CGA DIRT

Damage Information Reporting Tool

VOL. 16

2019 Analysis & Recommendations

Released, October 2020

To download or to access additional analysis, visit CommonGroundAlliance.com/DIRT.

Dear Damage Prevention Stakeholders,

On behalf of the Common Ground Alliance's Data Reporting and Evaluation Committee, I'm pleased to present the 2019 DIRT Report, the only comprehensive resource analyzing damages to buried infrastructure in North America.

The 2019 DIRT Report has quite a story to tell, and includes key findings and recommendations that we encourage you to share with your professional networks as we work together to reduce damages. One of the Report's most important – and concerning – conclusions is that estimated U.S. damages are trending upward for a fifth consecutive year. We, as a damage prevention industry, must consider how to most effectively reverse this trend, to protect those who live and work near these important assets and reduce the tremendous societal impacts of these damages, which are estimated to have cost $30 billion in 2019 alone.

Where do we have opportunities to drive damages down? The 2019 data suggests that targeting a singular practice or stakeholder group is unlikely to yield systemic improvements, as damage root causes are evening out among failure to notify, excavating issues and locating issues. While failure to notify remains the single biggest individual root cause contributing to damages, significant improvements will only happen if we collectively look at opportunities to reduce damages through comprehensive change.

A potentially important clue resides in the rise in volume of one call transmissions. The ratio of damages per one call transmission declined from 2018 to 2019, normally a positive sign. However, the 2019 data shows that incoming locate requests and outgoing transmissions increased at a greater rate than damages, while construction spending remained flat. This means that each dollar of construction spending is resulting in more transmissions than before, potentially putting pressure on the damage prevention process by creating inefficiencies in the system.

On the following pages, the Data Reporting and Evaluation Committee shares important analysis on the current state of damage prevention, as well as thoughtful input on how stakeholders can work together to move damage prevention forward. A key recommendation in the Report highlights the benefit of reviewing Best Practices with an eye for specificity. In order to facilitate a more comprehensive view of the future of damage prevention, CGA's Next Practices Initiative is currently examining some of the industry's most persistent problems and seeks to identify technologies and practices that are successfully reducing damages in those areas.

In addition to reviewing the important information in the 2019 DIRT Report, I encourage you to visit the DIRT Interactive Dashboard to explore the data that is most relevant to you. You will find excellent case studies from North Carolina 811 and National Grid in the Report's appendices that showcase how those organizations have leveraged DIRT data to reduce damages.

Finally, I would like to thank the Data Reporting and Evaluation Committee for their diligent work in preparing this Report, and all of you who submit data to DIRT. Without your valuable time and input, CGA would not be able to produce our annual DIRT Report and recommendations.

Be safe,

Sarah K. Magruder Lyle

Sarah K. Magruder Lyle
President and CEO
Common Ground Alliance

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CGA and PHMSA Resources

Below are links to additional CGA and PHMSA resources:

- CGA Online DIRT Dashboard:

  https://commongroundalliance.com/dirt-dashboard

  The interactive dashboard allows users to analyze the complete DIRT dataset, run queries, filter, sort, and extract trends of interest. Key features of the interactive DIRT analysis tool include the following: state summaries and interactive visualizations; easy comparisons between states; temporal damage trends over the year; interactive maps; and root causes and associated excavation information (type of excavator, work, and equipment).

- CGA Technology Advancements & Gaps in Underground Safety & Technology Collection Form:

  https://commongroundalliance.com/Publications-Media/Technology-Reports

- CGA DIRT Reports (Archive):

  https://commongroundalliance.com/DIRT

- U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA):
  - Determinations of Adequacy of State Enforcement Programs: https://www.phmsa.dot.gov/pipeline/excavator-final-rule/determinations-adequacy
  - State Pages (including damage prevention information):

    https://primis.phmsa.dot.gov/comm/states.htm?nocache=4418
  - Pipeline Incident Heat Map and Other State Information:

    https://primis.phmsa.dot.gov/comm/DamagePrevention.htm?nocache=384

Executive Summary

NOTE: For a glossary of terminology used in this report, please see Appendix A.

Damages in 2019

- Damages are on the rise. The number of damage reports entered in DIRT, both before and after applying the method to match and weight multiple reports of the same event, reached an all-time high at 534,151 and 453,766 respectively.
- The estimate of total damages in the U.S. increased 4.5% year-over-year to 532,000, mirroring a 4.5% increase in damages per million dollars of construction spending. Interestingly, the number of transmissions per every construction dollar spent rose in 2019 – a potential indicator of stress on the damage prevention system.
- Enhancements in the quality of DIRT submissions could substantially increase the strength of the DIRT Report and the resulting recommendations.

Enormous Societal Costs of Damages

- For 2019 alone, the societal costs of damages to buried utilities in the U.S. is estimated at $30 billion. This estimate accounts for direct costs (facility repair) and indirect costs (property damage, medical bills, businesses unable to operate, etc.). All stakeholders have a clear interest in reducing damages to buried utilities as a means of reducing these enormous societal costs.

Root Cause Analysis

- Failure to notify the one call center/811 (No Locate Request) remains the largest individual damage root cause, but the root cause groupings of Excavation Issues, Locating Issues, and Invalid Use of Locate Request all appear roughly equal, suggesting that improvements are needed in every step of the safe excavation process in order to reverse the damage trend.
- Distinguishing between damage liability and true damage root cause when submitting to DIRT would better illustrate where behavior changes could result in improved safety outcomes.

Reexamining Best Practices

- The biggest categories of damage root causes correspond to Best Practices that lack specificity, likely reflecting the difficulty of achieving consensus among all 16 CGA stakeholder groups, which is required by the Best Practices process.
- With low-hanging fruit harvested, the remaining issues facing the industry are more challenging ones. Still, the 2019 DIRT Report includes recommendations for reexamining key Best Practices to combat the largest drivers of damages to buried utilities.

Interactive Dashboard

- Explore the 2019 (and 2018) DIRT data using the Interactive Dashboard, which allows users to apply a range of filters to create custom data views.

Recommendations

With damages trending upward, DIRT Report analysis suggests that focusing on damage prevention practices at each step of the safe excavation process is necessary to drive damages down. *The first set of recommendations addresses issues that emerged as part of the root cause groupings analysis found in this Report:*

1. **Address potholing and excavating in the tolerance zone.** The Best Practices Committee should review Practices 5.19 and 5.20 to determine if more practical hands-on language could be developed, including a definition of "potholing." The Next Practices Advisory Committee should examine this issue.

2. **Examine pressures on locators.** The volume of locate requests and subsequent one call transmissions are rising: Each dollar of construction spending appears to be resulting in more locate requests and transmissions than in years prior. Mis-marks due to locator error appear as a top root cause in the locating group, suggesting that locate ticket volume is often a challenge for locate technicians.

3. **Emphasize the proper use of locate requests.** Changes to the DIRT form in 2018 have resulted in a clearer picture of the Invalid Use of Locate Request damage root cause group. Top damage drivers in this group include digging before the valid start date/time and digging after a ticket expired, pointing to the need to ensure that requests are being utilized properly to prevent poor safety outcomes.

4. **Develop strategies for addressing persistent no-call damages.** No Locate Request remains the single largest individual damage root cause, despite 811 and call-before-you-dig awareness reaching an all-time high (SOURCE: CGA's 2020 Public Awareness Survey). Additional research into the no-call group could help better address this damage category.

5. **Explore *all* opportunities for improvements to the damage prevention process - both modifications to individual stakeholder performance, enhancements to the current system as well as potential structural changes and innovative solutions to address persistent challenges.** Rising damages, increasing locate request volume and roughly equivalent root cause groups suggest the need to evaluate the system.

Additional recommendations based on DIRT data include:

6. **Increase the quantity and quality of DIRT submissions.** While DIRT submissions reached an all-time high this year, submitters whose Data Quality Index (DQI) score is below 70 should focus on improving the completeness of their forms. Additionally, root cause analysis should focus not on damage liability, but rather the true point in the process where a change in behavior could have prevented a damage.

7. **Use the new Interactive Dashboard to explore damage data.** Reported damages from 2019 and 2018 are displayed via a new PowerBI dashboard that makes it easier than ever to drill down into DIRT data that is most applicable or actionable for your organization.

8. **Read the Case Studies from North Carolina 811 and National Grid.** In Appendices F and G, North Carolina 811 and National Grid share how they used DIRT data to reduce damages, which may prove inspirational for your organization.

9. **Adopt new technologies to help prevent damages.** Technology has greatly advanced over the last 20 years. Consult the CGA Technology Report and explore ways to use technologies to reduce damages by improving one call center processes, locating and excavating practices, and communication in the field.

Introduction to the 2019 DIRT Report

- **Find key background information for understanding and interpreting the 2019 DIRT Report and data in this section, including a link to a glossary of terminology.**

Welcome to CGA's 2019 DIRT Report. As you review the valuable insights and findings in this report, it is important to understand where the data originates, how it is analyzed and the meanings behind specific terminology. **Please review Appendix A for a complete glossary of terms used in the 2019 DIRT Report.** In particular, understanding the differences between reported damages, unique damages and the U.S. estimate of damages is critical to an accurate reading of the figures, tables and graphs on the following pages.

Defining Damages

- **Reported events = All reports of a damage or near miss entered in DIRT**
- **Unique events = Number of unique events estimated after consolidating multiple reports describing the same event**
- **Estimate of U.S. damages = Estimate of damages based on DIRT data as well as an advanced predictive model**

Table 1—Reported events, near misses, and damages in Canada and the U.S., over time

	2017	2018	2019
Total Events Entered in DIRT	411,867	440,749	534,151
Near Misses (unique events)	1,588	4,198	2,524
Damages (unique events)	316,422	341,609	453,766

The number of events reported via DIRT for the U.S. and Canada in 2019 totalled 534,151. After consolidating multiple reports of the same events[1] and filtering out near misses, the number of unique damages was 453,766, comprised of 10,868 in Canada and 442,898 in the U.S. (Table 1). The DIRT Interactive Dashboard is based on reported unique damages and shows a total of 453,766 when no filters are applied. To better understand the path a DIRT report follows from event submission to presentation in the DIRT Report, reference Appendix B.

[1] See the 2015 Annual DIRT report for a description of the method used to match and weight multiple reports of the same event (https://commongroundalliance.com/DIRT)

The Impact of Data Quality

- **Damage prevention stakeholders can improve the quality of the DIRT Report by increasing the completeness of their report submissions.**

CGA uses a metric called the data quality index (DQI) to measure the completeness of DIRT reports. For 2019 data, the overall DQI scored 59 out of 100 possible points, very slightly down from 2017 and 2018 DQI scores of 63 and 62, respectively. While it's not realistic for all stakeholders to reach a DQI of 100 (as there is information certain stakeholders will not have access to), DIRT could be greatly improved by raising the scores of those below 70, as evidenced by Figure 1 below. Because DQI measures the quality of reports as originally entered in DIRT, Figure 1 does NOT account for multiple reports of the same event. For a more detailed explanation of DQI and its distribution across stakeholder groups, reference Appendix C.

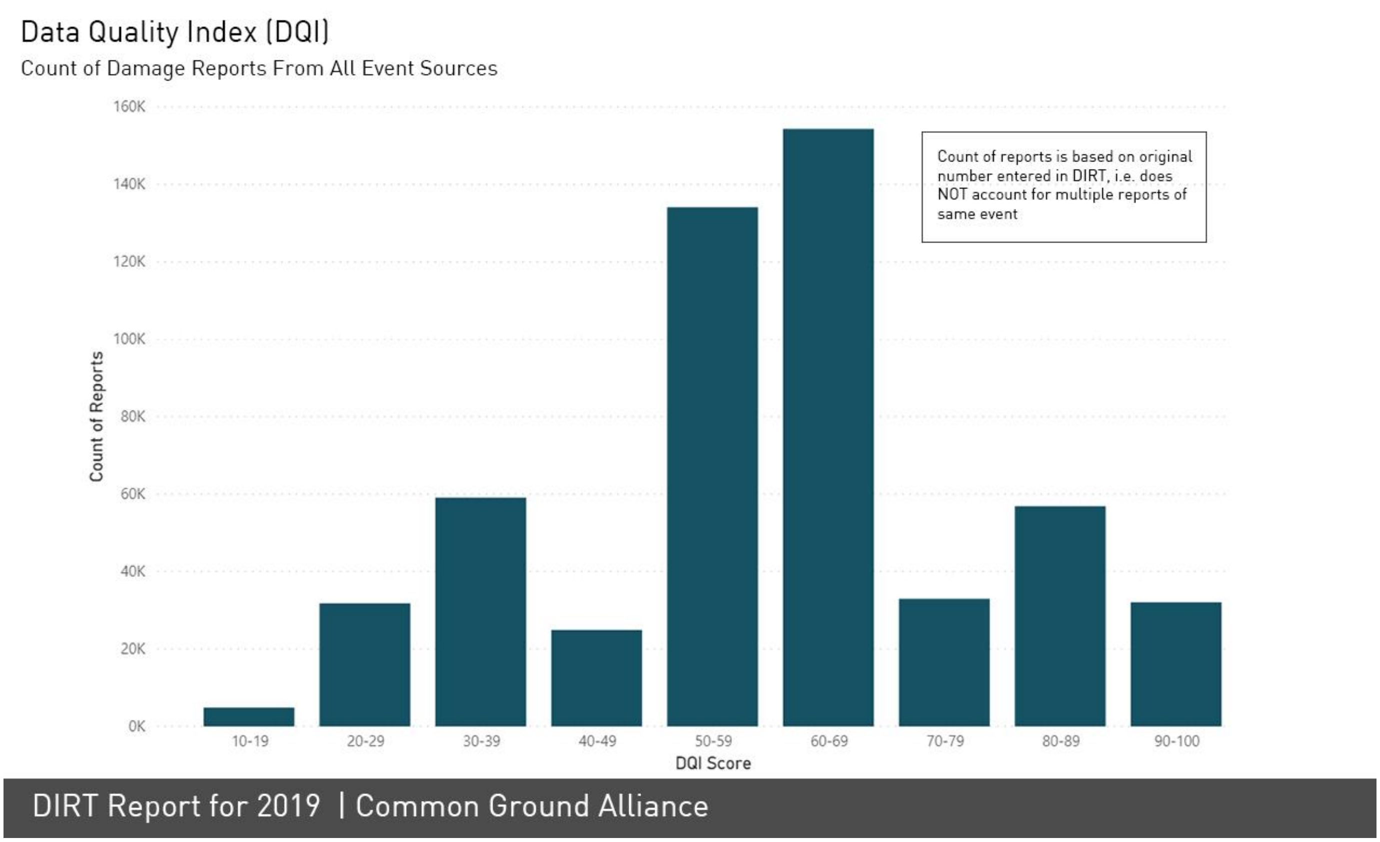

Figure 1

Where Does DIRT Data Come From?

- **Locators submit the majority of DIRT reports.**
- **Liquid pipeline and natural gas were the only stakeholder groups who self-submitted the majority of reports about incidents to their own facilities.**

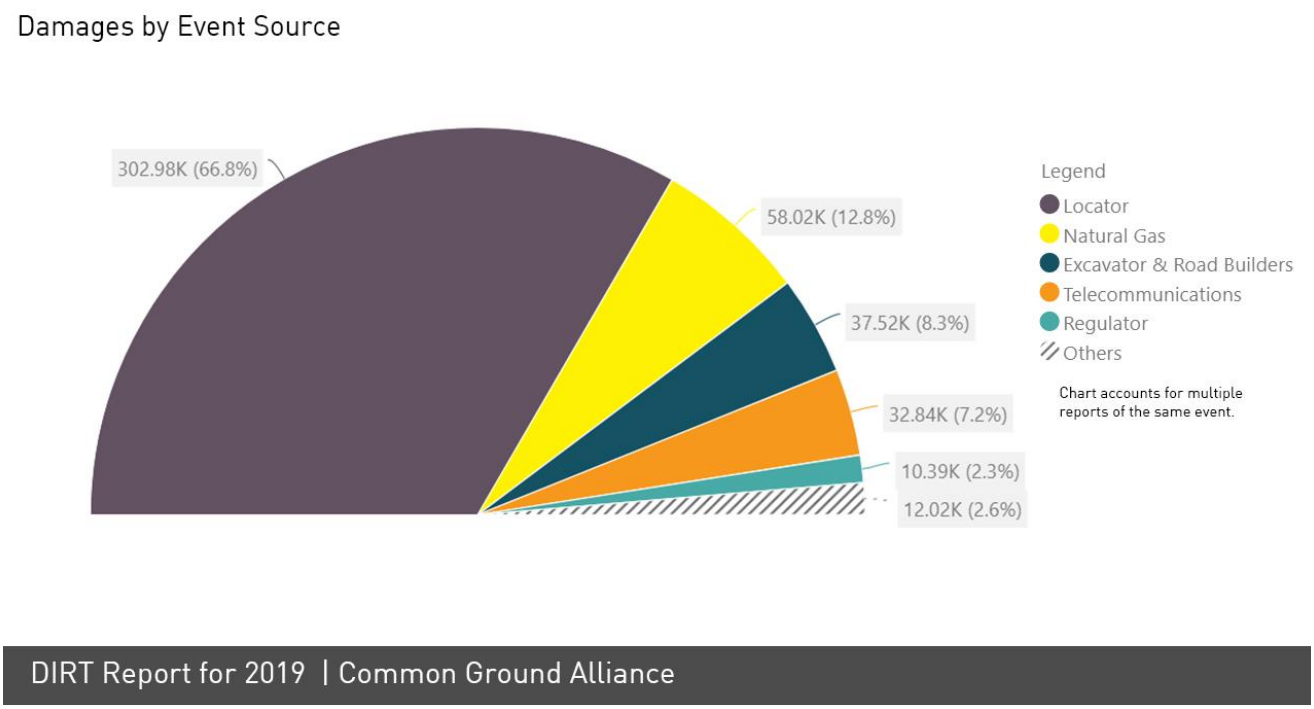

Figure 2

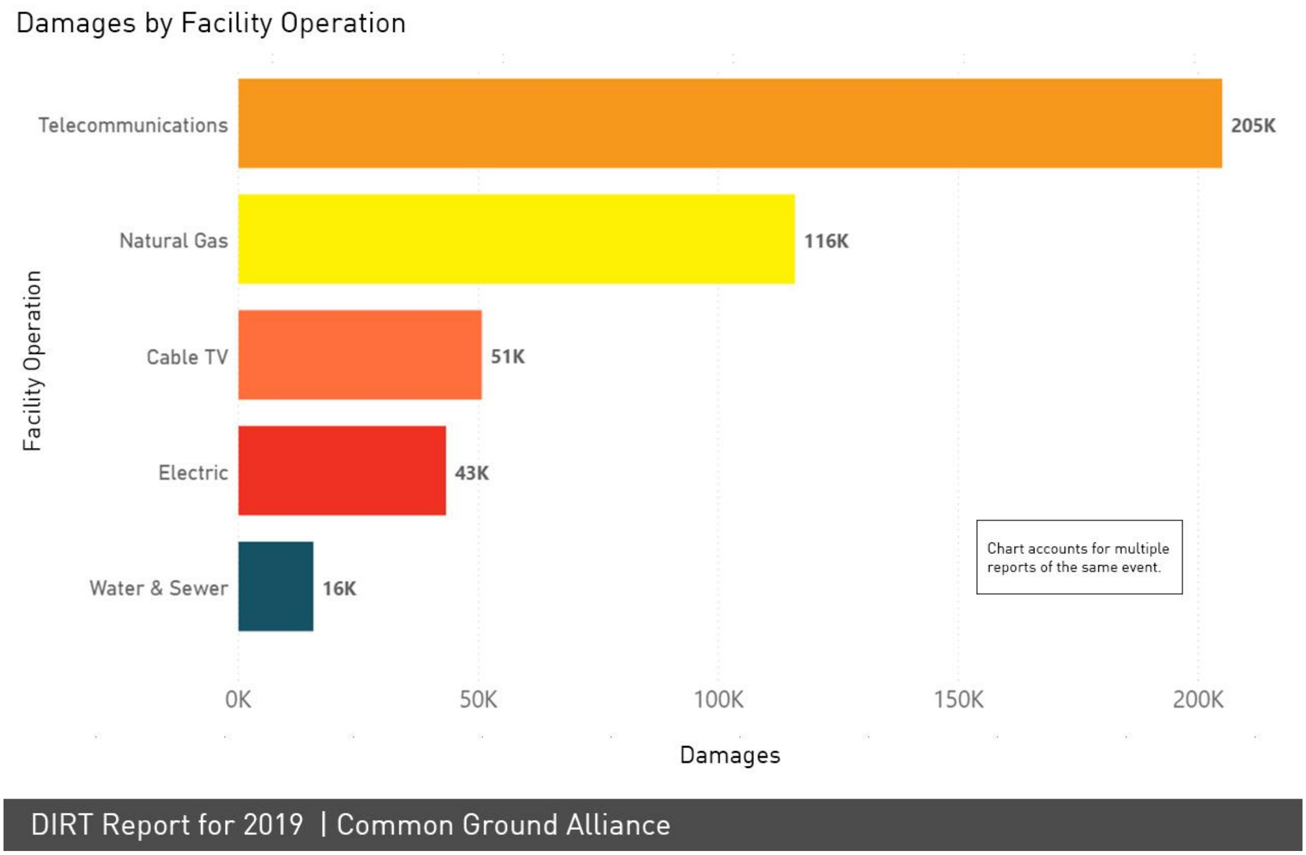

Figure 3

The two figures above summarize damage reports by event source (Figure 2) and illustrate reported damages by facility operation (Figure 3) in 2019. Taken together, these show that locators are the leading source of all events, and telecommunications is the leading facility damaged. Most telecommunications events are submitted by locators, versus being self-reported by telecommunications facility owners themselves.

Table 2 shows the leading event source for each type of facility damaged. The self-reporting columns indicate the level to which the corresponding event source (where applicable) submits DIRT reports. Liquid pipe and natural gas are the only ones with self-reporting as the leading source. They are less than 50% self-reporting because other sources such as locators, excavators and regulators also enter DIRT reports for those facilities.

Table 2—Leading event sources and self-reporting level by facility damaged, known data, in Canada and the U.S., 2019

Facility Damaged	Leading Event Source	% of Reports	Self-Reporting	% of Reports	# of Reports
Cable TV	Locator	85%	Telecommunications	6%	50,739
Electric	Locator	71%	Electric	13%	43,293
Liquid Pipe	Liquid Pipe	34%	Liquid Pipe	34%	158
Natural Gas	Natural Gas	48%	Natural Gas	48%	115,991
Sewer	Excavator	59%	Public Works	20%	1,395
Steam	Excavator	83%	N/A	N/A	24
Telecommunications	Locator	77%	Telecommunications	14%	204,990
Water	Locator	54%	Public + Private Water	8%	14,251

Estimating Total U.S. Damages

- **A statistical model that incorporates DIRT data, One Call Systems International (OCSI) transmission data, and digging activity indicators is applied to generate the estimate of total U.S. damages.**
- **Estimated damages were up 4.5% year-over-year in 2019.**
- **While construction spending was flat, data shows more transmissions per construction dollar spent in 2019. This suggests that the trend of rising damages correlates with the rise in transmissions, and that the damage prevention system is becoming stressed.**

Estimating the annual total of damages to buried utilities is a primary objective of the DIRT Report, because it helps the damage prevention industry understand the full scope of our challenges and successes. To generate the estimate of total U.S. damages, CGA's Data Reporting and Evaluation Committee engages a consultant (Green Analytics) to develop a statistical model predicting total U.S. damage events based on DIRT data and a number of other variables which are statistically assessed for correlation with the number of reported damages by state. Appendix D explains in detail the process followed by Green Analytics.

Table 3 presents key performance indicators generated using the prediction models. Indicators are presented for total estimated damages and one call transmissions for the U.S. over time. Figure 4 shows this information graphically.

Table 3—Key performance indicators for total estimated damages in the U.S., over time

	2016	2017	2018	2019
Total Estimated Damages	**416,000**	**439,000**	**509,000**	**532,000**
Lower Bound Confidence Interval for Total Estimated Damages	**201,000**	**270,000**	**230,000**	**430,000**
Upper Bound Confidence Interval for Total Estimated Damages	**1,159,000**	**715,000**	**787,000**	**666,000**
Total Estimated Transmissions	**221.9 M**	**234.9 M**	**244.3 M**	**267.6 M**
Total Estimated Damages per 1,000 Transmissions	**1.88**	**1.87**	**2.08**	**1.99**
Total Estimated Damages per million dollars of construction spending (2019 $)	**0.319**	**0.337**	**0.373**	**0.390**

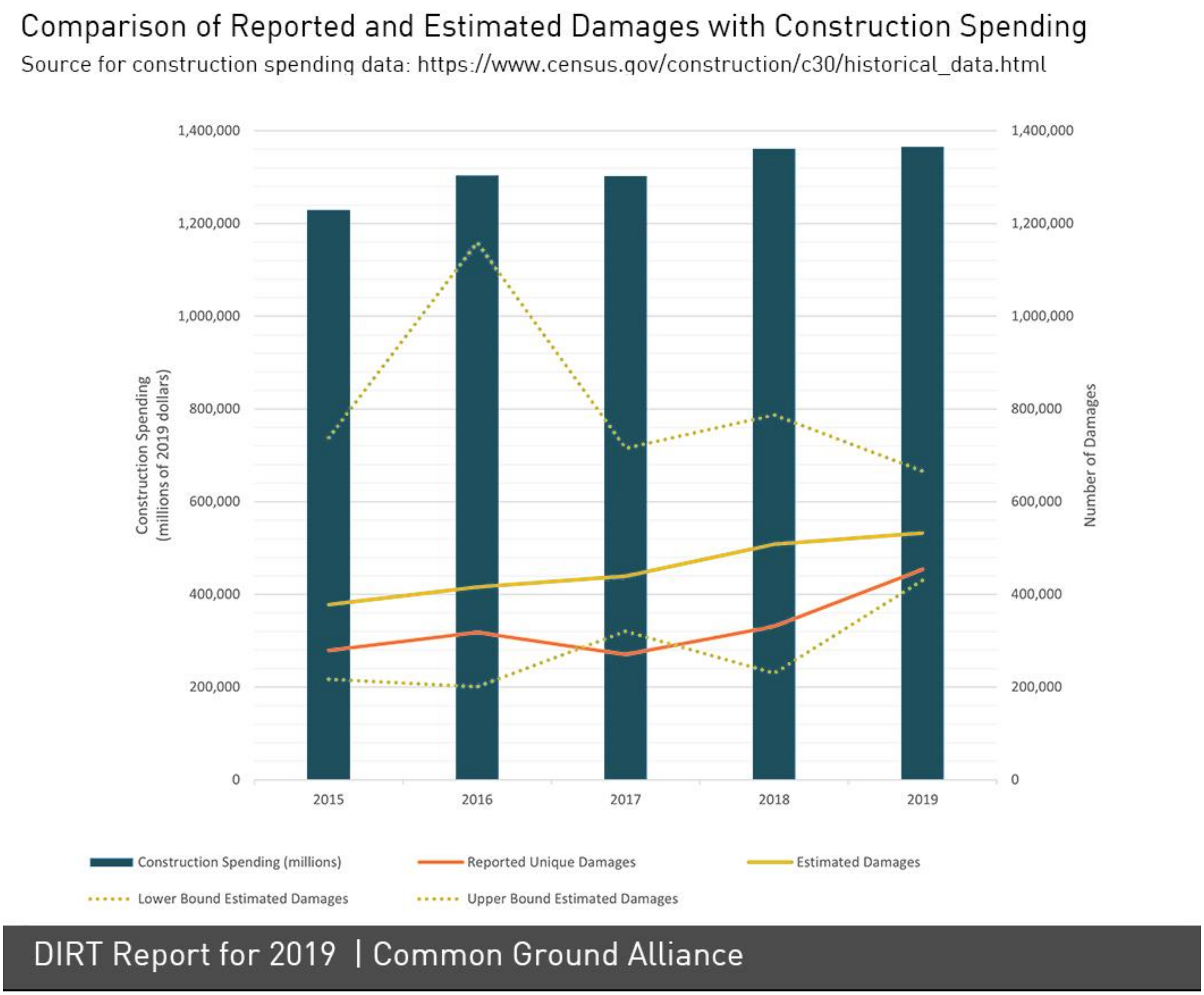

Figure 4 (Source for construction spending data: https://www.census.gov/construction/c30/historical_data.html)

While we expect variation in the number of estimated damages from year to year, the real value of this metric is in observing its overall trend, which has been moving upward since 2015. The large jump in estimated damages from 2017 to 2018 may reflect, in part, the faster rate of growth in the country's economy during that time (the rate of economic growth in 2018 was 2.9%[2] relative to 2.2% in 2017).

In 2019, the trend appears to be returning to its pre-2018 year-over-year rate of increase: Estimated damages were up 4.5% in 2019 compared to 2018, while transmissions were up 9.5%. Interestingly, 2019 digging activity variables seem to be showing that each construction dollar spent resulted in more one call transmissions than ever before, suggesting that the rise in damages may correlate with an increase in overall pressure on the damage prevention process. A number of factors could be contributing to the rise

[2] Source: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=US

in transmissions, including more digging activity, increased awareness of 811, better compliance with notification regulations due to state enforcement, more facility operators becoming members of one call centers, over-notification by excavators, or changes in how one call centers transmit tickets to members. Furthermore, it may not be the increase in transmissions alone stressing the system, but periodic unanticipated surges that impact the ability of locators to complete them all in a timely manner.

Damages to Buried Utilities Cost the U.S. Approximately $30 Billion in 2019

- **In 2019 alone, failure to prevent damages had a significant economic impact on the U.S., with an estimated $30 billion in societal costs, which includes direct (facility repair) and indirect (property damage, medical expenses, business closures, etc.) expenditures.**

Estimating the societal costs of damages to buried infrastructure gives the industry, regulators and lawmakers another lens through which to focus on just how critical it is to prevent damages. In 2019 alone, the cost of damages in the U.S. is estimated to be $30 billion, which represents an enormous amount of public and private resources that could be used more meaningfully if we are able to dramatically reduce damages. For perspective, consider that $30 billion is more than double the U.S.'s federal law enforcement budget for 2019.

To estimate the societal impact costs for 2019, Green Analytics examined both direct and indirect costs. The 2016 DIRT Report also estimated societal impact costs but utilized a different model and examined only direct costs of damages. Direct costs would include repair of the damaged utility and restoration of service to impacted customers. Indirect costs include but are not limited to property damage, medical expenses, loss of commerce while businesses are interrupted or evacuated, time spent in traffic due to road closures or detours, increased insurance premiums, litigation costs and reputational damage.

Green Analytics reviewed DIRT data, research from Canada and the United Kingdom, and publicly available data from PHMSA for U.S. natural gas and liquid pipeline damages to produce an estimated range of $400 million to $1.985 billion for direct repair costs and indirect costs ranging from $12 to $60 billion. Taking the medians of the range of direct and indirect costs produces a best overall estimate of $30 billion in total societal costs from damages to buried facilities. Appendix E describes the modeling approach in detail.

Examining Root Causes

- The main DIRT root cause groups are equalizing in terms of their contributions to the total number of damages, indicating that systematic improvements need to occur across the damage prevention process.
- It is important to distinguish between damage liability and true damage root causes in order to accurately identify where changes in behavior could lead to changes in outcomes.
- Failing to notify the one call center (No Locate Request) remains the single largest individual root cause of damages at 29.1%, followed by excavator failing to maintain clearance (16.7%) and facility marked inaccurately due to locator error (10.6%).

Root Cause by Group

Reported Damages by Root Cause for 2019

Coded by Root Cause Group

Root Cause	Reports	% of Total
No notification made to one call center / 811	100,163	29.10%
Excavator failed to maintain clearance after verifying marks	57,484	16.70%
Facility marked inaccurately due to locator error	36,397	10.57%
Excavator dug before valid start date/time	33,665	9.78%
Facility marked inaccurately due to abandoned facility	25,090	7.29%
Improper excavation practice not listed elsewhere	17,108	4.97%
Excavator failed to shore excavation/support facilities	13,411	3.90%
Facility not marked due to locator error	12,256	3.56%
Facility marked inaccurately due to incorrect facility record/map	7,446	2.16%
Excavator dug prior to verifying marks by test-hole (pothole)	6,661	1.94%
Excavator dug after valid ticket expired	6,588	1.91%
Excavator dug outside area described on ticket	5,182	1.51%
Marks faded, lost or not maintained	5,131	1.49%
Facility not marked do to unlocatable facility	4,941	1.44%
Facility not marked due to no response from operator/contract locator	4,362	1.27%
Facility not marked due to incorrect facility record/map	2,556	0.74%
Site marked but incomplete at damage location	1,402	0.41%
Deteriorated Facility	1,246	0.36%
Excavator provided incorrect notification information	855	0.25%
One call center error	590	0.17%
Facility not marked due to abandoned facility	498	0.14%
Facility marked inaccurately due to tracer wire	465	0.14%
Previous Damage	367	0.11%
Facility not marked due to tracer wire issue	223	0.06%
Improper backfilling	140	0.04%

Legend

- Excavation Practices
- Invalid Use of Request
- Locating Practices
- Miscellaneous
- No Locate Request

DIRT Report for 2019 | Common Ground Alliance

Table 4— Reported damages by root cause for 2019 (color coded by root cause group) The Data Committee sorts these 26 individual root causes into 6 groups to provide a high-level snapshot of what went wrong in the damage prevention process.

DIRT has 26 individual root causes to choose from (including Root Cause Not Listed AKA Unknown/Other). Table 4 lists the 25 known individual root causes for 2019 damage events sorted high-to-low and color-coded to match subsequent figures based on root cause groups. The **% of Total** column in Table 4 excludes "Not Listed" and "Unknown" root causes (109,538).

- **No Locate Request** represents damages caused by the failure to notify.[3]
- **Invalid Use of Request**[4] captures situations where the excavator invalidates the ticket by commencing work too early or digging beyond the expiration date or outside the work area described on the ticket. It also covers scenarios where the excavator provided incorrect information to the one call center in the initial notification.
- **Excavation Issue** captures damages where something went wrong in the physical digging process.
- **Locating Issue** captures damages caused by inaccurate or uncompleted marking.
- **Miscellaneous** captures damage causes that do not fit into a notification, locating or excavating category. These consist of deteriorated facilities, previous damage and one call center error. These typically account for around 1% of damages combined.
- **Unknown/Other** captures damages where the root cause was not collected or none of the available choices fit. When this is selected, the DIRT system requires[5] the user to also provide a free-text comment. Ideally this would be something relevant and useful, providing some indication of what caused the damage and why none of the available root cause choices fit.

The first three root cause groupings above – No Locate Request, Invalid Use of Request and Excavation Issue – are the responsibility of excavators, and can be generally aligned to the five-step safe excavation process geared to the contractor audience: https://call811.com/Start-Here/Contractors.

DIRT Root Cause Group	Safe Excavation Step
No Locate Request	Notify
Invalid Use of Request	Wait / Confirm
Excavation	Respect / Dig Carefully

[3] *Notification Not Made* is singled out—making it a group of one—because it has historically been the single leading root cause and because it is the focal point of 811 and Call Before You Dig awareness.
[4] In previous DIRT reports these were referred to as "Other Notification Practices."
[5] This comment field is optional when any other root cause is selected.

Figure 5 shows the major root cause groupings for 2015 through 2019, excluding unknown root causes. The DIRT root causes were revamped starting in 2018. Prior to that, abandoned facilities were grouped with Miscellaneous root causes. Abandoned facilities are now grouped with Locating Practices and are presented that way in Figure 5 for the entire graph. Moving abandoned facilities out of the Miscellaneous group leaves the total for the remaining Miscellaneous root causes negligible, and they are also filtered out of Figure 5. The revamping also contributed to the decrease in Excavating Practices and roughly corresponding increase in Invalid Use of Request at the 2017-2018 transition.[6] With these adjustments, Figure 5 allows us to visualize trends in root cause groups over the past five years. In 2019, the No Locate Request, Excavating Practices and Locating Practices root cause groupings are converging toward approximately equal, with the impact of Invalid Use of Request also becoming more focused.

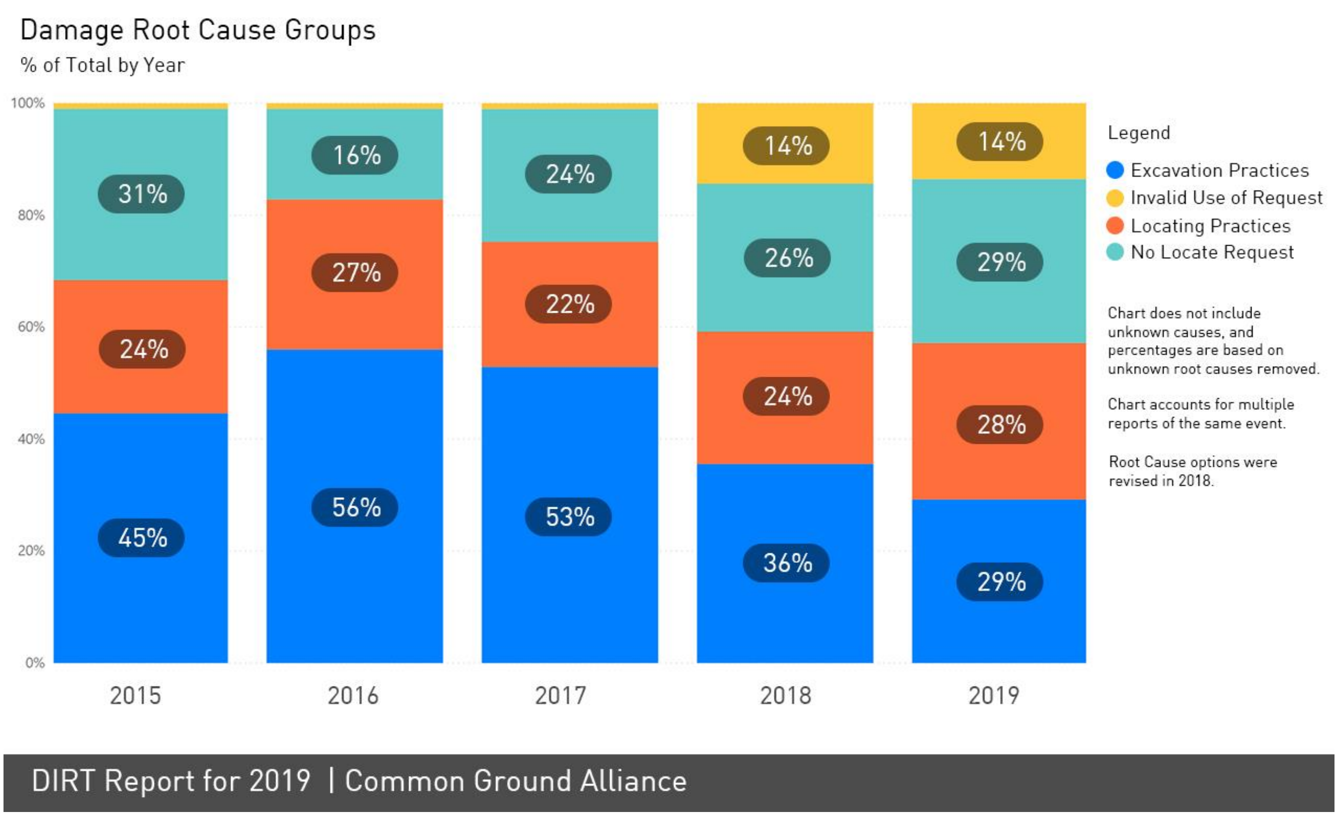

Figure 5

[6] The 2018 DIRT Report explains 2018 root cause revisions in greater detail.

The Importance of Separating Liability from Root Cause in DIRT Data

Root Cause is defined, for DIRT purposes, as the point where a change in behavior would reasonably be expected to lead to a change in the outcome (i.e., avoidance of the event). Many DIRT users utilize their damage/repair claims information as their DIRT data source and attempt to match their internal codes to an available DIRT root cause selection. Thus, their primary concern is not what would have avoided the damage, but rather who is going to pay for it. Take for example a damage that occurs on day 31 in a location with a 30-day life-of-ticket. If the marks are still visible, but inaccurate, from a pure root cause perspective it should be considered a locating issue. If the marks are still visible and accurate, the pure root cause could be an excavating issue such as failure to pothole or failure to maintain clearance. In this example, a facility operator may be justified in billing an excavator for repairs, but *Excavator dug after valid ticket expired* is more a technicality than a pure root cause.

The same dynamics could apply in a case of ticket "piggy-backing," which is when an excavating company relies on the marks from another contractor working at the same site.[7] If the excavator involved in the damage does not match the name on a one call ticket for the site, the facility owner/operator (or locator) would likely report it in DIRT with a root cause of *No notification to one call center/811*, regardless of what a deeper root cause analysis might find. These are examples where an excavator and locator/facility operator may both submit DIRT reports on the same event with conflicting root causes, yet both have truthful elements.

It is unrealistic to expect facility operators to keep one set of records for damage claims and another for DIRT. Having Invalid Use of Request root cause options available in DIRT gives DIRT users a home for some of these events and gives the Data Committee something to work with, which is preferable to having them hidden in a "not listed" category. At the same time, there may be some reports with pure locating and excavating root causes hidden in the Invalid Use of Request group. There may also be instances where the excavator did wait but the locate was unreasonably delayed and the excavator commenced work, meaning there could be some *Facility not marked due to no response from operator/contract locator* hidden in there as well.

We will next look at trends within each of the damage root cause groups over recent years.

[7] Best Practice 5.6 calls for every excavator on the job site to have a separate one call ticket.

No Locate Request (NOTIFY)

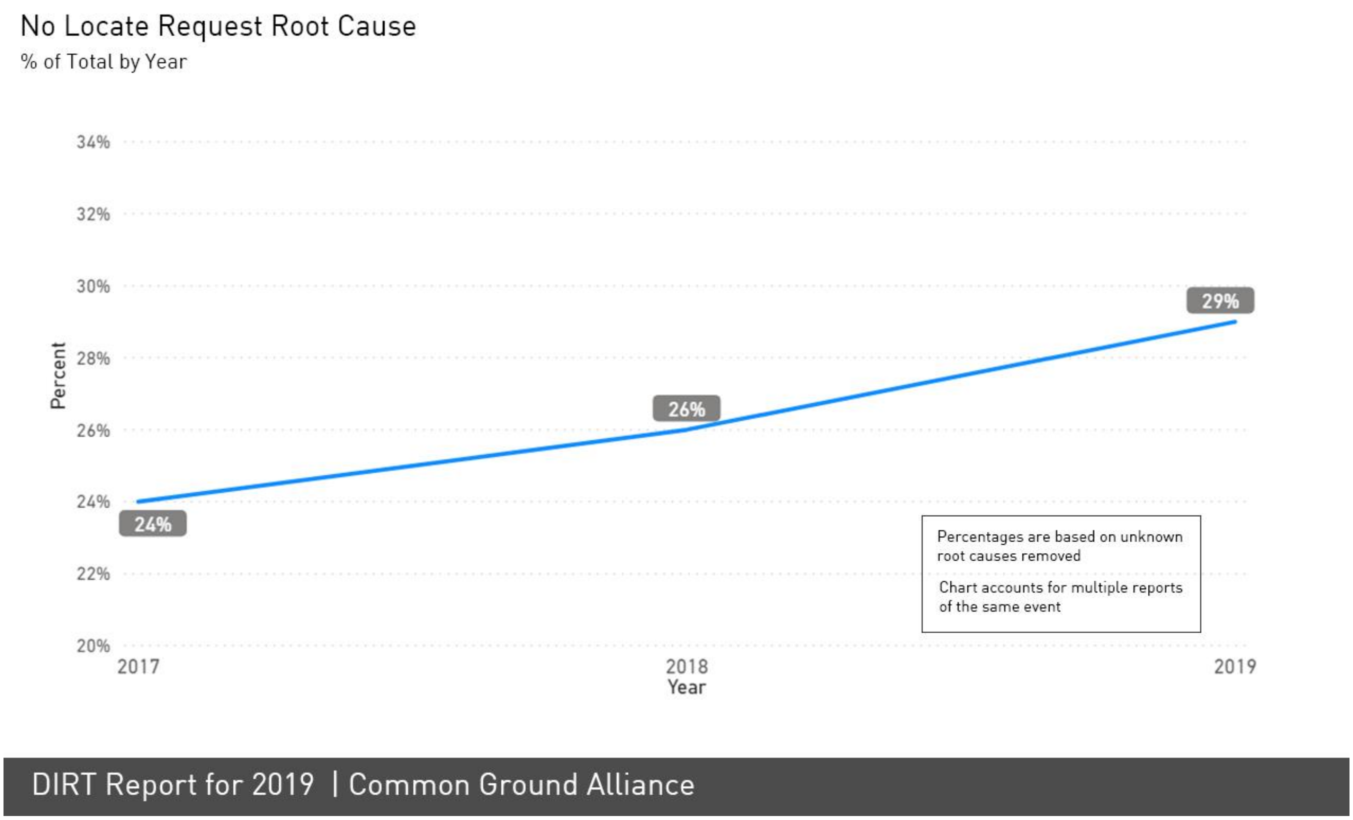

Figure 6

The percentage of damages due to No Locate Request has been trending upward for three consecutive years, despite call-before-you-dig awareness reaching an all-time high.

Invalid Use of Request (WAIT / CONFIRM)

Due to the vagueness of the root cause descriptions available prior to 2018, DIRT users were often categorizing situations as Improper Excavation Practice Not Listed Elsewhere or Root Cause Not Listed Elsewhere.[8] The revised root causes give DIRT users clearer options for situations that are now grouped under Invalid Use of Request, but complicates trending across the 2017-2018 transition period. Instead we show the two years following the transition in Figure 7, which indicates consistency over the period.

Excavator dug before valid start date/time stands out as the leading cause within this group. This is followed by *Excavator dug after valid ticket expired* and *Excavator dug outside area described on ticket*, which are approximately equal. The 2018 root cause revisions provide increased clarity on invalid use of locate requests, particularly to how often the WAIT step of the damage prevention process is not followed.

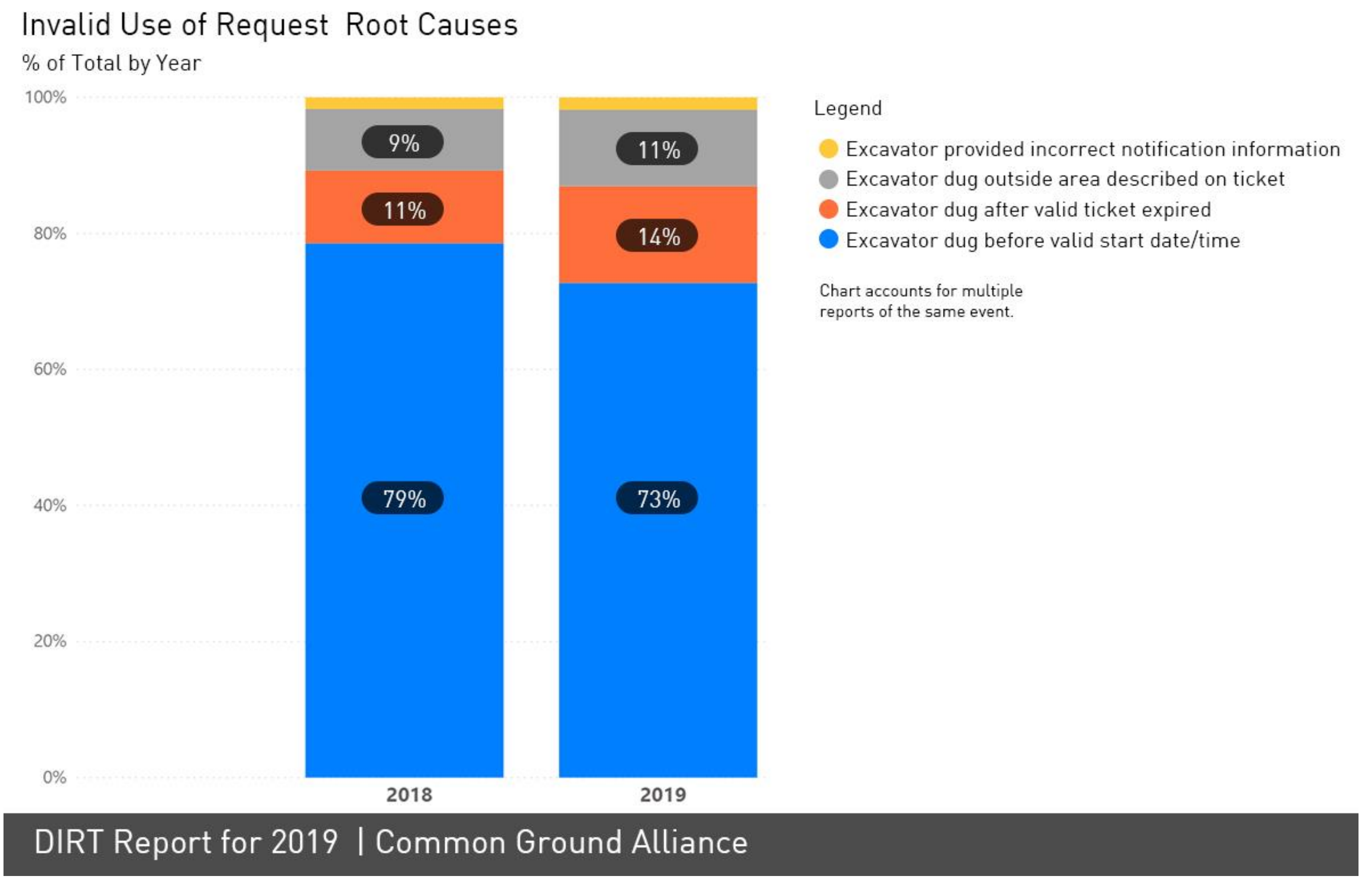

Figure 7

[8] Based on comments in the free-text field for unknown/other root causes.

Excavating Practices Root Cause Group (RESPECT / DIG CAREFULLY)

Figure 8 depicts the individual root causes that make up the Excavating Practices group. Up to the end of 2017, *Failure to use hand tools where required* was included as a DIRT option. It was removed as part of the 2018 DIRT revisions. The rationale was that "*where [hand tools are] required"* is while potholing and/or while digging in the tolerance zone. Those situations are already covered by *Excavator dug prior to verifying marks by test hole (pothole)* and *Excavator failed to maintain clearance after verifying marks*. It appears that DIRT users tended to shift back and forth between utilizing *Failure to pothole*, *Failure to maintain clearance*, and up to 2017—*Failure to use hand tools where required* to describe interrelated root causes, which all have to do with the DIG CAREFULLY step. To streamline the fluctuations among these three root causes, Figure 8 combines them (Clearance/Pothole/Handtool). This highlights the contribution of these root causes to total damages and indicates they should be addressed as a package.

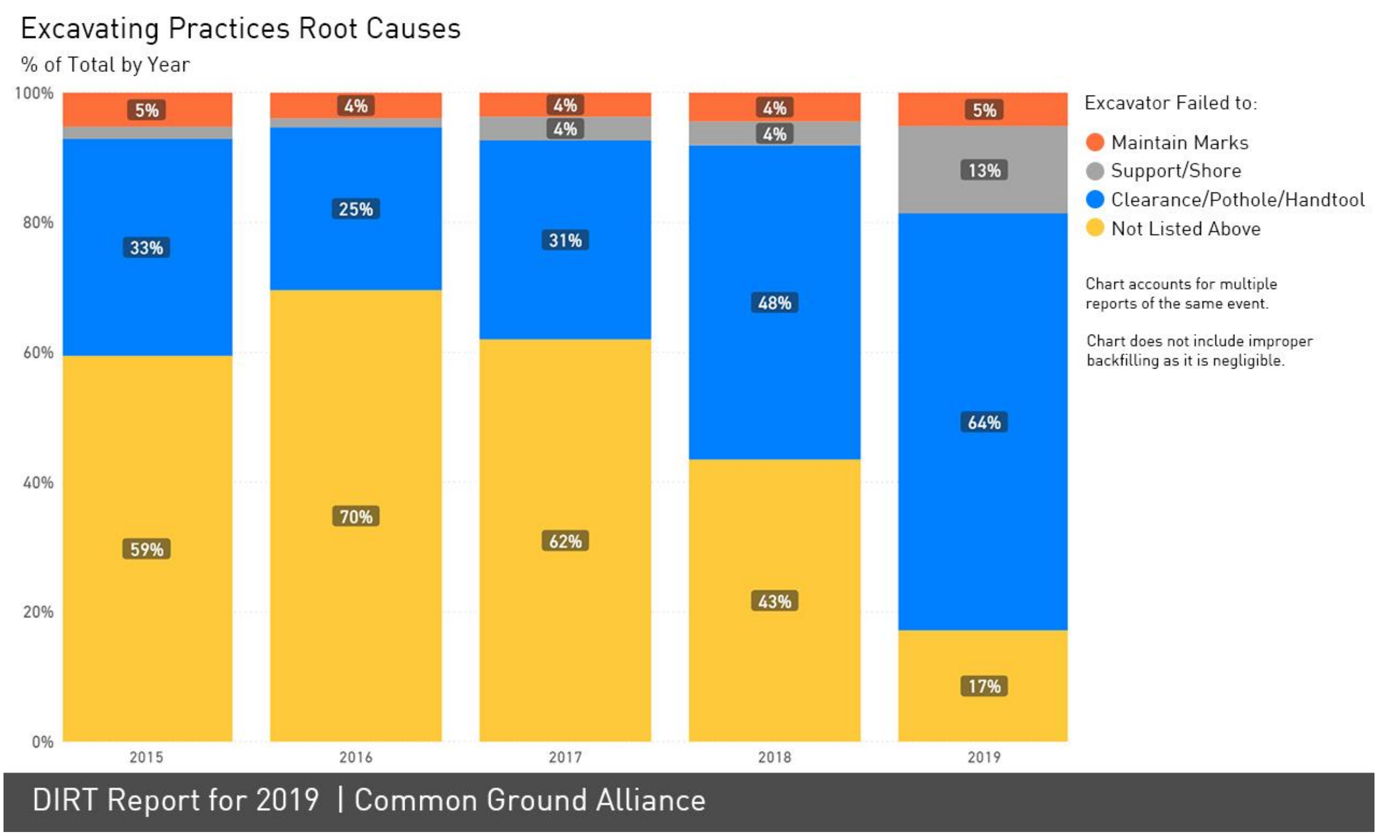

Figure 8

Improper Excavation Practice Not Listed Elsewhere (Not Listed Above (yellow) in Figure 8) is intended as a catch-all when a more specific excavating root cause is not captured. There are likely a significant number of *Failure to pothole*, *Failure to maintain clearance* and *Failure to use hand tools where required* events hidden in the blue of Figure 8. The individual root causes in the Excavating Practices group for 2019 are shown in Figure 9.

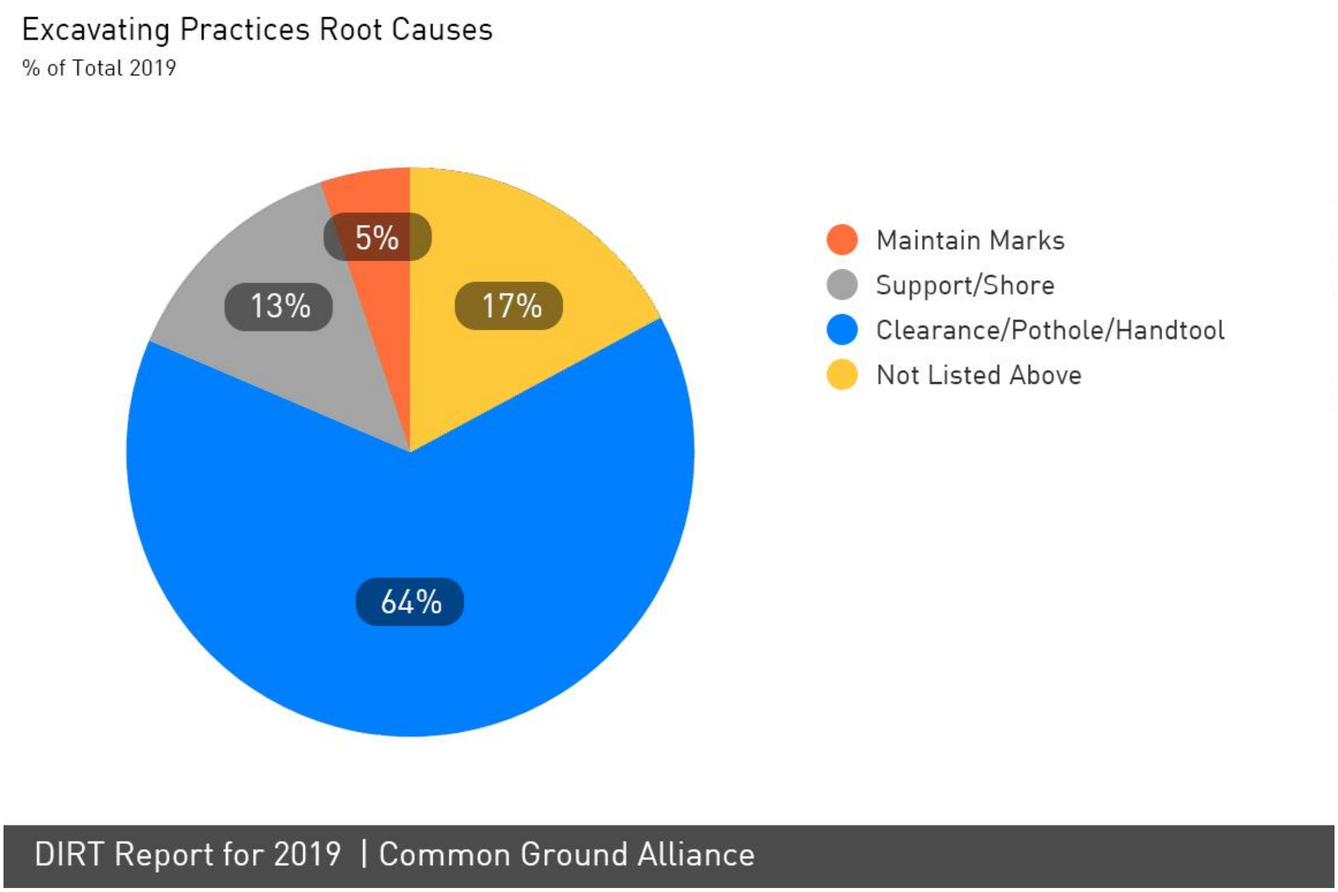

Figure 9

Locating Practices Root Cause Group Trends

Through 2017, DIRT listed four individual locating practice root causes:

- Facility could not be found or located
- Facility marking or location not sufficient
- Facility was not located or marked
- Incorrect facility records/maps

Locating Practices was the root cause group most affected by the 2018 revisions to the DIRT form. The first three root causes bulleted above were eliminated for 2018 DIRT data submissions because they were vague and indistinguishable. In their place, specific root causes were added, such as *Tracer wire issues*, *No response from the operator/contract locator* and *Locator error*. The 2018 revisions also attempted to distinguish between marks being present-but-inaccurate, versus not being present at all.

The DIRT form now lists eleven possible individual locating root causes. Incorrect facility records/maps translates most directly from the 2017 to 2018 version, although now with two variations: *Marked inaccurately* and *Not marked at all*. In addition, *Abandoned facilities* was moved from Miscellaneous to the Locating group, again with separate options for inaccurate and not marked. The first three items from the 2017 list above are now scattered among the other seven locating root causes.

Two new root causes involving locator error were introduced in 2018: One for marked-but-Inaccurate and one for no*t* marked. These are intended as a catch-all for when a more specific root cause is not known. For example, an excavator may only know that marks are inaccurate, while a locator or facility operator may be better able to determine if it was a mapping, tracer wire, or abandoned facility issue. There may be damages relating to mapping, tracer wire and abandoned facility hidden in the locator error category. Therefore, such errors should not always be interpreted to conclude that the technician is the responsible party. Inaccurate maps, broken tracer wire, abandoned facility, etc. could lead to an inaccurate locate even if the locator followed all proper procedures.

Finally, it is apparent that some DIRT users are not yet distinguishing between Inaccurate marks as opposed to not marked, but are combining them all together, usually under marks-present-but-inaccurate*.* These changes make navigating the 2017 to 2018 transition a challenge. Therefore, to simplify the analysis and help identify like areas of focus across the time period, we add together the marked-but-inaccurate and not-marked *for locator error*, *Abandoned facilities*, *Incorrect maps/records*, *Incomplete marks*, and *Unlocatable facilities*. The result is Figure 10.

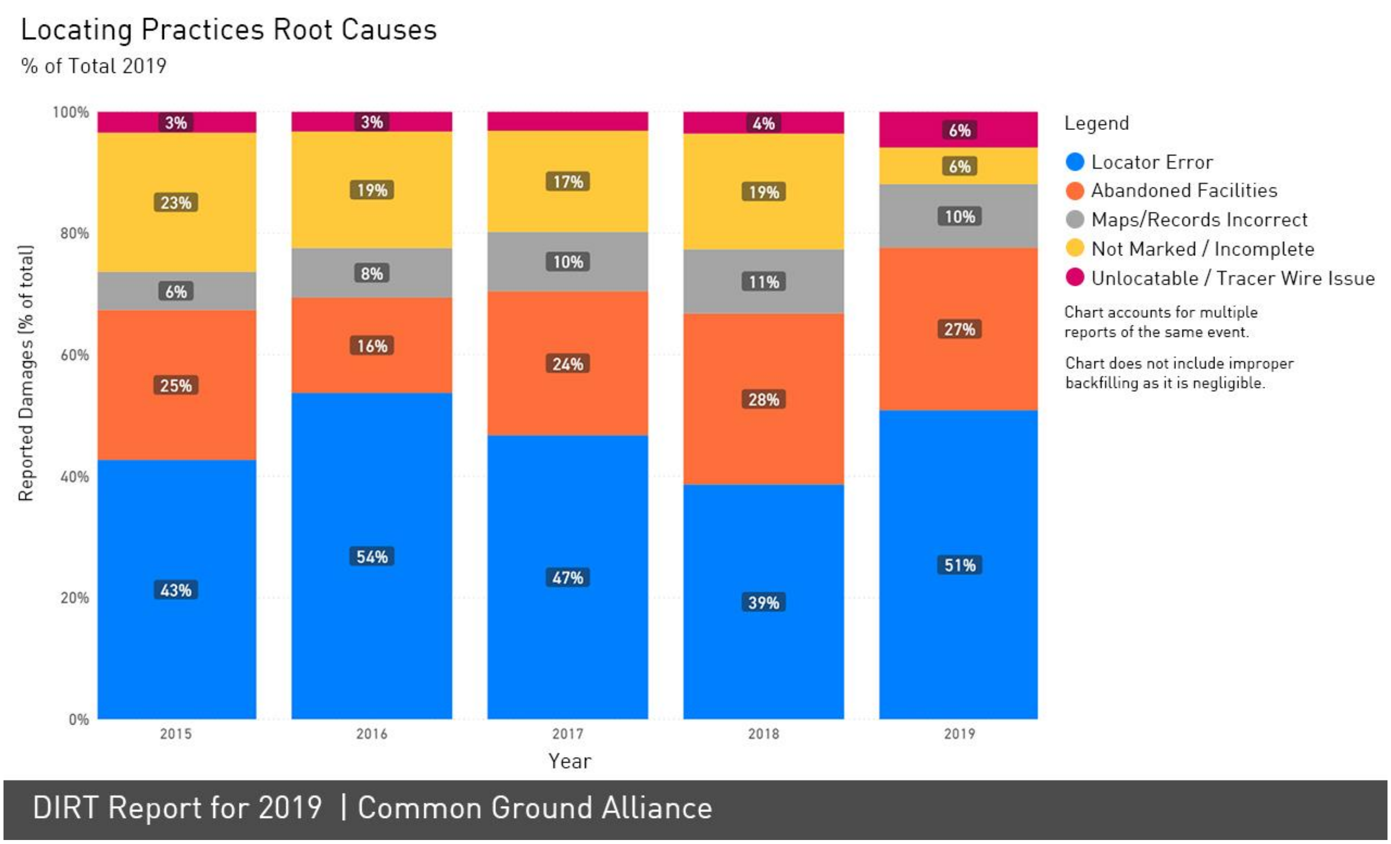

Figure 10—Locating root causes for 2015 to 2019

Locator error is the leading locating root cause for 2019, but as discussed above, it likely includes some combination of other more specific locating root causes. *Abandoned facilities* are included in the Locating Practices group for all years depicted in Figure 10 and stand out as a significant contributor.

Figure 11 shows the individual locating root causes for 2019.

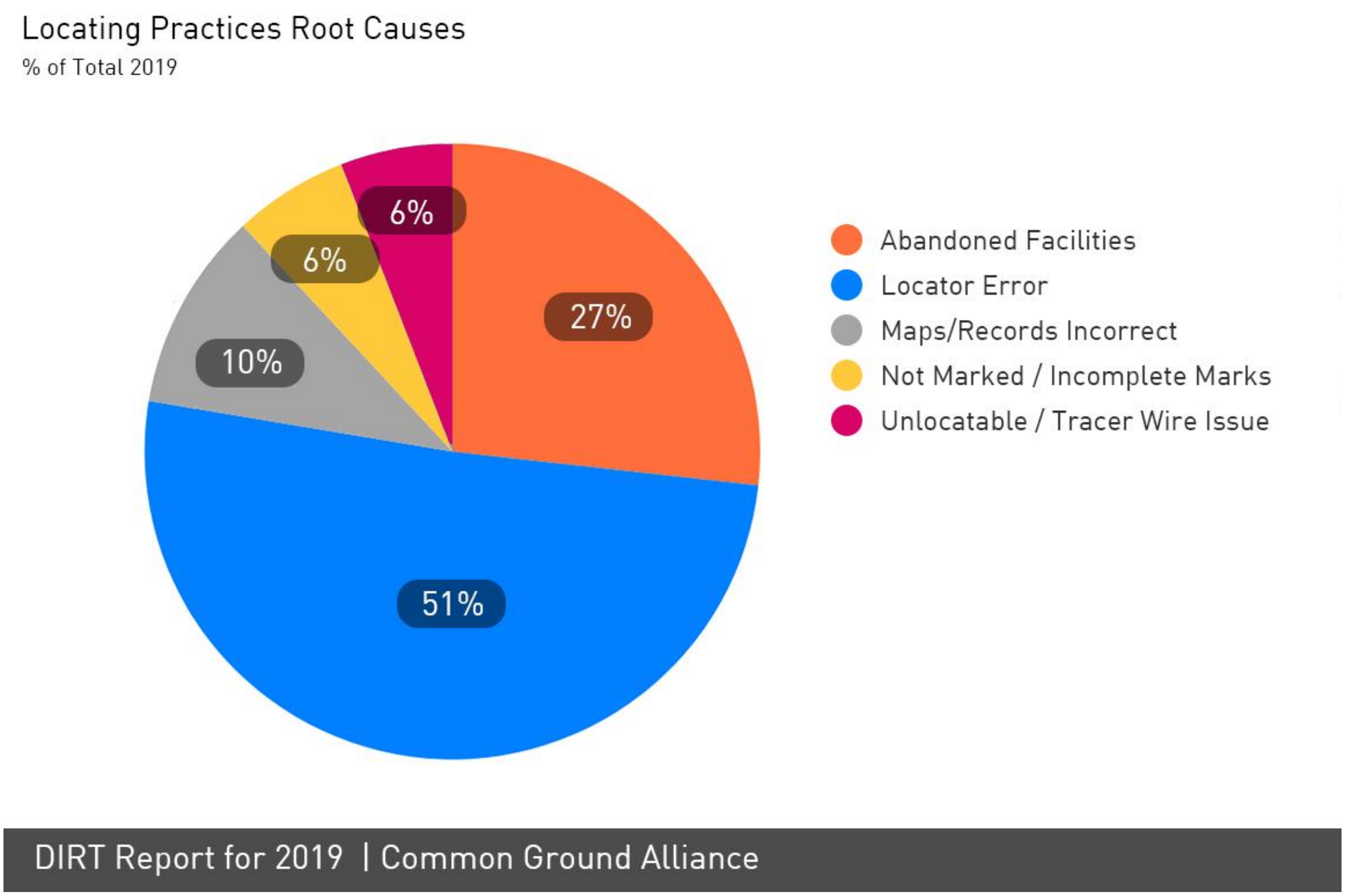

Figure 11

Root Cause Group by Event Source

Figure 12 shows some significant differences in the root cause group percentages by event source, although the number of total damages per event source should be considered when interpreting the graph. For instance, the 80 "Other" reports came from Equipment Manufacturers, Engineer/Design and Railroad stakeholders and are likely too small to draw any solid conclusions. Excavators/Road Builders report the highest percentage (69%) of Locating Practices. It should also be noted that unknown root causes data is filtered out in Figure 12. If unknown root causes were included, they would account for 65% of Excavators' and Road Builders' reports and drop Locating Practices to 24%.

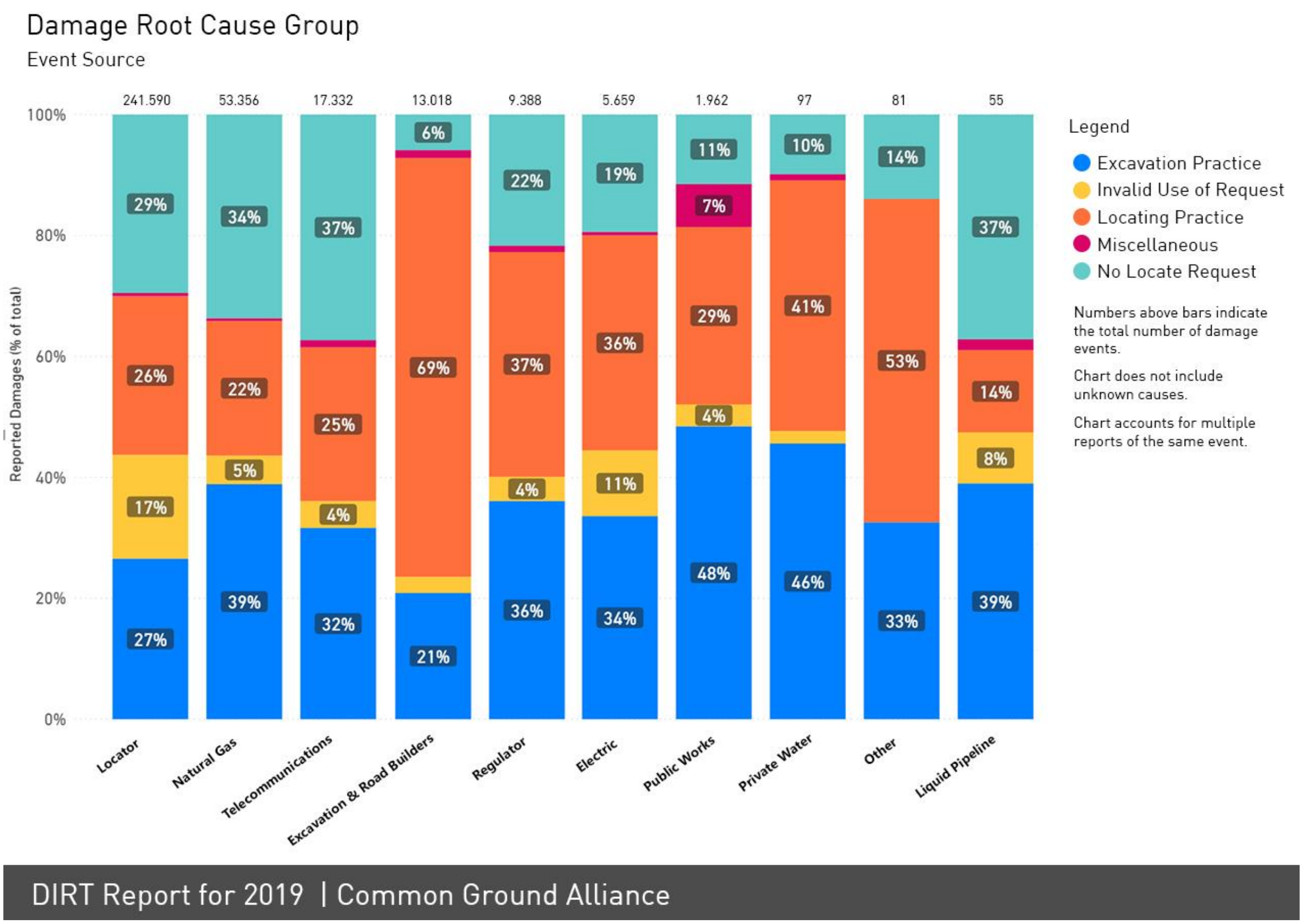

Figure 12

Excavator Type by Root Cause

Figure 13 shows the root cause groups by type of excavator involved. As can be seen in the figure, the leading cause of damages for occupants is *No Locate Request*, while for most other excavator types it is Locating Practices.

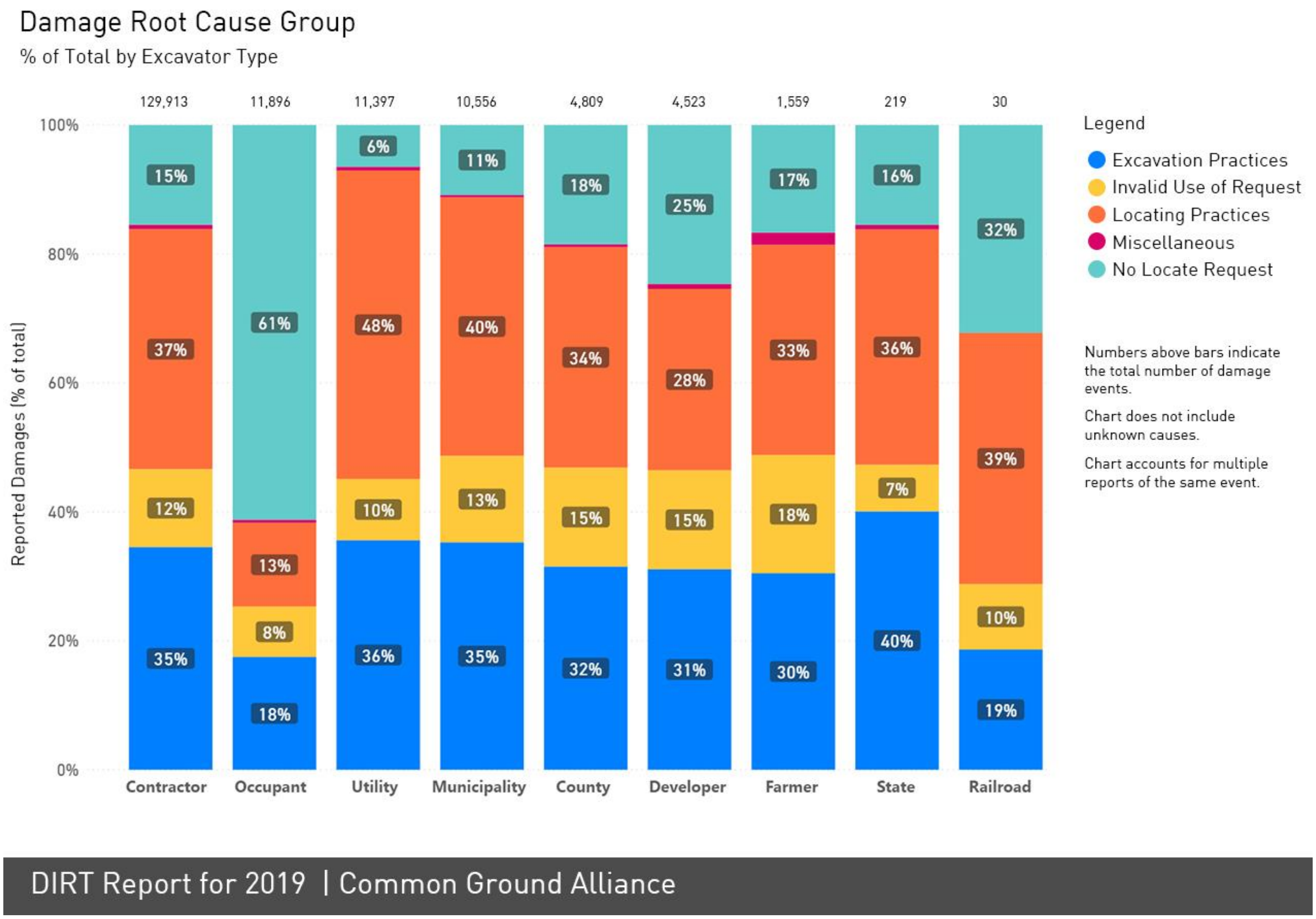

Figure 13

Facilities Damaged by Root Cause

Figure 14 demonstrates the relationship between damaged facilities and root cause.

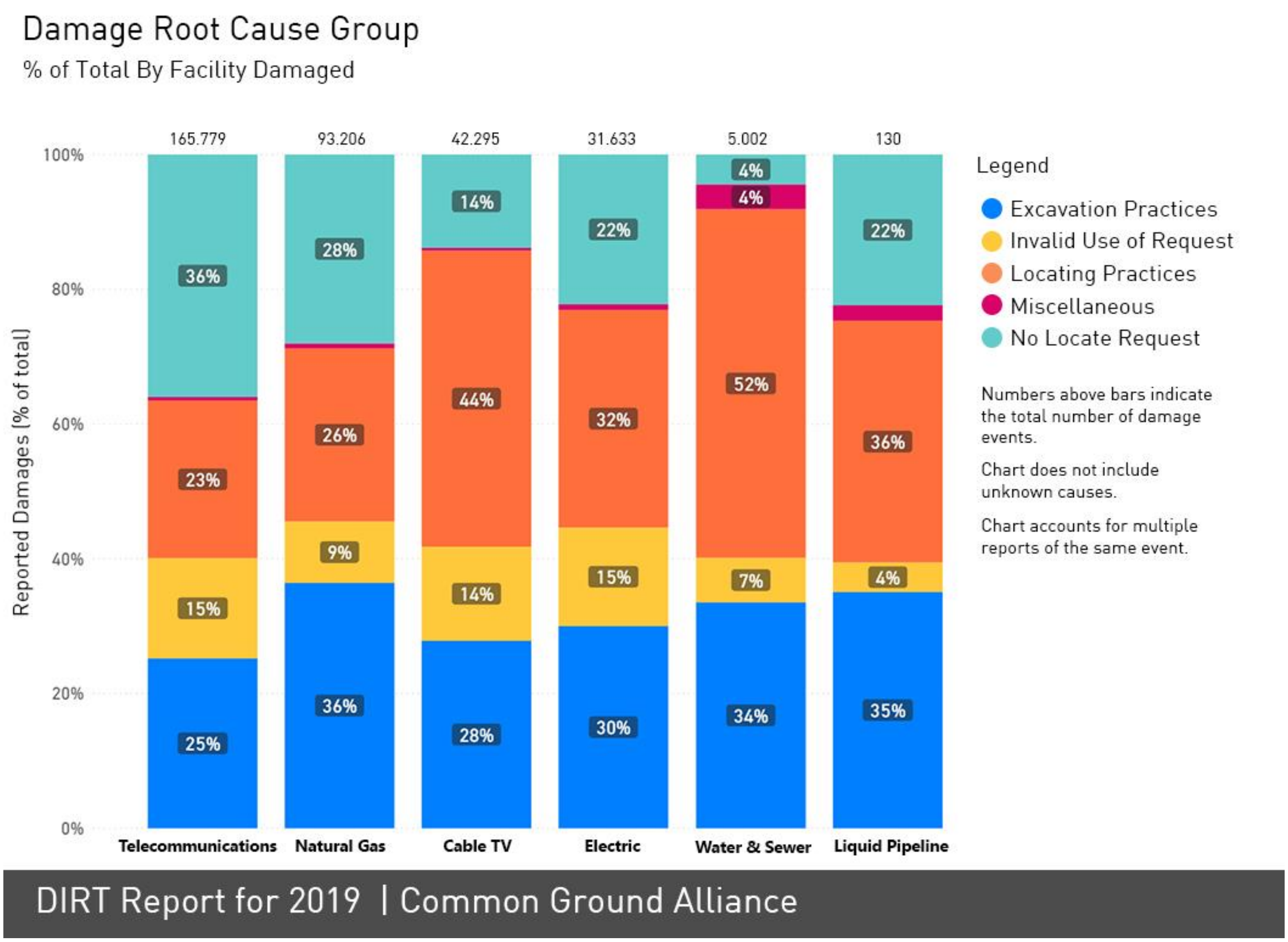

Figure 14

Leading Damage Root Causes and Corresponding Best Practices

- **Several of the top damage root causes correspond with Best Practices that lack specificity or practicality, likely reflecting the difficulty of achieving consensus from all 16 CGA stakeholder groups on a definitive practice that addresses some of the industry's most challenging issues.**
- **Specific recommendations for examining Best Practices are offered.**

The CGA Best Practices manual includes more than 160 practices that cover all phases of the safe digging process, agreed to by each of CGA's 16 stakeholder groups. All practices go through a seven-step process that includes review by a task team, the full Best Practices Committee, and finally the CGA Board of Directors. Two fundamental principles must apply for a Best Practice to be adopted by CGA—it must:

1. Actually be in use in the field, and
2. Achieve consensus from representatives of all CGA Stakeholder groups.

A description of the process can be found here: https://bestpractices.commongroundalliance.com/1-Introduction/104-Best-Practices-Process.

In this section, we relate the leading damage root causes to corresponding Best Practices and the five-step safe excavation process (where applicable) and offer opportunities for how practices could be strengthened. In some cases, the Best Practices that correspond to leading root causes are vague—more a generalization of a desired outcome than concrete steps on how to get there, which is likely a reflection of how difficult consensus is to achieve on these issues. The low-hanging-fruit has been harvested and what remains is the need to coalesce around the more difficult issues. It's important to note that behavior and work practices are also influenced by technology, enforcement, one call center policies and education, but for the purposes of this section, we are focusing on CGA Best Practices.

No Locate Request (NOTIFY):

> *5.1 One Call Facility Locate Request:*
>
> Practice Statement: The excavator requests the location of underground facilities at each site by notifying the facility owner/operator through the one call center. Unless otherwise specified in state/provincial law, the excavator calls the one call center at least two working days and no more than ten working days prior to beginning excavation.

Update Opportunity: *Consider updating to reflect three-digit dialing (811) which was introduced in 2007, and that electronic notifications have become the predominant method of one call center notices*.

Excavator Dug Before Valid Start Date/Time (WAIT/CONFIRM): No Best Practice specifically recommends that the excavator WAIT, although it is implied by Best Practices 5.8, 5.9 and 5.10:

5.8 Positive Response:

Practice Statement: The underground facility owner/operator either 1) identifies for the excavator the facility's tolerance zone at the work site by marking, flagging, or other acceptable methods; or 2) notifies the excavator that no conflict situation exists. This takes place after the one call center notifies the underground facility owner/operator of the planned excavation and within the time specified by state/provincial law**.**

5.9 Facility Owner/Operator Failure to Respond:

Practice Statement**:** If the facility owner/operator fails to respond to the excavator's timely request for a locate (e.g., within the time specified by state/provincial requirements) or if the facility owner/operator notifies the excavator that the underground facility cannot be marked within the time frame and a mutually agreeable date for marking cannot be arrived at, then the excavator re-calls the one call center. However, this does not preclude the excavator from continuing work on the project. The excavator may proceed with excavation at the end of two working days, unless otherwise specified in state/provincial law, provided the excavator exercises due care in all endeavors.

5.10 Locate Verification:

Practice Statement: Prior to excavation, excavators verify that they are at the correct location, verify locate markings and, to the best of their ability, check for unmarked facilities.

Update Opportunity: Most Best Practices in Chapter 5 describe actions the excavator takes, but Best Practice 5.8 describes action by the facility owner/operator, leaving the excavator passive. *Consider re-framing this practice to begin, "The excavator waits until the facility owner/operator…"*

Update Opportunity: Best Practice 5.9 recommends the excavator re-call the one call center if the facility/owner/operator fails to respond or a mutually agreeable time frame for marking cannot be arrived at. What is the one call center expected to do? There are Best Practices in the "One Call Center" chapter regarding positive response, but nothing that specifically addresses this situation. Nor is there anything in the "Locating & Marking" chapter. *Consider addressing actions by one call centers and/or facility owner/operator/locating vendor when an excavator reports a failure to respond.*

One, or some combination of 5.8 to 5.10, could also be updated to account for electronic positive response systems, which have become commonplace at one call centers. For example, "Prior to excavation, the excavator checks the electronic positive response system…" A Best Practice (3.27) along these lines was added to the "One Call Center" chapter in 2011, along with a corresponding glossary definition:

1.27 *Electronic Positive Response:*

Communication by telephone, fax, e-mail or internet from a facility owner/operator to an excavator providing the status of an owner/operator's statutorily required response to a notice of intent to excavate.

Excavator Dug After Valid Ticket Expired (WAIT/CONFIRM):

5.23 Locate Request Updates:

Practice Statement: The excavator calls the one call center to refresh the ticket when excavation continues past the life of the ticket (sometimes, but not always, defined by state/provincial law). This recognizes that it is a best practice to define ticket life. If not currently defined in state/provincial law, ticket life is ideally 10 working days but does not exceed 20 working days. Original locate request tickets are generated so that the minimum number of locate request updates are necessary for the duration of a project. After all the excavation covered by a locate request is completed, no additional locate request updates are generated. Communication between excavation project planners, field personnel, and clerical personnel is essential in accomplishing this task.

Table 5 lists ticket life in days and the number of states/provinces where that number is codified. There is only one U.S. state or Canadian province with a 10-day life-of-ticket: Saskatchewan. More than half have a ticket life over 20 days.[9] Several states and provinces have no ticket life. A few have rules stating the ticket expires if work does not commence within 10 days, but that is not the same as a 10-day ticket life. Short ticket life specifications may impose burdens on facility owner/operators and contract locators with little corresponding safety benefits.

Table 5—Number of States by Ticket Life

Ticket Life (Days)	# States/Provinces
10	1
12	1
14	5
15	8
20	5
21	5
28	4
30	10
45	2
60	2

Update Opportunity: Retain and promote a Best Practice establishing a ticket life, but do not focus on outlining an "ideal" ticket lifespan.

[9] Some specify working days while others are based on calendar days; the point here is whether the ticket lifetimes are too short.

Excavator Dug Prior to Verifying Marks by Test Hole (Pothole) and **Excavator Failed to Maintain Clearance After Verifying Marks (RESPECT/DIG CAREFULLY):**

As discussed earlier in the report, these should be addressed as a group. The relevant Best Practices are (emphasis added):

> *5.14 Facility Avoidance:*
>
> Practice Statement: The excavator uses *reasonable care* to avoid damaging underground facilities. The excavator plans the excavation so as to avoid damage or to minimize interference with the underground facilities in or near the work area.
>
> *5.19 Excavation Tolerance Zone:*
>
> Practice Statement: The excavator *observes a tolerance zone* that is comprised of the width of the facility plus 18 in. on either side of the outside edge of the underground facility on a horizontal plane. This practice is not intended to preempt any existing state/provincial requirements that currently specify a tolerance zone of more than 18 in.
>
> *5.20 Excavation Within Tolerance Zone:*
>
> Practice Statement: When excavation is to take place within the specified tolerance zone, the excavator exercises such *reasonable care* as may be necessary for the protection of any underground facility in or near the excavation area. Methods to consider, based on certain climate or geographical conditions, include hand digging when practical *(potholing),* soft digging, vacuum excavation methods, pneumatic hand tools, other mechanical methods with the approval of the facility owner/operator, or other technical methods that may be developed. Hand digging and non-invasive methods are not required for pavement removal.

The Best Practices Guide Glossary defines Tolerance Zone as: “The space in which a line or facility is located and in which *special care* is to be taken."

Figure 15 depicts a 24-inch tolerance zone. Most state laws specify either a 24-inch or 18-inch tolerance zone, measured from the outside edge of the facility if the diameter or width is provided with the marks, or from the centerline of the facility if not.

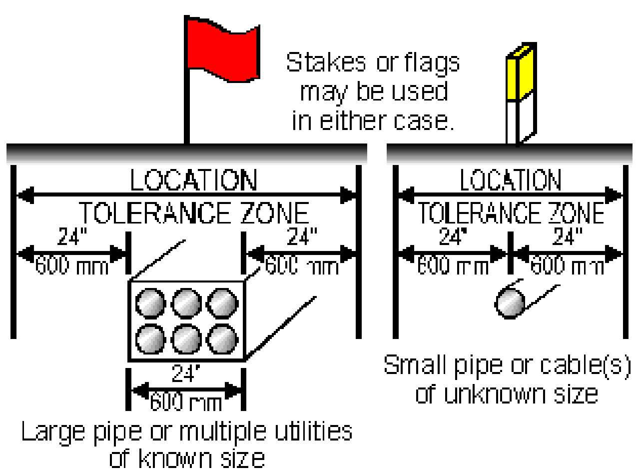

Figure 15—Tolerance Zone depiction from Dig Safely New York website

Within the Best Practices Guide, phrases such as "*observes a tolerance zone"* and "*reasonable care"* are nonspecific. The Practice Description for 5.20 also states: "A majority of states outline safe excavation practices to include hand digging or potholing." This is the only instances where "potholing" appears in the Best Practices Guide. The practice appears to equate hand digging and potholing, even though they are not the same thing: Not all hand digging is potholing. Hand digging is a method of potholing, but vacuum excavation is also widely accepted. There is no Best Practices Glossary definition of "potholing." There is however a Glossary definition of test hole: "exposure of a facility by safe excavation practices used to ascertain the precise horizontal and vertical position of underground lines or facilities."

The term "test hole" is not found in any actual Best Practice. Pothole and test hole are essentially the same thing. [10] "Daylighting" is sometimes used. There may be other terms in usage in some locations.

Another related Best Practice is *5.18, Excavation Observer:*

> Practice Statement: The excavator has an observer to assist the equipment operator when operating excavation equipment around known underground facilities.

Update Opportunity: These Best Practices could be revisited with the following considerations:

- Consistent usage of terms between the Best Practices and Glossary.
- Should "potholing," "test holes" and "daylighting" be distinguished from "hand digging," and perhaps be made a stand-alone Best Practice?
- Can language be identified to give practical hands-on guidance on what is expected of excavators with more specific language than "*observes a tolerance zone"* or "*reasonable care"*?
- Is the excavation observer supposed to prevent the equipment operator from encroaching on the tolerance zone, or is lesser clearance permissible once test holes/potholes have been dug?

Abandoned Facilities

4.11 Abandoned Facilities:

> Practice Statement: Information on abandoned facilities is provided when possible.
>
> Practice Description: When the presence of an abandoned facility within an excavation site is known, an attempt is made to locate and mark the abandoned facility. When located or exposed, all abandoned facilities are treated as live facilities. Information regarding the presence or location of an abandoned facility may not be available because of updating or deletion of records. In addition, abandonment of an existing facility, damage to an abandoned facility, or limited or non-existing access points may render an abandoned line

[10] Pothole is a noun, the hole that is dug. Potholing is a verb, the act of digging the hole.

non-locatable. It should be emphasized that recommendation of this practice is not an endorsement of the maintenance of records for abandoned facilities.

Like Best Practices 5.19 and 5.20, practice statement (4.11) is nonspecific and does not offer practical guidance. The practice also provides a high degree of flexibility.

Update Opportunity:

- Consider innovative options for identifying abandoned facilities, including recently implemented practices and new technologies.

Forecasting Locating Workload

4.17 Forecasting/Planning for Predictable Workload Fluctuations

Practice Statement: A plan is developed for managing *unpredictable* fluctuations.

Practice Description: Facility owners/operators and/or their representatives develop methods to sufficiently forecast and plan for future workloads so that ticket requests may be completed in a timely manner. This ensures that adequate personnel and equipment are available to complete all locate requests. Note: this practice does not limit the number of one call requests from excavators.

There appears to be a mismatch between “predictable” in the title and “unpredictable” in the practice statement.

Update Opportunity:

- Was the use of *predictable* in the title and *unpredictable* in the practice statement intentional?
- Should the Best Practice address both predictable and unpredictable fluctuations?

Excavation Circumstances Surrounding Reported Damages

This section describes the type of excavator, type of work performed, and type of equipment involved in 2019 reported damages.

- **Importantly, much of the details surrounding excavations that produce damages is still unknown. More complete information included in DIRT submissions would help the industry glean better insights from a more comprehensive understanding of the types of excavators, equipment and work performed surrounding damages.**

Excavator Type by Type of Work Performed and Equipment Used

Table 6 demonstrates combinations of excavator type, equipment used, and work performed. It is sorted high-to-low by number of reported damages, and only includes combinations above 1,000 with known values for all three variables. If unknowns were included, the leading combination would be all three variables unknown at 129,714 reports.

Table 6—Top combinations of excavator, work performed, and equipment used, known data, in Canada and the U.S., 2019

Excavator Type	Equipment	Work Performed	Reported Damages
Contractor	Backhoe	Water	6,304
Contractor	Backhoe	Sewer	5,336
Contractor	Backhoe	Natural Gas	3,864
Contractor	Backhoe	Electric	3,222
Contractor	Backhoe	Construction	2,124
Contractor	Boring	Telecommunications	2,094
Contractor	Backhoe	Roadwork	1,689
Utility	Backhoe	Water	1,595
Contractor	Backhoe	Telecommunications	1,545
Municipality	Backhoe	Water	1,516
Contractor	Hand Tools	Fencing	1,512
Contractor	Directional Drill	Telecommunications	1,486
Contractor	Backhoe	Drainage	1,297
Contractor	Hand Tools	Telecommunications	1,144
Contractor	Backhoe	Landscaping	1,133
Contractor	Hand Tools	Electric	1,103
Contractor	Hand Tools	Natural Gas	1,070

New DIRT Questions Gaining Traction

- **DIRT users are beginning to utilize five new DIRT questions added in 2018, although the vast majority of 2019 DIRT submissions did not provide data for the new areas of inquiry.**

In our continued effort to collect and analyze the most helpful data about damages and near misses, five new questions were added to DIRT in 2018. The following tables summarize the 2019 data, by facility damaged, for these questions.

Table 7—Did this event involve a cross bore?

Facility Damaged	No	Yes	Blank
Cable TV	1,063	69	49,606
Electric	2,967	259	40,066
Liquid Pipe	58	3	98
Natural Gas	16,483	703	98,805
Sewer	426	225	743
Steam	15	1	8
Telecommunications	5,249	180	199,561
Water	1,477	409	12,365
Unknown	2,202	48	20,676
Total	**29,941**	**1,897**	**421,929**

Table 8—Was work area white-lined?

Facility Damaged	No	Yes	Blank
Cable TV	754	551	49,433
Electric	2,028	862	40,403
Liquid Pipe	47	43	69
Natural Gas	17,750	6,606	91,634
Sewer	195	304	895
Steam	15	3	6
Telecommunications	3,295	1,668	200,027
Water	611	860	12,780
Unknown	760	410	21,757
Total	**25,455**	**11,307**	**417,004**

Table 9—If the one call center was not notified, was the excavation activity and/or excavator type exempt from notification?

Facility Damaged	No	Yes	Blank
Cable TV	406	13	50,319
Electric	1,489	41	41,763
Liquid Pipe	42	2	114
Natural Gas	13,793	2,104	100,094
Sewer	349	6	1,040
Steam	1	0	23
Telecommunications	1,919	54	203,016
Water	1,157	16	13,078
Unknown	382	60	22,485
Total	**19,537**	**2,296**	**431,933**

Table 10—If facility owner was not a one call center member, was it exempt from membership?

Facility Damaged	No	Yes	Blank
Cable TV	81	75	50,583
Electric	530	113	42,650
Liquid Pipe	5	2	152
Natural Gas	6,406	93	109,492
Sewer	9	14	1,372
Steam	3	2	19
Telecommunications	202	189	204,598
Water	175	32	14,044
Unknown	22	26	22,879
Total	**7,433**	**546**	**445,787**

Table 11—Measured Depth from Grade

Facility Damaged	Embedded	<18"	18” to 36”	> 36"	Unknown
Cable TV	23	400	402	0	49,913
Electric	41	373	1,619	47	41,213
Liquid Pipe	9	10	74	5	61
Natural Gas	662	3,323	17,125	686	94,195
Sewer	2	30	167	11	1,184
Steam	0	4	10	0	10
Telecommunications	230	4,206	2,747	11	197,797
Water	10	85	588	12	13,556
Unknown	106	162	412	7	22,241
Total	**1,082**	**8,592**	**23,142**	**779**	**420,170**

DIRT Report for 2019 Appendices

Appendix A: Terminology Used in This Report

Damage—Any impact or exposure that results in the need to repair an underground facility due to a weakening or the partial or complete destruction of the facility, including, but not limited to, the protective coating, lateral support, cathodic protection, or housing for the line, device, or facility. There does not need to be a release of product.

DIRT—Damage Information Reporting Tool.

Downtime—Time that an excavator must delay an excavation project due to failure of one or more stakeholders to comply with applicable damage prevention regulations or best practices. There may or may not be a damage associated with the downtime.

Event—The occurrence of facility damage, near miss, or downtime.

Facility Affected—The type of facility that is involved in a damage event: distribution, service/drop, transmission, or gathering.

Facility Damaged—The facility operation that is affected by a damage event: cable TV, electric, natural gas, sewer, water, etc.

Known Data—DIRT data, excluding unknown data. Unknown data depends on the DIRT field but usually is denoted as "unknown" or "unknown/other."

Near Miss—An event where damage did not occur but clear potential for damage was identified.

Pothole—Hand digging or using a "soft excavation" practice such as vacuum excavation to dig a test hole to verify accuracy of markings prior to beginning excavation within the tolerance zone (AKA test hole, daylighting).

Root Cause—The primary reason that the event occurred. For purposes of DIRT, the point where a change in behavior would reasonably be expected to lead to a change in the outcome, i.e., avoidance of the event.

Substantial Reporting States—A set of states at the high end of a continuum of states where DIRT reporting reflects damages occurring in those states. These states are used as the basis for the estimate of total U.S. damages by identifying statistical correlations with independent variables such as construction spending, population, weather, one call transmissions, etc., and using those to estimate damages in the remaining states.

Test Hole— Exposure of a facility by safe excavation practices used to ascertain the precise horizontal and vertical position of underground lines or facilities (NOTE: verbatim from Best Practices Glossary).

Tolerance Zone—The space in which a line or facility is located and in which special care is to be taken.

Transmissions—The number of initial notices of intent to excavate sent by one call centers to their member facility operators, including those sent directly to locating vendors on behalf of members. Each incoming notice of intent to excavate generates outgoing transmissions to several members, such as electric, gas, cable TV, water, sewer, telecommunications, etc.

Unique Events—The number of events after identifying and consolidating multiple reports of the same event. Unless otherwise noted, this is the number (453,766) used in this report and on the online interactive dashboard.

Appendix B: Damage Report Path—Entry to DIRT Report

Whether interpreting written analysis, tables or figures in the DIRT Report, it is important to be mindful of what the numbers represent. To help explain how we transform reports into the analysis in the annual DIRT Report and online dashboard, the following describes the path damage reports follow:

1. DIRT users entered 530,945 underground damage reports and 3,206 near miss reports from the United States and Canada for 2019.

2. A program was run to match and weight reports of the same event. This compressed the totals to 453,766 unique underground damages and 2,524 unique near misses. Near misses are set aside for separate analysis.[11] The online DIRT dashboard is based on the number of unique damages (453,766 with no filters applied), as are all figures and tables in this report, except those associated with Data Quality Index (DQI).

3. CGA's DIRT Report consultant generates an estimate of annual damages in the U.S. Recognizing that DIRT is voluntary and not all damage events are entered in DIRT, the consultant uses statistical methods to extrapolate, from the matched/weighted damage reports entered in DIRT, an estimate of damages not entered in DIRT. This process produced a total of 532,000 estimated U.S. damages.

4. For 2019, the U.S. estimate of damages (532,000) is remarkably close to the number of underground damages initially entered into DIRT (530,945). Keep in mind however, the 530,945 includes reports from Canada and consists of roughly 15% multiple reports of the same event.

[11] See separate report at: https://commongroundalliance.com/Tools-Resources/Resources-Library/searchCustom/true/PID/924/FilterMenu/973/FilterCategories/39

Appendix C: Data Quality Index (DQI) Background

Whenever a DIRT report is successfully entered, the system provides a DQI score. When a bulk upload file is entered, the average DQI score of all the individual reports in the file is provided.

Damage Report Submitted Successfully:	
Damage Report Id:	**3238321**
Overall Data Quality Score out of 100: (more info...)	**49**

Starting with a theoretical score of 100 (i.e., information is provided for all fields within DIRT), points are subtracted when *unknown* or *other* are used. Each non-mandatory DIRT question is assigned a relative "weight," depending upon the value that it provides to statistical analysis. No points are assigned to mandatory questions, such as date, country, state, etc., because a report cannot be entered unless those questions are answered. For example, Root Cause is worth 30 points, while Joint Trench is worth 1 point. The affected facility and excavation information questions range from 6 to 8 points apiece. The intent is for DIRT users to reference their DQI score to look for opportunities to gather additional data points during field investigations of damages and near misses.

Table C1 shows that in terms of the number of companies entering DIRT data, a large percentage score fairly well, although they submit a small percentage of data. Conversely, there are a small number of companies submitting large quantities of poor-quality data.

Table C1—2019 data quality index distribution

DQI	# Companies	# Records	% of Companies	% of Records
20-30	1	338	0.20%	0.06%
30-40	5	24,556	1.01%	4.62%
40-50	7	31,378	1.41%	5.91%
50-60	11	327,959	2.22%	61.77%
60-70	27	20,671	5.44%	3.89%
70-80	53	49,108	10.69%	9.25%
80-90	134	62,440	27.02%	11.76%
90-100	258	14,495	52.02%	2.73%
Total	**496**	**530,945**	**100.00%**	**100.00%**

Table C2 presents DQI trends over time by event source. Starting in 2018, One Call Center and Insurance were removed as selections to the event source question (formerly referred to as Reporting Stakeholder). One reason for this is that several one call centers take "damage tickets" from excavators and use them as the source of DIRT reports. When One Call Center was listed as the event source, it masked the number of reports originating from other sources, mainly excavators. However, some one call centers do not collect the root cause or other key data fields on these damage tickets, which contributes to their poor DQI scores. Reports from excavators submitting to DIRT through their own registrations rather than via one call centers have an average DQI of 81. The DQI of locators has been trending downward, pulling down the overall DQI because they submit the largest percentage of data. Locators are the leading source of reports with DQI in the 50 to 69 range from Figure 1 (of the main report, not this Appendix). If reports from locators were filtered out, the overall DQI for 2019 would be 69.

Table C2—Data quality index over time by event source 2019

Event Source	2017 DQI	2018 DQI	2019 DQI (A)	% of 2019 Reports (B)	(A) x (B)
Electric	68	72	74	1.56%	1.16
Engineer/Design	64	74	62	0.05%	0.03
Equipment Manufacturer	75	47	62	0.00%	0
Excavator	49	54	59	10.60%	6.25
Insurance	89				
Liquid Pipe	84	81	80	0.11%	0.09
Locator	63	59	54	62.50%	33.69
Natural Gas	73	80	81	12.92%	10.43
One Call Center	43				
Private Water	81	87	86	0.02%	0.02
Public Works	78	75	77	0.40%	0.31
Railroad	71	74	92	0.00%	0
Road Builder	70	65	58	0.05%	0.03
State Regulator	66	74	80	2.95%	2.35
Telecommunications	56	54	56	7.62%	4.24
Unknown	44	56	70	1.22%	0.85
Overall DQI	**63**	**62**	**59**	**100.00%**	**59**

It is difficult to achieve a DQI score of 100 because some information may be unavailable to certain stakeholders. A facility owner may not know the duration and cost of an excavator’s downtime. An excavator may not know if the type of locator was contract versus utility, or how long a service interruption lasted or how many customers were affected. Users with relatively high scores (above 80) should not be concerned with getting to 100, but DIRT could be greatly improved by raising the scores of those below 70.

Appendix D: Estimate of Total U.S. Damages

Green Analytics, in consultation with the Data Reporting and Evaluation Committee, developed a model to estimate the total number of facility damages in the U.S. and to provide insight into the relationships between key variables. The modeling process used is summarized in this section.

Damages reported to DIRT are voluntary and for many states under-reported. As a result, the total reported damages in the DIRT database do not reflect the actual number of damages that occur in the U.S. By relying on states that are substantially reporting actual damages, statistical methods can be used to estimate damages for the states with less adequate reporting. In this way, an estimate can be made of the total number of damages in the U.S. To start, a subset of states where damages are deemed to have been substantially reported was established. This subset was then used to develop a predictive model as outlined in the following sections.

Substantial Reporting States

This report uses the same set of substantial reporting states as in the 2017 and 2018 DIRT reports. For more details on how the states were determined as substantially reporting, see the 2017 and 2018 DIRT Reports. Table D1 lists the 10 substantial reporting states used for this analysis along with their reported damages over time.

Table D1—Reported damages from substantial reporting states, 2016 to 2019

State	2016	2017	2018	2019
Colorado	12,660	6,786	12,411	18,748
Connecticut	561	562	711	1,027
Florida	10,661	21,877	26,628	34,390
Georgia	37,562	29,655	29,844	43,538
Illinois	21,293	19,256	20,702	23,452
Kansas	4,650	5,476	5,435	5,965
New Mexico	1,431	1,479	1,825	2,069
Pennsylvania	7,983	8,878	9,706	14,239
Texas	53,899	45,384	36,543	70,011
Virginia	4,273	4,877	4,862	4,865
SUBSTANTIAL REPORTING STATES TOTAL	154,974	144,230	148,667	218,304
TOTAL DIRT REPORTED DAMAGES	317,869	316,442	341,609	453,766
Reported Damages Attributed to Substantial Reporting States	49%	46%	44%	48%

Statistical Method

A Poisson regression model, with standard errors adjusted for the panel data structure, was used to develop the predictive model. The Poisson regression is a generalized linear model that is typically used to understand and model count data, such as the number of damage events in a state that is contained within the DIRT database. This model yields estimates of the percentage change in damages given a range of independent (or explanatory) variables.

The modeling exercise involved running a series of Poisson models to explore which independent variables had a statistically significant influence on the count of damages in a given state and month. In general, the modeling process involved adding all potential predictor variables to an initial model. Model coefficients deemed insignificantly different from zero by a t-test were then iteratively dropped from this initial specification. Thus, the final model used for predictive purposes included only significant coefficients.

Two different model specifications were initially run: 1) a model with linear quantitative variables and nominal variables; and 2) a model with linear and quadratic or log-normal quantitative variables, as well as nominal variables. The specification with quadratic variables accounts for potential non-linear relationships. For this specification, the modeling process proceeded by first adding quadratic variables for certain quantitative predictors to the linear model independent of other quadratic variables. If the relationship was statistically significant, then the quadratic variable was considered a candidate for the final model. Though the quadratic and log-normal specifications yielded certain informative results, the analysts chose not to use them for predictive purposes because they generated unreasonable estimated damage counts.

The same procedures were used to run models for the two sets of substantial reporting states. However, in this appendix only the larger dataset of 10 states is presented because this data is more representative of all 50 states (although the trade-off is that the damage counts reported for the larger set of data may be more under-reported). Furthermore, certain estimated damage counts based on the smaller set of substantial reporting states were unreasonably large. For these reasons, the 10 states were used as the substantial reporting states in the main body of the report. However, damage estimates should still be treated as an underestimate because it is known that DIRT data used in the modeling process does not capture the actual total number of damages.

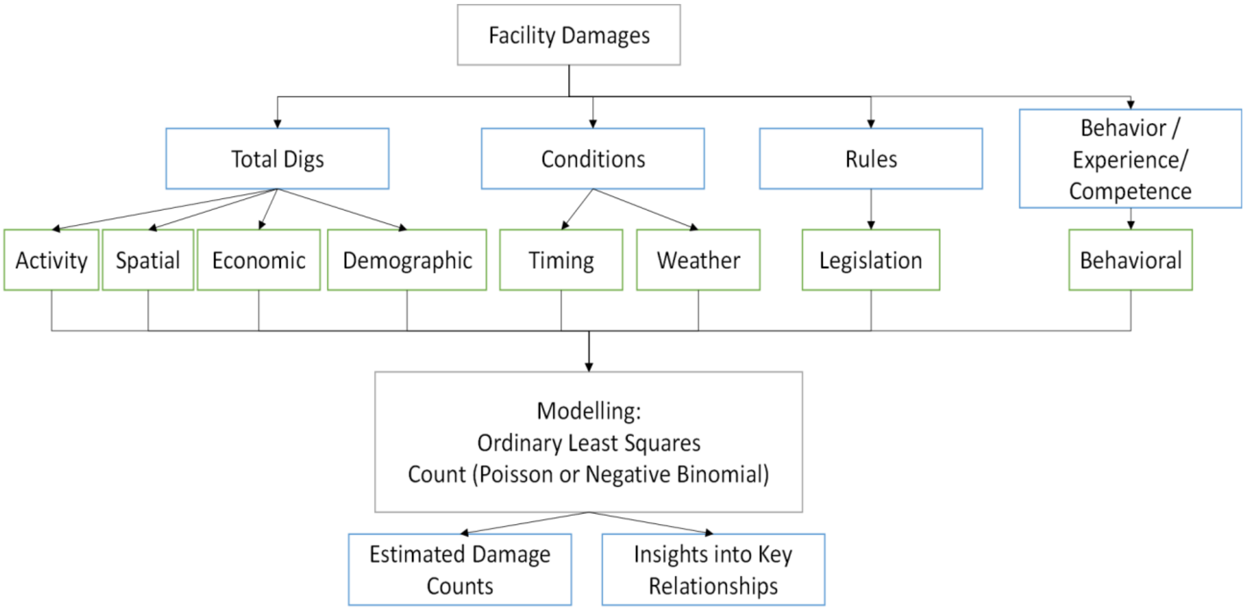

Figure D1—Conceptual framework of damage counts and possible outputs of modeling process

Data

The dependent variable in the model is the weighted damage count, rounded to the nearest integer. The dependent variable in the model is structured such that each observation represents the number of facility damages in a particular state ***s*** and month ***t***. The potential independent variables representing each data category in Figure D1 are summarized in Table D2. The analysts made efforts to match the resolution of each independent variable to that of the dependent variable. However, not all data was available on a monthly basis. For the final set of independent variables, the analysts attempted to focus on variables representing activity rather than value (e.g., number of building permits rather than the value of permits, or employment in an industry instead of its gross domestic product).

Table D2—Variables considered (Type categories correspond to those in conceptual model)

Type	Variable
Activity	▪ Total construction spending in state by month ▪ Construction employment in state by month (total and per capita) ▪ Outgoing transmissions from one call center(s) in state in the year[a] ▪ Total residential unit construction in state by month ▪ Quarterly real gross domestic product for construction by state
Weather[b]	▪ Mean precipitation in state by month ▪ Mean temperature in state by month
Time	▪ Rough indicators of season (Winter: Jan, Feb, Mar; Spring: Apr, May, Jun; Summer: Jul, Aug, Sep; Fall: Oct, Nov, Dec) ▪ Aggregate of rough indicators of season corresponding to spring and summer versus fall and winter (cannot enter model at same time as other season indicator variables)
Population	▪ Total population in state (2019) ▪ Population change in percent from 2018 to 2019 ▪ Population density in state (2019)[c]
Legislation	▪ Tolerance zone in inches ▪ Hand dig, vacuum, or soft excavation within tolerance zone (hand dig clause)
Spatial	▪ Area of state in kilometers[c]
Economic	▪ Unemployment rate in state by month ▪ Total employment in state by month (total and per capita) ▪ Quarterly gross domestic product for all industries by state

[a] One call transmissions were not reported for certain states. In these cases, a model was developed to impute the missing observations. Transmissions for certain other states were only partially reported (multiple one call centers in a state). To be conservative, the analysts did not impute these observations.

[b] Weather data was available from the NOAA National Climatic Data Center for all states except Hawaii. For Hawaii, the analysts estimated mean monthly temperature and precipitation using data from the state's weather stations.

[c] The area variable was causing unrealistic estimated damage counts for the state of Alaska in certain models for all years, so this variable was dropped from the analysis. Similar problems were encountered with the 2018 and 2019 data when predicting damage counts for Washington, D.C., and these were caused by the population density and per capita employment variables.

Before running the models, variance inflation factors (VIFs) were calculated and used to check for high correlation between independent variables, a situation known as multi-collinearity that affects the interpretation of coefficients and can impact predictions based on the model. The VIFs indicated that multi-collinearity is a problem when all independent variables are included (Table D3). Variables with the highest VIF scores were iteratively dropped. As noted above the analysts focused on retaining variables representing activity and not value during these iterations.

Table D3—Checking for multicollinearity variance inflation factors[a]

Variable	2019		2018		2017		2016	
	Initial	Reduced	Initial	Reduced	Initial	Reduced	Initial	Reduced
Total units	42	6	40		45		67	
Population	12,474		4,547		17,239		15,517	
Employment	13,644		3,174	6	14,521		16,245	
Construction employment	1,320		305		641		936	
Population change	92	6	26	5	71		232	5
Employment per capita	58	4						
Construction employment per capita	145	4	27	5	62	2	74	
Hand dig clause	130		15		60		50	5
GDP: All industries	4,040							
GDP: Construction	2,181							
Transmissions	275	4	16	6	44	1	22	7
Tolerance interval	39		15		31		16	6
Unemployment rate	23	4	16	2	25	2	8	5
Population density					13	2	11	2
Total construction spending	12		13		12	6	19	
Mean temperature	22	7	14	4	11	4	20	5
Winter (Jan, Feb, Mar)	8	2	4	2	7	6	Omitted	5
Fall (Oct, Nov, Dec)	Omitted	Omitted	Omitted	Omitted	4	3	9	4
Spring (Apr, May, Jun)	6	3	3	2	2	2	4	2
Summer (Jul, Aug, Sep)	8	5	4	3	Omitted	Omitted	8	Omitted
Mean precipitation	2	2	3	2	2	2	2	2
Mean VIF	1,817	4	511	4	1,929	3	1,955	4

[a] Rounded to the nearest integer

The analysts used a rule of thumb of a VIF score of 10 as a cut-off value for when to stop dropping variables. Although there were still some issues after removing the most collinear variables, multi-collinearity was much less of an issue. Note that different sets of data have different issues with collinearity, so the same set of variables was not used for each year.

Results

Table D4—Regression results for the final count models of facility damages

Variable	Poisson Count Coefficients[a]				
	2019	2018	2017	2016	2015
Constant	-9.599709*** (1.463239)	5.117257*** (0.5495457)	4.58841*** (0.4610575)	5.146535*** (0.2155254)	8.301317*** (0.8659892)
Construction spending total					0.00000517* (0.00000306)
Population change				-0.00000383*** (0.00000146)	
Population density					-0.0042612** (0.0021191)
Transmissions		0.0000000418*** (0.00000000981)	0.0000000524*** (0.00000000819)	0.000000172*** (0.0000000372)	0.000000113*** (0.0000000141)
Natural log of transmissions[b]	1.007144*** (0.0857529)				
Spring and summer			-0.3651772** (0.1504601)	-0.2838454*** (0.0988685)	
Winter		0.002818 (0.0928489)			
Spring		-0.2659848* (0.14766)			
Summer		-0.4020203** (0.197851)			
Fall		*Base season*			
Mean temperature	0.0132245*** (0.0020339)	0.0269653*** (0.0090757)	0.032051*** (0.0071174)	0.0268825*** (0.0051069)	0.0166688*** (0.0018208)
Total employment in construction per capita					-111559.3*** (39309.74)
Hand dig clause				-1.152784*** (0.2592687)	-1.636223*** (0.3911967)
N	120				
Log pseudolikelihood	-7383.01	-22,112.56	-16,195.66	-7,608.79	-7,654.93
Pseudo R^2	0.93	0.62	0.76	0.91	0.88

***, **, * the coefficient is significantly different from 0 at the 99%, 95%, and 90% levels of significance, respectively

[a] Coefficient with the corresponding robust standard errors in brackets

[b] The natural logarithm of the transmissions variable was used in the 2019 version of the model.

Table D4 presents the best models for the top 10 substantial reporting states for the 2015 through 2019 data. Model fit, as indicated by the pseudo R^2 measure, was best for 2019, followed closely by 2016 and 2015, and then more distantly 2017 and 2018.

- The model for 2019 differs from the other models in that it used the natural logarithm of the transmission variable. The use of a natural logarithm was chosen this year as it better captured the trends in the damage data, whereas in past years the model performed better without this non-linear adjustment. Regardless, similar to the other years it indicates that damages rise with increases in outgoing transmissions and a state's mean monthly temperature. Since the primary objective of this model is to predict total U.S. damages, the model is developed to maximize the explanatory power. For 2019 the data was best represented with only two variables, transmissions and mean temperature. Other variables that have been helpful in the past, such as construction spending, economic activity, or population changes were not needed. In essence all variables are attempting to act as a proxy for dig activity.
- The model for 2018 indicated that damages rise with increases in outgoing transmissions and a state's mean monthly temperature. Relative to the fall season, damage counts appear significantly lower for spring and summer though do not significantly differ in winter.
- For 2017, the models suggested that damages increase with increases in outgoing transmissions and the mean monthly temperature for the state—there are fewer damages in spring and summer relative to fall and winter.
- For 2016, the models also indicated that damages increase with outgoing transmissions and the mean monthly temperature for the state (similar to 2017 and 2018). However, for 2016, the results suggest that damages decrease with population declines (from 2015 to 2016), are lower for spring and summer relative to fall and winter and are lower for states with a hand-dig clause.
- For 2015, the model suggested that damages increase with the total amount of money spent on construction, outgoing transmissions, and mean monthly temperature in the state. Damages in 2015 are lower in states with higher population density and higher per capita employment in construction and in states with a hand-dig clause.

These results are largely expected. For instance, it is sensible that damages increase with outgoing transmissions because transmissions directly reflect excavation activity; or that damages decrease during the spring and summer months because excavating conditions are likely better in this period relative to fall and winter. While this may seem counter intuitive, and counter to the calendar heat map on the DIRT Dashboard, note that the calendar is highlighting that more damages happen in the summer, which is largely because there is more activity in the summer. The regression model, in contrast, is examining the relationship between variables holding all other variables constant. In other words, holding activity constant, there are fewer damages during the spring and summer. If rising temperatures extend construction seasons, given this relationship, it is reasonable to anticipate increased damages, all else being equal. The negative coefficients observed for population change and construction employment per capita in the 2016 and 2015 models, respectively, were not expected.

Using these regression results, all other state total damages can be estimated by applying the value of each variable from each state and then aggregating to estimate total U.S. damages (Table D5). This process assumes that reported damages in the defined substantial reporting states approximate total actual damages in those states, and that the estimated relationships in Table A5 hold for the states not included in these models. Though there is variation from year to year and an upward trend since 2015, the estimated damages are not terribly different from 2015 to 2019. Variation is expected, given that these are estimates based on incomplete data. However, in 2019 the explanatory power of the model improved significantly. Large jumps in damages—notably from 2017 to 2018—may reflect factors such as different rates of economic growth (e.g., economic growth in 2018 was 2.9% relative to 2.2% in 2017). However, in 2019 the trend appears to be returning to its pre-2018 year-over-year rate of increase, which also corresponds an economic growth rate of 2.3%, further suggesting that the spike in 2018 may have been partially attributable to a relatively higher level of economic activity.

Table D5—Estimated damage counts and upper and lower bound estimates for the U.S. (top 10 states), rounded to the nearest 1,000

Year	Estimated Total U.S. Damages	Lower Bound of Estimated Total U.S. Damages	Upper Bound of Estimated Total U.S. Damages
2019	532,000	430,000	666,000
2018	509,000	230,000	787,000
2017	439,000	270,000	715,000
2016	416,000	201,000	1,159,000
2015	378,000	217,000	738,000

To examine the strength of the relationship between the data for the substantial reporting states and the broader DIRT database, the substantial reporting state dataset was compared with the broader database for a number of key variables. Results of that examination are presented below for event sources, root cause, excavator type, and facilities damaged. In general, the examination revealed that the substantial reporting state dataset is a strong representation of the larger DIRT database.

Event Sources for Substantial Reporting States

Table D6 illustrates the percentage of reported damages for all states in relation to those for the substantial reporting states. The data exhibits a high degree of alignment between all states and the substantial reporting states. In both cases, locator, natural gas, and excavator are the dominant event sources.

Table D6 – Reported damages for all states in relation to the substantial reporting states, 2019

Event Source	Percentage of Reported Damages—All States	Percentage of Reported Damages—Substantial Reporting States
Locator	68.41	69.12
Natural Gas	12.10	7.43
Excavator	8.14	9.45
Telecommunications	6.50	6.94
Federal/State Regulator	2.35	4.69
Electric	1.32	1.00
Unknown/Other	0.58	0.92
Liquid Pipeline	0.12	0.24
Public Works	0.40	0.17
Private Water	0.02	0.02
Road Builders	0.05	0.00
Engineer/Design	0.02	0.03
Railroad	0.00	0.00
Equipment Manufacturer	0.00	0.00

Root Cause for Substantial Reporting States

Root cause data for the substantial reporting states is presented in Table D7 along with root cause data for all states. As was the case with the event source data, the root cause data for the substantial reporting states is a strong representation of the dataset for all states. The percentage of damages attributed to any given root cause for all states is comparable to that for the substantial reporting states.

Table D7 – Root cause for all states in relation to the substantial reporting states, 2019

Root Cause Group	Percentage of Reported Damages—All states	Percentage of Reported Damages—Substantial Reporting States
Excavation Issue	21.64	18.98
Invalid Use of Request	10.43	11.43
Locating Issue	21.38	20.75
Notification Not Made	21.99	21.81
Miscellaneous	0.48	0.53
Unknown	24.08	26.51

Excavator Type for Substantial Reporting States

Table D8 presents excavator type data for all states in relation to the same data for the substantial reporting states. Here again, the distribution of damages across excavator types for the substantial reporting states is consistent with that for all states.

Table D8 – Excavator type for all states in relation to the substantial reporting states, 2019

Excavator Types	Percentage of Reported Damages—All states	Percentage of Reported Damages—Substantial Reporting States
Unknown/Other	49.69	50.97
Contractor	37.64	36.18
Utility	3.48	3.48
Farmer	0.51	0.86
Municipality	3.12	3.40
Occupant	2.96	2.44
Developer	1.26	1.34
County	1.27	1.26
State	0.07	0.06
Railroad	0.01	0.01

Facilities Damaged for Substantial Reporting States

Table D9 considers facilities damaged for substantial reporting states in relation to that for all states, demonstrating once again the strong alignment between the two datasets. In both cases, the majority of reported damages occur to telecommunications and natural gas.

Table D9—Facilities damaged for all states in relation to the substantial reporting states, 2019

Facilities Damaged	Percentage of Reported Damages—All states	Percentage of Reported Damages—Substantial Reporting States
Telecommunications	45.16	48.54
Natural Gas	25.17	22.30
Cable TV	11.45	10.67
Electric	9.59	8.57
Unknown/Other	5.07	5.49
Water	3.19	3.87
Sewer	0.31	0.48
Liquid Pipeline	0.03	0.05
Steam	0.02	0.03

Appendix E: Societal Impact of Damages in the United States

The 2016 DIRT Report made an initial attempt at estimating the direct damage costs that result from damage events occurring across the U.S. The total direct cost in 2016 was estimated at $1.5 billion. These estimated costs were associated with excavators, emergency responders and customers, in addition to facility owners. For the 2019 DIRT Report, the social impact analysis was revisited with the goal of laying out the information readily available. This section, therefore, provides an overview of some of the existing estimates of direct damage costs, as well as indirect damage costs. This information is used to approximate direct and indirect costs for the U.S. using a few different approaches.

Review of Social Impact Estimates

In the context of the DIRT Report, social impact analysis refers to the direct and indirect costs associated with a damage event. Naturally, any situation where an underground utility is damaged requires some form of repair. Existing research defines direct damages as costs that arise from repairing the damage (e.g., the cost of replacement materials, labor costs, loss of product, and administrative costs) and indirect costs that arise from the damage (i.e. economic costs of all disruptions related to damages to underground facilities).[12] This includes lost productivity and inconvenience to customers from service outages, traffic disruption, legal costs, and reputational damage. Other research goes further and distinguishes societal costs from indirect costs.[13] Regardless, the true cost of a damage events is much greater than its repair costs.

A handful of research reports have attempted to take a closer look at these social costs. Table E1 provides a summary of some key findings from samples of this research.

Table E1. Summary of key findings from the literature

Description	Key Finding	Location	Reference
A case study examined a damaged gas conduit in a downtown metropolitan area. A total of 1,720 customers were impacted by associated power outage which lasted over 1h30.	The estimated direct cost was over $12,000. The indirect cost was estimated to be over $1M representing 99% of the total cost.	Quebec	de Nathalie Marcellis-Warin et al. (2015) [14]

[12] de Nathalie Marcellis-Warin, Ingrid Peignier, Marco Lugo, Mohamed Mahfouf and Vincent Mouchikhine. “Évaluation des coûts socio-économiques reliés aux bris des infrastructures souterraines au Québec – Mise à jour”, CIRANO Research Report, 2015RP-14, October.

[13] Makana, L., Metje, N., Jefferson, I., & Rogers, C. (2016). What do utility strikes really cost? University of Birmingham: Birmingham, UK.

[14] de Nathalie Marcellis-Warin, Ingrid Peignier, Marco Lugo, Mohamed Mahfouf and Vincent Mouchikhine. “Évaluation des coûts socio-économiques reliés aux bris des infrastructures souterraines au Québec – Mise à jour”, CIRANO Research Report, 2015RP-14, October.

A case study examined a damaged telecommunication network located at a major arterial road. Repair work took 23 days to complete causing significant traffic disruption.	A cost of $330,000 was attributed solely to traffic disruption. Overall, 88% of total costs were considered indirect costs.	Quebec	de Nathalie Marcellis-Warin (2015)
Minor damages to a water pipe in a residential section of a medium sized city.	Indirect costs related to a boil water advisory (laboratory tests, costs of communications to citizens, etc.), to traffic congestions and detours as well as the loss of drinking water were estimated at $3,900, or about 34 % of total costs.	Quebec	de Nathalie Marcellis-Warin (2015)
Major damage to a water pipe in a small town. Closing the main conduit caused an excess pressure on the network of an adjacent neighborhood, which caused minor damages on the secondary conduits.	Total estimated costs were $1.1 M of which only 18% were direct costs.	Quebec	de Nathalie Marcellis-Warin (2015)
Using a detailed methodology indirect costs were measured for damage events reported in the Province of Quebec.	Indirect costs in 2014 were estimated to be $125M, or 0.038% of construction GDP.	Quebec	de Nathalie Marcellis-Warin (2015)
A detailed analysis of 16 case studies in the U.K. explore the direct, indirect, and societal costs.	The ratio of indirect and social costs compared to direct cost of repair was 29:1	United Kingdom	Makana et al. (2016)[15]
Nine organizations in the U.K. provided detailed information on a total of 3,348 damage incidents.	Using the available company data, average direct cost was estimated by facility type damaged. The average value per incident ranged from £315 for water facility damage to £969 for electric facility damage.	United Kingdom	Metje et al. (2015)[16]

[15] Makana, L., Metje, N., Jefferson, I., & Rogers, C. (2016). What do utility strikes really cost? University of Birmingham: Birmingham, UK.

[16] Metje, N., Ahmad, B., & Crossland, S. M. (2015). Causes, impacts and costs of strikes on buried utility assets. In *Proceedings of the Institution of Civil Engineers-Municipal Engineer* (Vol. 168, No. 3, pp. 165-174).

Drawing on the results summarized in table E1, we can examine the ratio of direct to indirect damage costs. Table E2 provides this information. The ratio of direct to indirect costs varies significantly depending on the specific situation of what was damaged, how difficult the repair was, whether emergency responders were needed, the degree to which traffic was interrupted, and how many customers were impacted. Despite the wide range for individual events, at an aggregate level this research suggests one could anticipate indirect costs being 30 times the direct costs.

Table E2. Synthesized summary of ratio of Direct to Indirect costs

Direct	Indirect	Source	Facility Type Damaged
1	99	CIRANO result 2 - case study 1	Gas
1	7.3	CIRANO result 2 - case study 2	Telecommunications
1	0.5	CIRANO result 2 - case study 3	Minor water damage
1	4.6	CIRANO result 2 - case study 4	Major water damage
1	29	U.K. Study	Range of facilities based on 16 case studies in the U.K.
1	**28**	**Average of above estimates**	

One of the U.K. studies noted above reported average costs by facility damaged.[17] Those average values converting from Pounds to U.S. dollars are summarized in table E3. These estimates capture only the direct cost of repairing the damaged facility.

Table E3—Average Value of a Damage Event

Type	Average value of a damage event based on U.K. estimates (USD 2019)
ELECTRIC	1,851
NATGAS	927
WATER	602
TELECOM	781
SEWER	1,878
CATV	678

Leveraging Existing Information to Provide Insight on U.S. Damage Costs

There is a significant lack of information from which to base an assessment of social damages resulting from damage events. Because of this, it is not possible to provide actual or approximate social damage costs. Instead, in this section, we synthesize the existing information and use it to provide a best guess at a lower bound of social damage costs.

Within the DIRT database, data fields track:

- If there was a service interruption
- Hours of service outage
- Number of customers affected
- Repair/restoral costs

Completing these field is optional, and many companies either don't track or don't enter that information into DIRT as part of their reporting process. As a result, the information on these fields is sparse. Tables E4 and E5 provide a summary of the information contained in the DIRT database for 2019. Table E4 shows that overall, 64% of known events had service interruption. Known events account for 23% of reported damage events. If that pattern holds for all events, then an estimated 332,000 events could have resulted in a service interruption.

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[17] Metje, N., Ahmad, B., & Crossland, S. M. (2015). Causes, impacts and costs of strikes on buried utility assets. In *Proceedings of the Institution of Civil Engineers-Municipal Engineer* (Vol. 168, No. 3, pp. 165-174).

Table E4—Summary of Damage Events with Service Interruption by Facility Damaged, 2019

Facility Damaged	Number of Events WITHOUT Service Interruption	Number of Events WITH service interruption	% of Known Events WITHOUT Service Interruption	% of Known Events WITH Service Interruption	Unknown
CATV	1,491	7,195	17%	83%	50,914
ELECTRIC	3,317	5,773	36%	64%	37,838
LIQPIPE	85	58	59%	41%	18
NATGAS	22,712	39,477	37%	63%	73,943
SEWER	1,142	585	66%	34%	350
STEAM	2	46	4%	96%	38
TELECOM	9,087	17,430	34%	66%	20,2475
UNKNOWN	1,911	1,646	54%	46%	24,787
WATER	3,196	3,954	45%	55%	9,791
Total	**42,943**	**76,164**	**36%**	**64%**	**400,154**

Table E5 shows that for those events that reported a repair cost, a total of $94 million was spent. In addition, at least 355,000 hours of service outage was reported, and 130,00 customers affected. Since these represent only a small fraction of the total number of events recorded in DIRT, and events recorded in DIRT are only a portion of the actual events that occurred, we know these to be significantly underestimated totals. However, the data clearly shows that services and customers are regularly affected, which drive up the indirect costs.

Table E5—Summary of Outage Hours, Customers Affected, and Repair Costs by Facility Damaged, 2019

Facility Damaged	Total Outage Hours Reported	Total Number of Customers Affect Reported	Total Reported Repair Costs (2019 USD)
CATV	3,033	5,163	2,047,003
ELECTRIC	4,918	22,561	4,259,104
LIQPIPE	399	26	27,481,363
NATGAS	51,807	60,295	46,444,366
SEWER	2,447	783	2,242,177
TELECOM	286,915	20,848	7,873,711
UNKNOWN	772	118	593,521
WATER	4,099	17,747	2,637,959
Total	**354,514**	**128,103**	**93,579,204**

Table E6 proves a summary of some key cost statistics extracted from the DIRT database. Given the nature of the DIRT data, for the purpose of this analysis only entries that had a reported repair cost were included. However, to properly analyze the costs, the data needed to be cleaned. The database repair/restoral cost field accepts either an exact value or a categorical value that represents a cost range. For example, an entry of 1 means the repair costs ranged from 1 to 1,000. To address this any reported repair cost using the categorical variable was assumed to be the mid-point of the range (i.e. $500 for the 1 to 1,000 range). In addition, there were a number of multiple reports of the same event entries into the DIRT data. As a result, any damage events with multiple reported repair costs were adjusted to avoid double counting. In some cases, these costs were exact duplicates, while others tended to be an exact repair cost and a categorical value range. In these latter cases the exact value was kept, and the category range was removed. Finally, DIRT data reports were compared against public PHMSA data for Liquid Pipe and Natural Gas repair costs. There were 20 reports identified in both DIRT and PHMSA, where the PHMSA data had cost information not included in the DIRT reports. These additional costs were pulled into the final repair cost dataset for this analysis.

Overall, there were 23,375 unique events with a reported repair cost. Average repair cost per event was $4,000 and ranged by facility damage from $2,400 (Natural Gas) to $687,000 (Liquid Pipe). The high average cost from Liquid Pipe is the result of three larger damage events with reported repair costs over $5 million one of which exceeded $10 million. This highlights the challenge of using a mean estimate to estimate direct repair costs. A few large costly events can skew the mean. In these cases, the median cost can be used as a better representation of the "typical" event cost. Table E6 shows that the median value of repair costs ranged from $500 to $3,000.

Table E6— Summary Statistics of Reported Repair Costs by Facility Damaged, 2019

Facility Damaged	Number of Events with Known Repair Costs	Mean Reported Repair Costs	Median Reported Repair Cost	Max Reported Repair Cost	Min Reported Repair Cost
CATV	559	3,662	3,000	50,001	500
ELECTRIC	975	4,368	3,000	62,826	33
LIQPIPE	40	687,034	3,000	10,468,125	500
NATGAS	19,229	2,415	500	3,904,413	2
SEWER	166	13,507	3,000	1,536,882	431
TELECOM	1,713	4,596	3,000	92,000	3
UNKNOWN	112	5,299	3,000	50,001	232
WATER	581	4,540	500	920,000	140
Total	**23,375**	**4,003**	**500**	**10,468,125**	**2**

Based on DIRT data we know direct costs in the U.S. are at least, but more likely greater than $94 million. Using the average value per damage event report in the U.K. and multiplying that by the number of reported damage events in the U.S., the direct cost of damages could be $400 million (Table E7). Using an assumed 1 to 30 ratio of direct to indirect costs suggests that indirect costs could amount to $12 billion. Alternatively, we can use the U.S.-based mean cost of repair estimated from Table E6 above. This approach results in direct repair costs that are significantly larger than those published in the U.K. study. It is difficult to know exactly what the difference is attributable too. It could be a function of the smaller sample size used in the U.K. study, differences in what is included in the costs, differences in repair costs between U.K. and the U.S., or a combination of the above. However, using the average values estimated from the DIRT data provides a direct cost of $2.0 billion and indirect costs of $59.6 billion, once the 1 to 30 ratio is applied. However, as mentioned above the mean prices might be overstating the "typical" damage cost as a result of a few very large repair costs. Using the median repair cost instead results in a direct repair cost of $994 million and an indirect cost of $30 billion, once the 1 to 30 ratio is applied.

Table E7—Summary of Estimated U.S. Direct and Indirect Damage Costs by Facility Damaged

Facility Damaged	U.K. based Average Direct Repair Costs (Millions USD)		DIRT based Median Direct Repair Costs (Millions USD)		DIRT based Mean Direct Repair Costs (Millions USD)	
	Direct Repair Cost	Indirect Damage Cost	Direct Repair Cost	Indirect Damage Cost	Direct Repair Cost	Indirect Damage Cost
CATV	34.4	1,031.8	152.1	4,564.1	185.7	5,571.1
ELECTRIC	78.7	2,359.6	127.5	3,823.9	185.6	5,568.0
LIQPIPE	NA	NA	0.4	13.0	99.0	2,971.4
NATGAS	103.3	3,098.3	55.7	1,672.0	269.2	8,076.8
SEWER	2.6	77.7	4.1	124.1	18.6	558.9
WATER	8.5	255.3	42.4	1,272.6	65.0	1,949.8
TELECOM	156.3	4,688.4	600.0	18,001.2	1,059.9	31,797.9
UNKNOWN*	17.6	526.8	11.2	337.1	102.0	3,061.0
Total	**401.4**	**12,037.9**	**993.6**	**29,808.0**	**1,985.2**	**59,554.9**

* Metje et al. (2015) [18] does not provide an average cost for "unknown." An average of all U.K. cost estimates was assumed for the unknown facilities damaged.

While it is difficult to estimate what the societal impacts of damages are, the above approach provides an assessment of the potential impacts based on a range of existing information. Simply using the repair damages reported within DIRT we know at a minimum the 2019 damages cost $94 million. However, this only accounts for direct repair costs and only for a fraction of events reported in DIRT. Using a range of average repair costs per damage event from data in the U.K. and U.S., the total direct repair costs are estimated to range from $400 to $1,985 million, with a best estimate of $993 million. If the reported ratio between direct and indirect costs from the literature (1 to 30) holds for these average costs, then indirect costs could range from $12 to $60 billion.

[18] Metje, N., Ahmad, B., & Crossland, S. M. (2015). Causes, impacts and costs of strikes on buried utility assets. In *Proceedings of the Institution of Civil Engineers-Municipal Engineer* (Vol. 168, No. 3, pp. 165-174).

Appendix F: Case Study: How North Carolina 811 Uses DIRT to Reduce Damages

By Louis Panzer, Executive Director, North Carolina 811

North Carolina 811 (NC 811) began taking a deep dive into damages and related data in 2013 with the creation of the Supermega Spreadsheet (^Mega). The purpose of ^Mega is to consolidate data shared with the center, through DIRT via a Virtual Private DIRT (VPD) and Data Grants, with other internally collected data, such as positive responses, ticket volumes and first-time caller surveys. The data is pulled together and sorted by the state's 100 counties to further identify where positive change and challenges exist.

The DIRT data is only the beginning when a state is investigating trends and root causes. Once NC 811 began working from a statistical research position, the importance of validation became evident. One means of validation includes analysis of data from the automated positive response system. One call centers maintain important internal data and have the ability to scrub out specific member information. This allows for a glimpse into such things as on-time locates and work commencing before a ticket is legally valid.

DIRT data provides the base upon which further surveys and research is built. Additional excavator surveys have been used to gauge satisfaction with the process as a whole. This included the 811 notification interaction, on-time locates and accuracy of marks, as well as if a damage occurred. Survey data contributed to research papers co-written with Dr. Al-Bayati, an assistant professor at Lawrence Technological University, and published in ASCE Journal of Construction Engineering and Management. To access the research papers scroll down to the "Library" section on this page: https://www.nc811.org/education-department.html.

Over the past seven years, NC 811 has refined the ^Mega. Even after the law changed in 2014 requiring excavators to report damages to NC 811, a need was identified to reconcile counts between DIRT data shared with NC 811 and the data shown in annual DIRT Reports and online dashboards. CGA staff were extremely helpful through the reconciliation process, and NC 811 recommends any state interested in performing similar statistical analysis to begin with that resource.

During the year, NC 811 shares damage data with the 49 Utility Coordinating Committees across the state, highlighting the specific data for each county. Although the data is limited, it allows communication about trends and provides the ability to compare year-over-year performance within a county, the types of damaged facilities and the types of work being performed when a damage occurs.

While we applaud the CGA DIRT initiatives, NC 811 has identified the following concerns based on its use of the data:

1) Validation of DIRT data with a state's internal data and surveys is critical in order to reduce bias and to improve confidence in root cause findings.
2) It is critical to improve the DQI for DIRT events. The type of work performed when a damage occurs is arguably the single most important guide to targeted education.

3) "Normalization" of the one call ticket volume is vitally important for comparison between state damage-per-thousand ticket ratios. This refers to finding a method to compare individual state laws and procedures when determining ticket distance and life-of-ticket to arrive at a more consistent denominator in the formula (damages reported/ (number of tickets/1000)).

In conclusion, NC 811 believes that combining DIRT damage data with individual state data and research helps fill in the gaps and filter out any biases that could potentially be introduced. It is also critical that all stakeholders contribute their data into DIRT to help provide a balanced picture of root causes. Finally, raising the DIRT DQI will improve confidence and assist one call centers to better focus education where it is needed most.

More information can be found here: https://www.nc811.org/incident-analysis.html.

Appendix G: How National Grid Uses DIRT to Reduce Damages

By Robert Terjesen, Damage Prevention Manager, National Grid

Like all facility owners in North America, National Grid's Damage Prevention program is designed to reduce excavation damages to our buried infrastructure. The three main components to a successful damage prevention program are:

- Educate and promote the 811 call-before-you-dig number/process.
- Respond to all 811 excavation notification requests and accurately locate our underground facilities.
- Educate and promote local state safe digging requirements and CGA's Best Practices.

National Grid focused on those three components for over a decade and saw consistent, annual improvement in reducing the number of damages to our system, as well as a significant reduction in the damage rate per thousand tickets.

National Grid New York	2006	2014	Improvement
Damages	1,424	841	41%
Damage Rate per 1,000	5.36	1.89	64%

But suddenly the year-over-year improvements slowed, we plateaued, and our damage rates stayed within a narrow range. An internal review of our program revealed that our damage prevention program was doing what we had always done. So why did we stop seeing that continuous, annual improvement? We promoted 811 and were slowly reducing the number of damages due to No Notification.
Additionally, we worked with our locators on their performance and continued to see incremental improvements in marking our facilities accurately.

But despite our best efforts to educate and promote safe excavating best practices, the excavator-at-fault damage rate flatlined. And since that was our biggest driver of damages, that explained why we plateaued.

National Grid turned to CGA and recent DIRT Reports to help us assess our program. The 2018 DIRT Report showed that we were not alone: the analysis of submitted industry data indicated that "…progress in reducing damages has plateaued." But the DIRT Report does more than just analyze the data. It also provides valuable recommendations on how to improve and interpret your own data to inform your education, outreach and damage prevention efforts.

More importantly, the DIRT Report recommends that companies embrace new, emerging technologies and approaches to improve their Damage Prevention efforts.
National Grid agreed with these recommendations but needed to identify which data was most valuable and how it could be used to improve our performance.

Most of our data comes from damages or near miss events, but all are lagging indicators. We needed to analyze the leading indicators – data that could help us get ahead of future damages.

Reducing Excavator Error Damages

Excavator error damages were always our greatest problem, so National Grid partnered with Urbint to analyze all 811 tickets to provide a risk score for each ticket. Each 811 ticket contains the same information – the excavator's name, location of the proposed work, type of work performed, type of equipment used, etc. While that data may seem basic, there's a lot of information behind each of those data fields.

As an example:

- ABC Contracting has a great history of digging safely around National Grid's buried assets.
- XYZ Contracting, however, does not; they've damaged our correctly marked facilities frequently.

As a result, any 811 tickets listing XYZ Contracting as the excavator should have the excavator field weighted higher than those listing ABC Contracting based on their specific histories with National Grid. The same weighting and risk analysis are performed on other data points on each 811 ticket – backhoes are weighted higher than post-hole diggers; municipal sewer work higher than homeowners planting rose bushes using a shovel, etc.

National Grid analyzes each 811 ticket using the "Urbint Lens for Damage Prevention" – a software platform for risk-based damage prevention using predictive artificial intelligence – to identify excavations with the highest risk for damage. This provides each 811 ticket with a risk score based on the weighted analysis of each of those various data points.

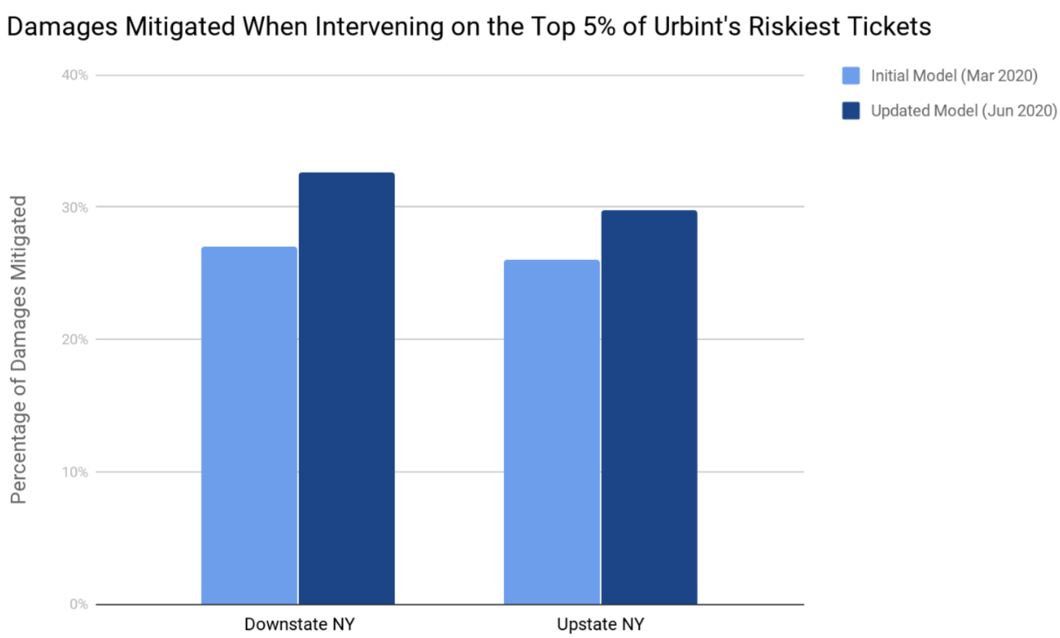
We use the Urbint Lens daily to instantly prioritize tickets with the highest risk so we can send our field resources to intervene before damage occurs. It allows us to have productive conversations with the excavators onsite before work commences to help minimize the risk and hopefully avoid a damage. Since implementing this predictive analytics approach into our damage prevention efforts in 2017, those targeted field visits have helped us reduce our damages and damage rates by helping the riskier contractors become safer excavators.

National Grid New York	2017	2020	Improvement
Damage Rate per 1,000	1.60	1.01	36%

The Urbint Lens' artificial intelligence technology allows for risk scoring to adapt and improve with each additional ticket and outcome – in other words, the AI is constantly learning.

Damages across our territories are not evenly distributed. It is most often the case that a relatively small percentage of tickets account for a large percentage of all damages (whether due to problem contractors, high-risk tasks, dense environments, or other factors). Urbint helps National Grid identify the largest quantity of likely damages in the smallest number of tickets, so we can intervene on the riskiest tickets to maximize our damage prevention efforts.

Its technology, using artificial intelligence, continuously increases in precision to identify as many tickets as possible that are likely to cause damages. This has proven true in National Grid's New York territory: Urbint's models for both our Upstate and Downstate territories have improved in capturing the most likely damages in the narrowest group of tickets.



As excavators engage the National Grid personnel onsite and learn how to minimize the risk, they become safer excavators. And as they reduce the number damages to our facilities, their 811 ticket risk scores come down. As a result, the riskiest excavators in 2017 are no longer high risk. They have become safer excavators by adopting the recommended safe digging best practices.

The DIRT Report's analysis, recommendations and conclusions look to "ensure that maximum value is derived from each event entered into DIRT." Our data was always there, we just weren't recognizing its full value and putting it to good use.

In conclusion, the CGA's DIRT Report has challenged the industry to embrace the data, to improve on the data quality and combine it with new, emerging technology to enhance our current damage prevention programs. With the help of partners like Urbint, National Grid hopes to do that.