

The participants were asked about sharing the collected data, mainly ticket type data, with excavators, utility owners, and the general public. The results suggested that only eight one call centers

shared their data with excavators and utility owners, and only six one call centers shared their data with the general public (Table 5). The participants were also asked about the methods they use to communicate data. The results indicate that electronic means (e.g., email blasts and social media) represent the main communication method, followed by face-to-face meetings (e.g., damage prevention committees, annual damage prevention events, and trade shows), outreach efforts, and print (e.g., magazines and newsletters). Finally, the survey asked whether outreach efforts emphasized the importance of clear communication between excavators and locators. The responses suggested that most participants emphasized the importance of clear communications, focusing on white lining, excavators' responsibility to check for a positive response, and accurate ticket information (Table 4).

## Theoretical and Practical Implications

Many studies in recent years have been published to aid in reducing the damage rate to underground utilities, but the majority of these studies do not consider the shared responsibility concept and the role of one call centers. The results of this study advance theoretical knowledge in the area of managing subsurface infrastructures during excavation activities. The study represents the first comprehensive empirical effort to evaluate the interrelationship among excavators, utility owners, and one call centers by illustrating the Segra case study. The findings suggest that management techniques such as training and communication on utility owners' projects can reduce the utility owners' expenses in terms of membership fees and locators' compensation. In addition, these management techniques will improve one call centers' overall performance in terms of accurate and timely locates.

More specifically, emphasizing the importance of damage prevention and the economic consequences of excavators' noncompliance actions could reduce damage to subsurface infrastructure and reduce utility owners' overall expenses. Thus, the study shows the importance of shared responsibility and teamwork among stakeholders to better managing subsurface infrastructure during construction activities. According to Diab et al. (2017), addressing the risk of utility damage helps reduce the contingency amounts needed by contractors. Thus, it may lower their overall contract bid amounts, which will increase their probability of winning sealed bid contracts. As a result, mitigating the risk of utility damage benefits all stakeholders. Accordingly, this study successfully links the research findings at the level of one call centers to the project level of utility owners and excavators. Thus, the study satisfies the framework recently proposed by Naderpajouha et al. (2020), which calls for direct resilience-oriented research in the project management domain.

A closer examination of the damage data presented in the yearly DIRT reports suggests that there is a continuous increase in the amount of damage from year to year despite the significant efforts of one call centers across the United States. It should be evident that these efforts have reached saturation with respect to influencing the practices of stakeholders at the project level. Thus, other means should be utilized to enhance the resilience of damage prevention efforts. The study provides a clear path for one call centers to proactively address the noticeable high number of damage events involving underground utilities. The PHMSA encourages one call centers to analyze data to improve program effectiveness. However, the most recent evaluation of one call centers by PHMSA suggested that data collection and utilization are rarely implemented (PHMSA 2020). The fact that only two of the one call centers that participated in the study were collecting damage data is alarming.

**Table 5.** One call center benchmarking—quantitative data

Characteristic	Number (%)
Does your one call center collect emergency ticket data?	
Yes	11 (91.7)
No	1 (8.3)
Does your one call center collect update ticket data?	
Yes	10 (83.3)
No	2 (16.7)
Does your one call center collect damage mark ticket data?	
Yes	5 (41.7)
No	7 (58.3)
Is reporting damage to your one call center required by law?	
Yes	2 (16.7)
No	9 (75.0)
Not reported	1 (8.3)
Does your one call center share data with utility owners and excavators?	
Yes	8 (66.7)
No	4 (33.3)
Does your one call center share data with the public?	
Yes	6 (50.0)
No	6 (50.0)

Furthermore, the lack of in-house data analysis of the factors that most contribute to system noise should be reconsidered. Continuous improvement of the system requires an endless evaluation process. This study reveals a promising opportunity to improve overall damage prevention by utilizing currently collected data (e.g., emergency tickets and update tickets). There is also a need to revisit damage prevention laws to require damage reporting. Damage reporting to one call centers seems to be vital to tailoring outreach and educational activities. Thus, it is expected that the findings of this study will encourage one call centers in the United States to improve their overall work procedures to reduce system noise and improve communication among stakeholders.

Segra's case illustrates a practical method that is proactive in nature to reduce system noise by utilizing NC 811 data and communicating abnormal trends. Furthermore, this case study suggests that incorporating cost analysis into the damage prevention process is vital to sustaining a resilient damage prevention program. Consequently, utility owners are encouraged to conduct internal data analyses in collaboration with one call centers and to take action, in partnership with those working on their behalf, to reduce system noise and damages. However, it must be noted that this effort should be viewed as a continuous improvement initiative that should be implemented on an ongoing basis. A continuous improvement is a systematic approach that aims to achieve ongoing incremental performance enhancements (Audretsch et al. 2011). Furthermore, the cost-benefit analysis presented in this study could be used to justify the needed funds to monitor and reduce system noise by utility owners. This manuscript goes beyond the traditional causes of damage to highlight other avenues to reduce damage and improve the resilience of one call systems.

The reduction in damage to underground utilities due to the NC Resolution Committee indicates that the current suggested causes of the damage (i.e., excavators' and locators' practices) ignore the shared responsibility concept. It is not practical to view the process as if there were no overlap among stakeholders' actions; the process does not happen in a vacuum. Thus, a detailed incident investigation is required to reveal the possible measures that could improve the overall process, not just the direct causes of damage. On the other hand, one call centers may consider providing incentives to utility owners who actively work with their subcontractors to reduce system noise. Furthermore, state legislators should consider revising the damage prevention laws to address the actions that could lead to system noise.

## Concluding Remarks

This article discussed strengthening infrastructure damage prevention resilience by improving stakeholder and one call center practices. Accordingly, innovative methods were discussed and suggested to facilitate system noise reduction and damage prevention. Specifically, the study highlighted the importance of utility owners' involvement in ensuring the resilience of the damage prevention process. As a result, the study's most important contribution is providing a practically tested method (i.e., Segra case study) that could help reduce system noise, damage to underground utilities, and unnecessary expenses. One call centers could duplicate the NC Resolution Committee initiative to reduce system noise and damage. This is vital since benchmarking revealed a lack of an objective analytical methodology to identify the major contributors to system noise.

This study provides a road map for one call centers to improve general communication among stakeholders in a proactive way. Overall, the study offers promising techniques to elevate the damage prevention process into a new steady state that is more efficient and resilient. Finally, the reported benchmarking can promote better damage prevention laws and one call center practices. As a result, the study could help in improving the efficiency and integrity of the one call process in the United States, which in turn could reduce damage to the nation's infrastructure.

## Data Availability Statement

All data, models, and code generated or used during the study appear in the published article.

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