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SETU: Safety in Excavation and Trenching, for yoU — A training and decision-making tool for worker safety in excavation and trenching operations in construction

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May 2024

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This research was funded by the US National Institute for Occupational Safety and Health (NIOSH) grant U60OH009762. The findings and conclusions in this manuscript, as well as the resources and products described, are those of the authors and do not necessarily represent the views of NIOSH. The CPWR Data Center was not involved in the analysis or interpretation of the data used in this study.

Report # 21-2-PS

Abstract

Trenching and excavation are basic, and often indispensable, activities in construction. However, they can create hazards and cause injuries and deaths. This research uses a mixed methods framework to understand the reasons for the limited adoption of proven protective systems during trenching and excavation. Two separate surveys were developed to obtain industry feedback, and findings from primary and secondary data analysis were used to build a training and decision-making application to improve safety in excavation and trenching. The result—Safety in Excavation and Trenching for yoU (SETU)—is a free, platform-independent tool designed to improve worker safety by 1) making information about trenching safety available on handheld devices, 2) breaking down cognitively complex safety ideas and intricate jargon into everyday language, and 3) offering an intuitive, easy-to-use interface about measures to improve safety for excavation and trenching requiring no training for adoption. The SETU website (https://shalini-priyadarshini.shinyapps.io/v4-calculatetrench/[1]) will improve access to information about hazards, soil classification, and protective systems, allowing users to choose the most appropriate option to improve safety.

[1] The SETU website is an app/website that is currently being refined and will continue to be improved with user feedback and suggestions.

Key Findings

The list below summarizes the findings:

- Based on published data from OSHA, 419 trenching/excavation incidents have resulted in 435 deaths in excavation and trench work between 2009 and 2021, an annual average of 33.46 deaths.
- The citation type per incident averaged 3.15 Serious and 1.76 Willful, with an average penalty of $43,000.
- More than 60% of the fatality cases are from three NAICS codes: 237110 (Water and Sewer Line and Related Structures Construction), 238910 (Site Preparation Contractors), and 238220 (Plumbing, Heating, and Air-Conditioning Contractors).
- Fifty percent of the fatality cases were cited for inspections, 80% for protection systems and 60% for safety training and education.
- There have been 389 reported cases of severe injuries in excavation and trench work since 2015, of which 23% were cave-ins from the unprotected side of trench. In 17% of cases, a trench box was involved.
- Survey 1 responses (n = 101) indicated that incidents occur because of lack of training, negligence, protection system not used or incorrectly used, and absence of a competent person.
- Over 90% of expert responses from Survey 2 (n = 140) suggested that lack of hazard recognition as the primary reason for continued deaths.
- SETU was pilot tested with the GC team of an active construction project in Washington, DC in Fall 2022. The group consensus was that SETU was straightforward, intuitive, and precise.

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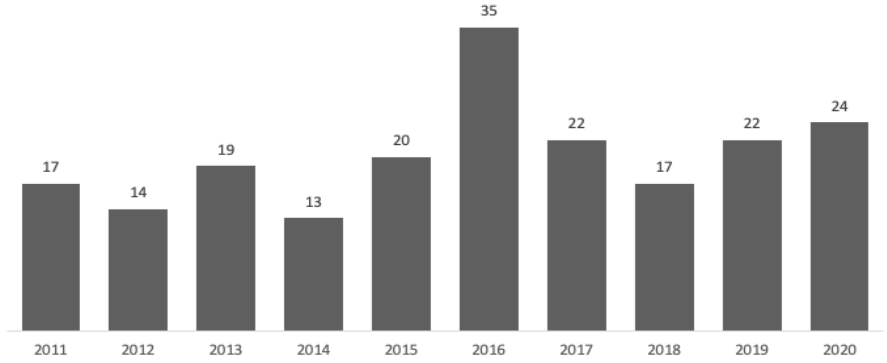
Introduction

Safety and health hazards are a part of the construction work environment, with activities that expose workers to hazards such as falls, electrocutions, struck-by, and caught-in/between incidents. Excavation and trenching are particularly dangerous, with severe injuries and deaths being a familiar problem for workers, contractors, regulatory agencies, and researchers.

Figure 1 represents the total number of excavation and trenching cave-in fatalities in the private sector for 2011-2020 (source: Bureau of Labor Statistics (BLS)). Based on the latest available data, we observed that the number of worker deaths is increasing. It is noteworthy that the numbers represent a specific incident type, i.e., soil cave-ins. Soil cave-ins are a subset of incidents that may occur during these operations and are separate from other reasons for fatalities and severe injuries, including confined spaces, electrocutions, falls, being stuck-by and getting caught in/between while working in and around trenches and excavations.

Figure 1: Soil cave-in fatalities in private sector (2011-2020)



In 2018, the Occupational Safety and Health Administration (OSHA) released a directive for the continued implementation of their National Emphasis Program (NEP) for excavation and trenching "to identify and reduce hazards which are causing or likely to cause serious injuries and fatalities" during these activities. It established the requirement of developing and implementing outreach programs, including providing compliance assistance materials to those directly and indirectly involved in such operations. This OSHA directive strongly advocates for the importance of the ready availability of correct information to those who need it at the time of need.

According to the National Institute of Occupational Safety and Health (NIOSH), excavation and trenching hazards are identified and sufficient guidelines exist to prevent them, including standards and regulations, specifying engineering controls, PPE, and safe-work practices. Furthermore, OSHA maintains that incidents are avoidable by "using widely recognized and established safety practices."[2]

This research argues that these "widely recognizable and established practices" have an inadequate reach to the target population and hypothesizes that diversification of the channels used to disseminate knowledge and information is needed.

Training is important to construction site safety and for sustaining and improving safety performance (Demiskesen & Arditi, 2015). Moreover, many OSHA standards include explicit requirements for training

[2]https://www.trumpadministration.archives.performance.gov/labor/2019_dec_DOL_Worker%20Safety_Reduce_Trenching_and_Excavation_Hazards.pdf

designed to empower workers with the necessary skills and knowledge to complete their jobs in a safe and healthful manner. Researchers have argued that a worker's ability to identify risks and evaluate their magnitude, which is another key element of safety, develops through a combination of training and experience (Sacks, Perlman, & Barak, 2013). Some researchers have commented that the traditional, pedagogical approach to learning and teaching may not always be very effective in engaging adult learners or for increasing information retention (Bhandari, Hallowell, & Correll, 2019). Self-paced and self-directed learning that uses visual and auditory aids is another recommended approach.

In recent years, there has been an increasing interest in exploring digital tools for education, including mobile technologies, to expand learning opportunities for adults. Advances in the computing capabilities of the ubiquitous smartphone offer the option to take knowledge dissemination outside classroom settings (Jones, Scanlon, & Clough, 2013).

Objectives

This research investigated the reasons incident numbers for excavation and trenching remain high despite reduction efforts from both within and outside the construction sector. In particular, it examined why worker safety measures and proven protective systems are not adopted more broadly.

This project was designed as a three-phase study. In the first phase, a review of scientific literature was conducted to develop a comprehensive understanding of the topic and to benefit from previous work and research methods. Concurrently, excavation and trenching fatality data was collected from publicly available information. The work in this phase was completed prior to applying for the Small Study grant.

In the second phase, two web-based survey instruments were designed and administered to industry members familiar with trenching and excavation. Analysis of this data provided important insights that informed the design of the proposed training tool.

The final deliverable of this multi-phase project is a training and decision-making application—*SETU: Safety in Excavation and Trenching for yoU*—to increase safety awareness in excavation and trench work and reinforce the value of proven protective measures. SETU is available in English and Spanish. It is designed to assist those responsible for those working in and around trenches in making informed decisions about the protection systems to choose.

Methods

Industry Survey Data: Primary Data

Literature review findings from the database analyses presented in the results section were used to build two separate surveys. The CMU-IRB reviewed and granted approval under exempt review for this application (IRB ID STUDY2020_00000311). The surveys aimed to develop an understanding of the factors that influence worker safety in excavation and trenching and to create a comparison with the results from the database analysis. To establish content validity, the surveys were reviewed by safety experts and field professionals, with suggested revisions incorporated in the final surveys. The surveys were made available in English and were administered online using the Qualtrics platform. Qualtrics is a cloud-based portal for creating and distributing web-based surveys and is widely used for academic research.

Participation was requested using multiple modes of communication, including professional social networks, websites, emails and phone. Professional contacts in the construction industry were leveraged. Experts at NIOSH, OSHA, and construction equipment rental companies were contacted by phone for one-to-one

discussions about the research and requested to participate. These efforts logged moderate to high success rates.

Survey 1 was a 24-item instrument designed for site personnel input on aspects of site safety and the challenges of implementing OSHA regulatory requirements in the field. Several questions were close-ended designed for responses on a 7-point Likert scale, while others were multiple choice. Survey 2 used a 12-item, open-ended design and was intended for management and policymakers exploring reasons behind high fatality and severe injury cases in this type of work. Survey questions are included as Appendix 1.

Secondary Data

OSHA Investigation Reports: Secondary Data

A master fatality database for excavation and trenching was developed at Carnegie Mellon University that captured information from publicly available data through OSHA. Incident files for Federal/State summaries from OSHA archive (available at https://www.osha.gov/fatalities/reports/archive) were used to identify trenching and excavation related deaths for FY09 - FY17. Incident reports for cases from April 30, 2017 onward are available on the OSHA website at https://www.osha.gov/fatalities. Data was filtered using the following keywords: trench, excavation, collapse, soil, engulf, asphyxiate, sewer. Data was also collected for cases that fell under an OSHA Emphasis program for excavation and trenching. In order to build a database, further information was retrieved using the investigation number, when available, else narrowing down on the case using incident date and location. Collected incident information includes the report no., date, city and state of the job-site of the incident occurrence, employer's ownership status and North America Industrial Classification System (NAICS) code, victim's union status, OSHA emphasis program categories (whether National, Regional, or Local). Additionally, the original and current penalty $ value, violation items including initially cited standard, citation type were retrieved. Event description and investigation summary were also collected.

OSHA Severe Injury database: Secondary Data

OSHA requires reporting of all severe work-related injuries by employers falling under federal OSHA jurisdiction. Severe injuries are defined as cases of an amputation, in-patient hospitalization, or loss of an eye. The requirement came into effect at the start of 2015, and the publicly available case documentation includes, among others, the event date, employer, city, state, NAICS, narrative, nature of injury, body part, event, and source.

Accomplishments and Results

Fatality reports findings

Between 2009 and 2021, a total of 419 fatality cases resulting in 435 deaths appeared in the available data for excavation and trenching. It is worth noting that OSHA has estimated a minimum 3-year case backlog, so the actual number of cases may be much higher (FOIA response #888182). Table 1 lists the NAICS codes with the highest caseloads, with Water & Sewer Line Construction (NAICS 237110) recording as many cases as the sum of the four NAICS codes that follow.

Table 1. NAICS codes with highest caseloads

North America Industrial Classification System	No. of cases
Water and Sewer Line and Related Structures Construction (NAICS 237110)	149
Site Preparation Contractors (NAICS 238910)	80
Plumbing, Heating, and Air-Conditioning Contractors (NAICS 238220)	33
Poured Concrete Foundation and Structure Contractors (NAICS 238110)	19
Highway, Street, and Bridge Construction (NAICS 237310)	18
Oil and Gas Pipeline and Related Structures Construction (NAICS 237120)	13
All Other Specialty Trade Contractors (NAICS 238990)	13
Commercial and Institutional Building Contractors (NAICS 236220)	11
New Single-Family Housing Construction (except Operative Builders) (NAICS 236115)	10
Power and Communication Line and Related Structures Construction (NAICS 237130)	9

Table 2 illustrates the frequency of citations for violations of 1926.0651 (Specific Excavation Requirements), 1926.0652 (Requirements for Protective Systems) and 1926.0021 (Safety Training and Education) for the cases cited under Federal OSHA (n = 256). Note that multiple citations were issued per case, bringing the average citation per case to 3.15 for Serious and 1.176 for Willful. OSHA defines a "Serious" violation as "when the workplace hazard could cause an accident or illness that would most likely result in death or serious physical harm, unless the employer did not know or could not have known of the violation." On the other hand, a "Willful" violation per OSHA's definition is one "in which the employer either knowingly failed to comply with legal requirements (purposeful disregard) or acted with plain indifference to employee safety."

Table 2. Citation Frequency

Citation Number[3]	Number of Instances	Percent	Citation Detail
0651 CO2	97	38%	Means of egress from trench excavations.
0651 H01	27	11%	Protection from hazards associated with water accumulation
0651 I	30	12%	Stability of adjacent structures.
0651 J02	75	29%	Protection of employees from loose rock or soil.
0651 K01	132	52%	Inspections: Daily inspections by competent persons
0651 K02	29	11%	Inspections: Employee removal from hazardous area until necessary precautions are taken
0652 A01	197	77%	Protection of employees in excavations: by an adequate protective system
0021 B02	148	58%	Employer responsibility: instruct each employee in recognition and avoidance of unsafe conditions

Fifty-two percent of the cases were cited for non-compliance with the "Daily inspections by competent persons" requirement and 77% for "Protection of employees in excavations" requirement. Since, per OSHA, a competent person performs tasks including soil classification, inspecting protective systems, conducting site inspections, designing structural ramps, and monitoring water removal equipment, it may be argued that citations for 1926.0651: Specific Excavation Requirements fall within the responsibilities of a competent person. OSHA defines a competent person as "one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them" [29 CFR 1926.32(f)]. Therefore, the presence of a well-trained competent person on site is critical for the safety of those working in and near excavations and trenches.

We found that 65% of cases were cited under the OSHA National Emphasis Program (NEP) for excavation and trenching and 78% of cases fell under some emphasis program (National, Regional, State, or Local). Penalty ranged from minimum of $375 to a maximum of $1,475,813, averaging at approximately $43, 000.

A staggering 58% of the cases received a citation for not complying with the requirement to instruct employees in recognition and avoidance of unsafe conditions (1926.0021-B02). These figures provide ample evidence of the divide between safety strategies typically implemented on site and those required by law.

Severe injury data findings

Between January 1, 2015, and August 31, 2021, there were 67,434 severe injury cases. Based on the content analysis performed on incident narratives, 389 involved excavation and trenching. The research found that 17% of the 389 involved trench boxes and their parts. In 23% of the cases, a cave-in from the unprotected

[3]0651: Specific Excavation Requirements
0652: Requirements for Protective Systems
0021: Safety Training and Education.

side of a trench led to injuries. Approximately half the cases (47%) resulted from workers either being struck-by machinery or getting caught in/between tools, equipment and/or surfaces. 20% of the cases involved falls or slips and trips, and 10% resulted from miscellaneous causes, mainly burns or heat-related incidents.

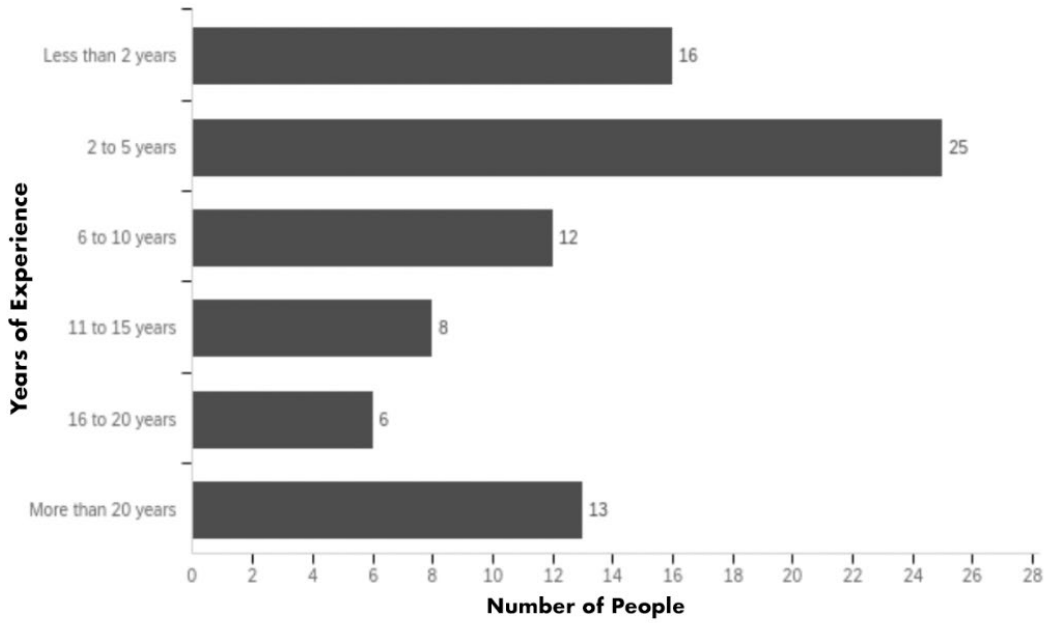
Survey analysis and findings

A total of 101 responses were collected for Survey 1 and 140 for Survey 2. There were a few incomplete responses. We defined an incomplete response as one in which fewer than 10% of the questions were attempted. We discarded incomplete responses at the close of the surveys and prior to analysis. Construction is male-dominated, and the respondents who completed the survey reflected that demographic: 82% self-identified as male for Survey 1, 78% for Survey 2.

Findings from Survey 1:

Figure 2 represents the industry experience of the respondents of Survey 1, with about a quarter of the responders reporting at least 11 years of construction industry experience.

Figure 2. Construction Industry Experience of Survey 1 respondents



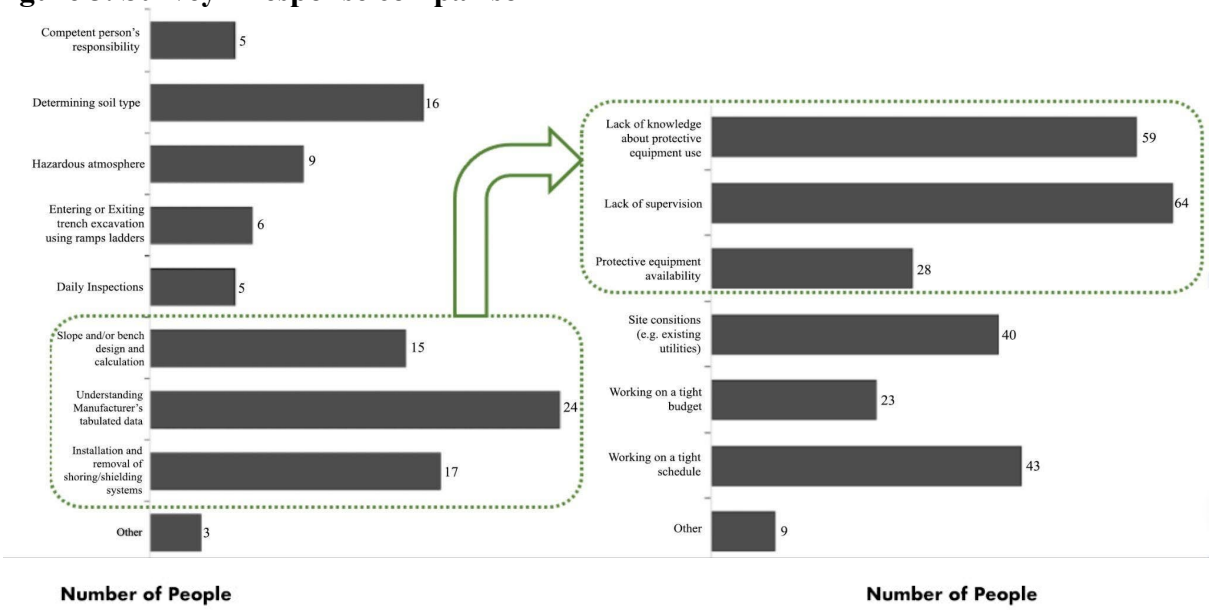
Sixty percent were "competent people" in excavation and trenching work, and from this subset, 50% had completed refresher training less than 2 years prior and 67% within the last 5 years. Typical project size for the employing firms was self-reported as greater than $5 million for 70% participants.

Respondents were in strong agreement regarding the importance of OSHA standards for worker safety (75%). There was more variation in opinions on whether these standards covered all aspects of worker safety, with 20% strongly agreeing and 6% disagreeing, and whether they were relevant and applicable to jobs irrespective of the size, where 25% strongly agreed and 10% chose the "disagree" or "strongly disagree" options.

In response to a question about why accidents occur during this work, lack of training, negligence, protection system not used or incorrectly used, and absence of competent persons were reasons with which more than 60% respondents agreed. Fewer responses considered language/communication (37%) and weather/site conditions (38%) as important considerations.

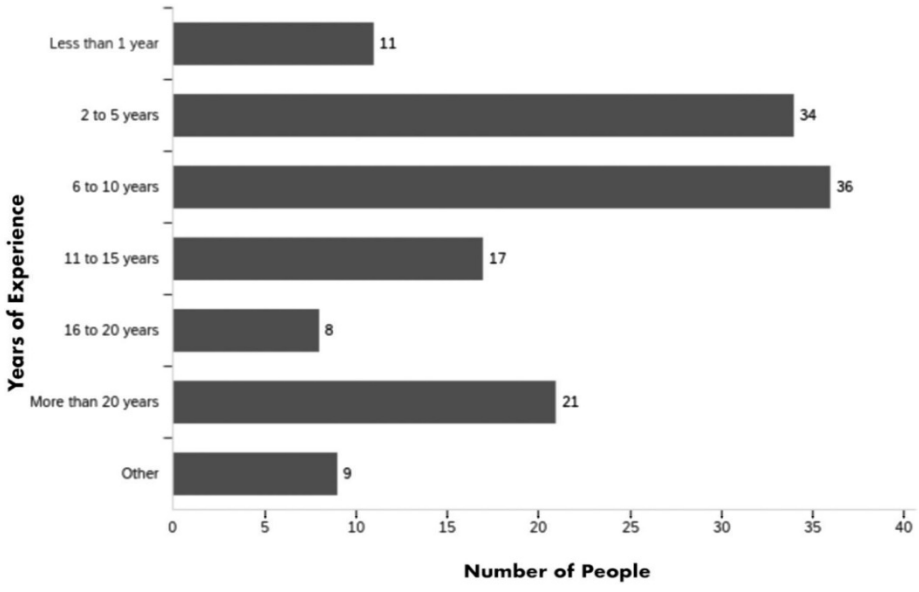
Figure 3 captures responses to questions about the aspects of the OSHA standard that are complex and the list of possible reasons why protective systems are not being used during excavation and trenching operations. Other than soil type identification, use of protective systems (slope, shore, shield) was identified as most difficult to understand. This is substantiated by the reasons these systems are not used ("lack of knowledge about use, equipment availability and lack of supervision"). Therefore, it can be argued that there needs to be a greater push for simplifying the decision-making for the use of these systems. In recent years, shoring and shielding systems have found greater acceptance, in part because of the technical advancements in the equipment and the limited real-estate availability for sloping systems, especially in cities. This spells the need to streamline the decision-making process for choosing these systems.

Figure 3. Survey 1 response comparison



The open-ended format of Survey 2 allowed richly informative responses to questions about approaches for incident prevention, specific concerns among trades that have the highest number of fatalities, changes required to the OSHA excavation and trenching standard, and opinions on the functionality/content of smartphone-based applications. As shown in Figure 4, 41% of respondents had more than 11 years of safety management experience. Sixty percent (60%) identified as a safety manager at a construction firm, OSHA professional or Safety trainer.

Figure 4. Safety management experience of Survey 2 respondents



In response to a question in Survey 2 about the reasons for deaths in excavation and trench work, the surveyed professionals said that the inability to fully understand and respect the threats posed by disturbed soil might be psychological and rooted in human perception of sturdiness of earth (author emphasis):

> *"We interact with the ground from birth as a solid unmoving. That experience **fools us into thinking** it's always going to be safe and static. Our natural fear instinct is rarely triggered when interacting with the earth."*
>
> *"a **perceived notion** that trench collapses don't happen unexpectedly"*
>
> *"Standing in a 10-foot excavation **does not appea**r to be as hazardous as standing at a 10-foot elevation."*
>
> *"The fact that a 5' trench simply **does not look** very dangerous causes workers to take risks that are not fully understood."*

Over 90% of respondents felt that the inability to recognize hazards was the main reason for continued deaths. A relatively low incident rate leads to complacency and there is the tendency to take shortcuts to save time and cost. Based on the research findings, the researchers want to emphasize the severe consequences of incidents and the importance of taking all necessary steps to prevent such occurrences—among the employees as well as employers. As stated by one of the respondents, "vigilance towards safety is a must, not an extra*."* These findings highlight the need for comprehensive, repeated training for all those who are involved in such jobs.

Company size, enforcement, unique challenges of retrofit projects, and working around existing utilities were some other important considerations for the type of training that should be provided to reach different demographics. Several respondents noted the need for more emphasis on instructing in the correct use of protection systems, including how to read and use equipment manufacturer's tabulated data for trench shields and shoring systems. Others mentioned the need for education to challenge the notion that temporary systems do not require planning.

In response to specific concerns from workers in the NAICS groups with the highest number of recorded fatalities, experts agreed that work that involves moving earth is labor intensive, requiring use of hand tools, and workers face the hazards of working in congested areas, especially as the number of underground utilities continue to grow. Workers are often near heavy machinery, which increases the probability of struck-by incident and hazards of vibration loads. Changing atmospheric conditions affect soil properties, and dangers from water accumulation and soil saturation are common. Other challenges include incorrectly identified existing underground conditions and a non-standardized approach from doing work across different municipalities and jurisdictions. Some noted that companies that fall in these NAICS codes are typically present on site at the beginning of projects when the focus on safety is somewhat limited and, as stated by one of the survey respondents, "regular safety practices are overlooked" while working in trenches. The pressure to complete many activities concurrently and sub-optimal planning by the general contractor were other reasons suggested why this demographic has been most vulnerable to incidents.

Opinions varied on whether OSHA standards that govern this type of work are sufficiently comprehensive or need to be updated given technical advancements over the past decade. Some responses suggested that the standards are well-written and effective, and incidents can be contained with better enforcement and consistency of use; others felt that improving ease of use and diversification in the tools for delivering information would improve adherence. Some commented that technological progress outpaces changes to standards and advocated for an update based on actual events and accidents. Greater emphasis was

recommended for pre-planning activities, including locating underground utilities and atmospheric monitoring. Better documentation of trench inspection and identifying the protective system prior to starting work were also suggested.

Respondents said that hazard identification, soil classification, and use of protective systems would be the most important aspects of a useful and effective training tool. Awareness of the threats that may be faced inside the excavation or trench and those that result from site specific conditions, including a correct understanding of those threats, were also considered important. The training should help workers understand the temporal aspect of an incident and its severe consequences. Respondents suggested video and graphics-based material on types of soil, methods to determine soil types, and how to use this information to make decisions about the protective systems as means to help train construction workers. They recommended that all important aspects of the OSHA 1926 Subpart P be included, along with worker rights, employee protection and employer responsibilities. Some responses suggested developing a daily inspection checklist and even a standard operating procedure that would include steps to ensure safety. There were recommendations to develop a site-specific risk assessment tool to provide guidance based on company policy. There were also suggestions to include information about emergency and rescue procedures, work area signage, fall hazards, and access. Some of the more advanced features suggested were using a phone camera to determine the slope angles, virtual reality simulators for cave-in sensation, and artificial intelligence to model the work and identify the most feasible solution.

A small subset of responses disagreed with using technology for training purposes:

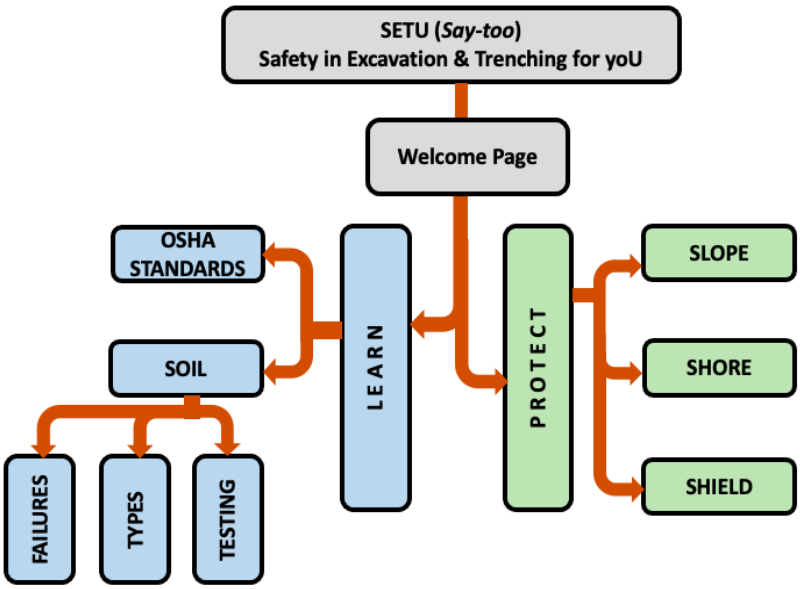
> *"too much reliance on the user"*
>
> *"nothing compares to in-person training and retraining"*
>
> *"more instruments and old-fashioned tools"*

Some responded that change is needed in organizational approach and attitude and that more on-site supervision is the answer.

Developing the training and decision-making application

Analysis and discussion of the findings from primary and secondary data was used to develop the roadmap and framework for SETU web-app. The English version of SETU is available at https://shalini-priyadarshini.shinyapps.io/v4-calculatetrench/). The Spanish version of the tool is available at https://shalini-priyadarshini.shinyapps.io/v4-calculatetrench-espanol/.The design is graphically represented in Figure 5:

Figure 5. SETU architecture



The user may opt to either use the self-study option under **Learn** or choose **Protect** to find the protection system most suited to their requirements.

The **Learn** section is further split into subsections: **Standards** and **Soil**. The information contained in each is briefly discussed below.

Standards provides a reference to the subject matter under the following OSHA standards:

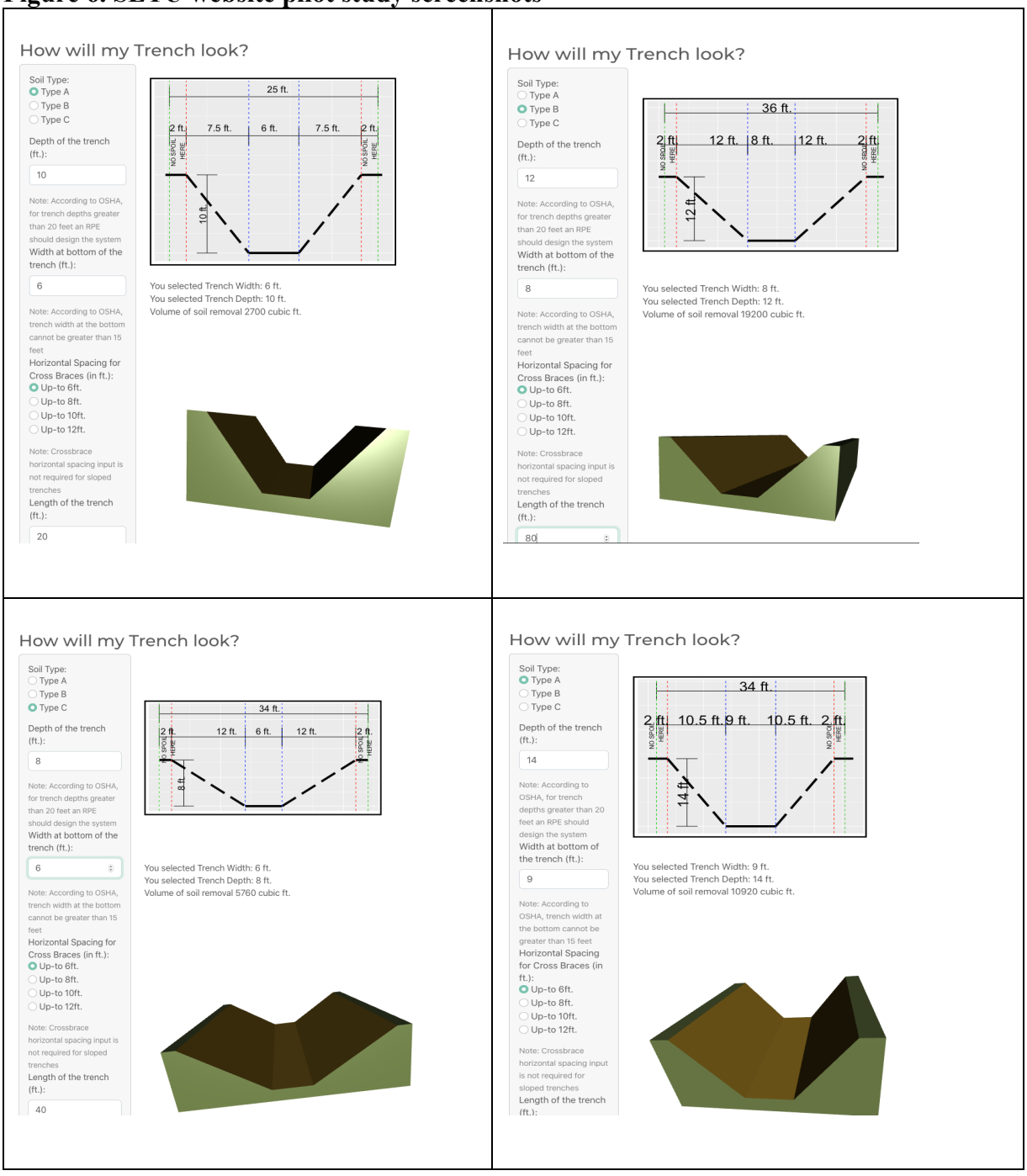
1. General Duty Clause of OSH Act of 1970
2. 1977.3 – General Requirement of Section 11(c) of the Act
3. 1926 Subpart P – Excavations *(future version)*
4. 1926 Subpart AA - Confined Spaces in Construction *(future version)*
5. 1926.0021 Safety training and education (from 1926 Subpart C – General Safety and Health provisions)

Soil educates the user about the hazards of working in and near disturbed soil using simple 2-D visualizations for different types of trench failures. The information comes from the OSHA technical manual Section 5 - Chapter 2 (Excavation: Hazard Recognition in Trenching and Shoring). Soil types and testing to determine soil types are also part of this section. Information about existing utilities, hazardous atmosphere, and dangers of water accumulation will be included in a future version of the tool.

Protect is the decision support section of the SETU tool. It is subdivided into the three protection systems, namely: **Slope, Shore,** and **Shield**.

In the **Slope** tab, a user can input the soil type and data (in feet) for slope depth, width at the bottom of the trench, and length. As shown in Figure 6, the app returns a 2-D diagram of the trench cross- section with the dimensions of each section. The overall width includes the 2-ft. space on either side of the trench that should be free of any spoils. The application also calculates the volume of soil to be removed. This information may be useful in determining the type of equipment needed for the job. Help text has been added between sections for user input as a reminder for OSHA guidelines. A 3-D surface-rendered final trench is delivered as an output. Examples from the tool as it appeared on a laptop computer during the pilot study are presented below (for each soil type A, B and C).

Figure 6. SETU website pilot study screenshots



In the **Shore** tab, tables from 1926 Subpart P, Appendix C help the user choose from size options for the different members that make up the timber-based shoring system for bending strength of 850 psi. As shown in Figure 7, this information will help the user determine the total quantity of material needed for the job. Examples for each soil type A, B and C are presented below.

Figure 7. SETU website soil type screenshots

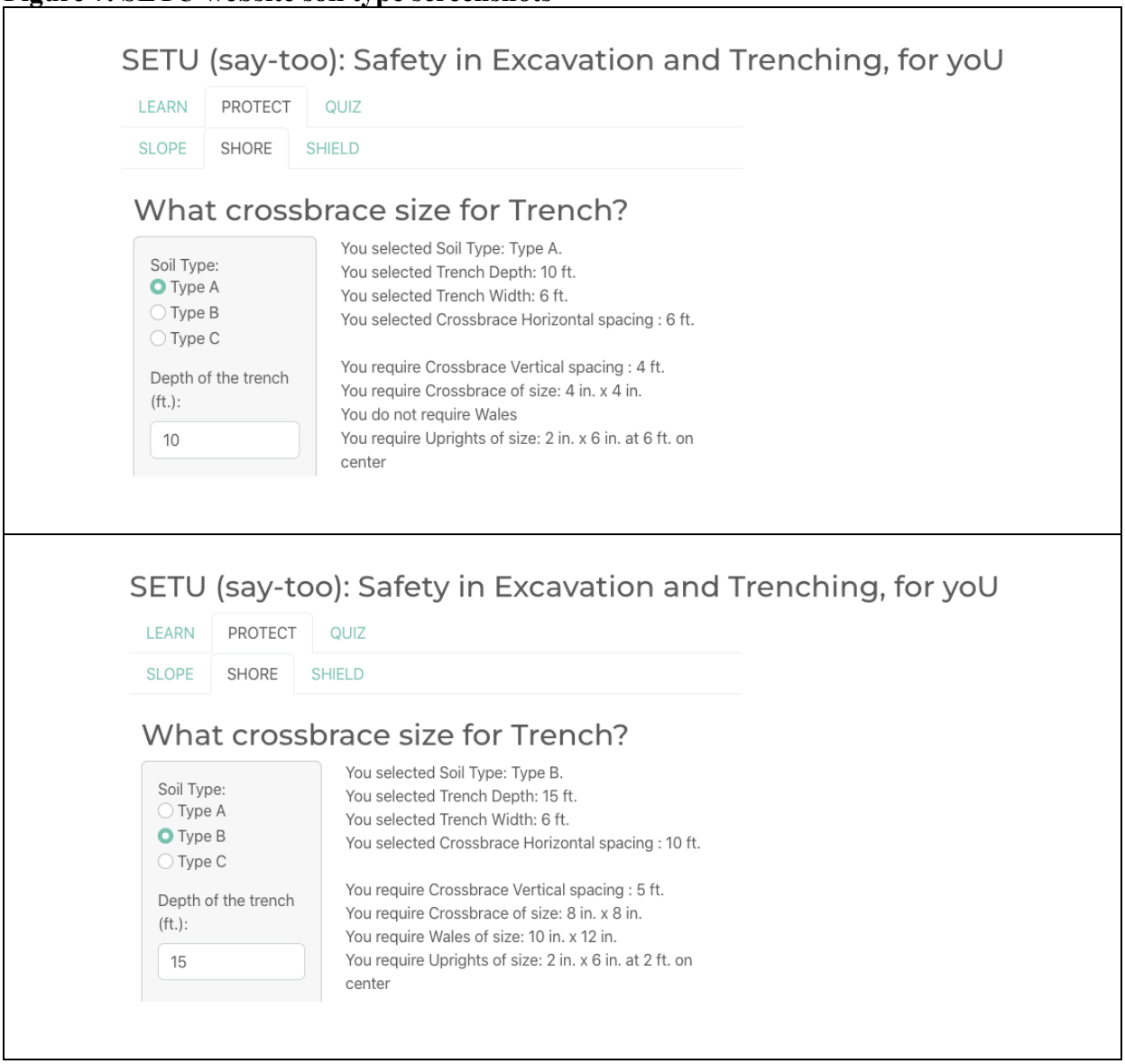
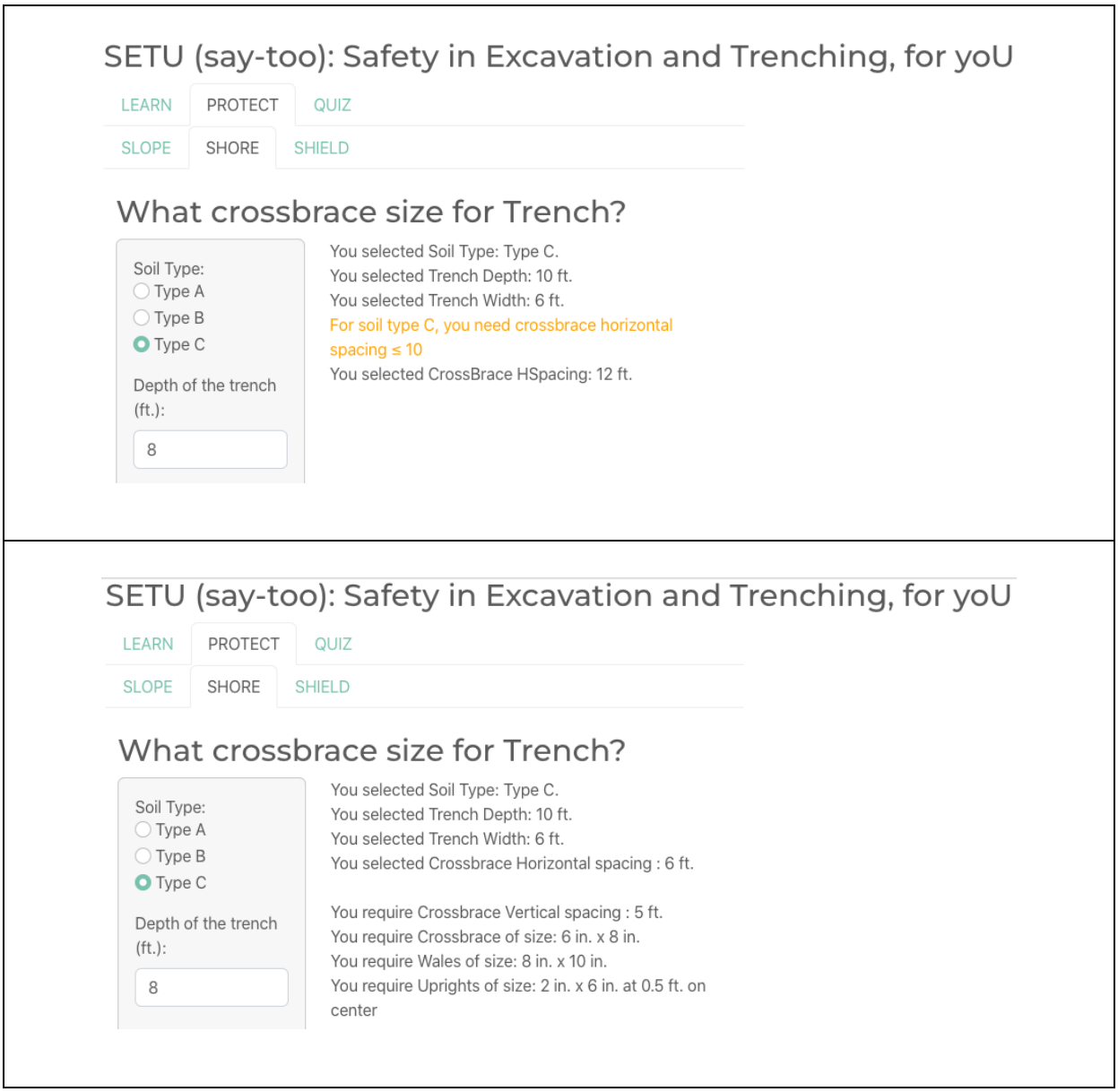


Figure 7. SETU website soil type screenshots (continued)



SETU field-test results

The research team conducted a pilot study in October 2022 at a field location in Washington, DC, to test the features of the tool. A second pilot study was conducted in Pittsburgh later that month to verify the results of the Washington pilot and to provide an opportunity to contrast and compare the findings.

SETU was piloted with a user group at a general contractor in the Washington area. There was a 5-minute introduction about worker safety challenges, the importance of repeated training and ready availability of information, and the features of SETU. The group was then directed to use the link on their smartphones or their laptops for 4- to- 5 minutes to explore SETU, followed by a researcher-led discussion.

There was a consensus that the "Protect" tab was of greater advantage on job sites. Members of the group described the "Slope" tab as a "handy calculator" and the "Shore" tab as a "useful back check." There was also a positive comment about SETU's ability to inform the user when any input needed to be revised based

on information in the OSHA shoring tables. The group appreciated the reasonably quick re-calculations that SETU made possible for both “Slope” and “Shore” tabs.

At least one survey respondent in the Washington pilot suggested that several lines of written content make scrolling through the screen tedious. Multiple workers who participated in the Pittsburgh study expressed the same concern. Suggestions were made to shorten the text or wrap it inside rollback tabs and for a more graphics-based interface. At least one user felt the tool was not meant for experts, to which the researchers pointed out that it targeted the demographic of inexperienced workers. One user pointed out that the Slope calculator can be improved by including benching calculations and related graphics. Both the Washington and Pittsburgh groups provided strategies for incorporating information about trench shield use and suggested that describing the broad steps involved in the installation and removal of such systems would be helpful.

Overall, the group consensus was that SETU was straightforward, intuitive, and precise.

The research team expects that subsequent iterations will fine-tune the tool’s capabilities to include a bench calculator in the “Slope” tab and provide the option to select between the “Shore” member bending strength of 850 psi or 1500 psi.

SETU is available in English and Spanish. The researchers aim to emphasize that SETU is not intended to replace a formal competent person certification training, nor can it be a proxy for the experience gained on-site. It is a knowledge dissemination and decision-making tool designed to make the fundamentals of the process of selection from among the protection systems available to all.

Changes/Problems that resulted in deviation from the methods

The architecture of SETU application was envisioned to be based on a decision support matrix (DSX) framework, which is useful where several diverse parameters need to be simultaneously considered. However, based on the findings from the industry survey, the base design was modified to allow the user to navigate and explore the available information based on their interests and needs.

Future Funding Plans

Applications for various grants are planned to make SETU available for training workers and small contractors engaged in this type of work.

List of presentations/publications

“SETU – Safety in Excavation and Trenching for yoU: A training and decision-making tool for worker safety in Excavation and Trenching operations in Construction” Conference paper presented at INTED 2024 – 18th annual International Technology, Education and Development Conference, March 2024, Valencia, Spain

SETU was presented and pilot tested with a construction field crew at a general contractor company in metropolitan Washington, DC. The findings are discussed in Section 6.4 of this report.

SETU was tested by several small subcontractors in Pittsburgh, PA. Their comments were in a similar vein to those received during the pilot testing session, including suggestions to add more graphics and making the selection tabs more definable by using additional colors.

SETU was presented to the safety manager group at a general contractor company in the DC metropolitan area.

Discussions are underway for presenting SETU at the Safety Professionals' meeting at Constructors Association of Western Pennsylvania (CAWP). Functionalities and features of the application will be showcased and discussed in a 20-minute presentation. Feedback from the group will be incorporated in future iterations.

Dissemination Plan

We anticipate that, pending permissions, the app will be available on the CPWR, CAWP and CMU websites for use on smartphones, tablets, and desktop/laptop computers. CAWP has previously offered to provide it on their website. It will be added to the CMU School of Architecture, AECM webpage during the next scheduled website update.

Works Cited and References

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Jones, A.C., Scanlon, E., & Clough, G. (2013). Mobile learning: Two case studies supporting inquiry learning in informal and semiformal settings. *Computers & Education, 61,* 21-32. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0360131512001947

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OSHA Instruction CPL 02-00-161 National Emphasis Program on Trenching and Excavation 10/01/2018. Available at: https://www.osha.gov/enforcement/directives/cpl-02-00-161

Appendix

Carnegie Mellon University

Informed Consent

A survey designed to collect input from **site engineers, construction foremen, superintendents and labor** who work in and around excavations and trenches. These findings will be used to design and build a smartphone based knowledge and training app for reducing the number of accidents during earthwork operations.

Invitation to participate

It is a frightful reality that in the US alone, approximately **40 workers die each year** while working in and around excavations and trenches. We know that accidents and the resulting loss of life and limb can be prevented with safe work practices as promoted by Occupational Safety and Health Administration (OSHA) and the construction industry. *Correct and consistent use of safety equipment can go a long way in ensuring that at the end of a workday a construction worker returns home to his family, safe and healthy.*

Worker training is an important focus area of construction safety. With the idea that a **knowledgable worker is a safe worker**, research at Carnegie Mellon University, Pittsburgh, USA is developing a smartphone-based training app to improve **access to safety related information** for excavation and trenching. The app is expected to be especially helpful for people who are new to construction business and/or require simple, accurate interpretation.

We need your help in this process. I invite you to take this brief survey based on your experiences on construction projects. The survey is divided into five sections and is expected to take 15 minutes or less. Kindly note that this is an anonymous survey and your responses will not be linked back to you. Your participation is voluntary and does not provide compensation in any form. Please do not include any private and/or personally - identifiable information about yourself or others in your answers. While there is a small chance of breach of confidentiality, we will do our best to keep this information secure. Completed surveys will provide valuable input for the app design, therefore please answer as completely as possible.

Please direct your questions / concerns to Shalini (spriyada@andrew.cmu.edu)

Thank you for being a safety champion!

If you wish to proceed, and as part of your consent, please read and check the appropriate box below

- I am 18 years of age or older.
- I have read and understand the above information.
- I want to participate in the research and continue with the survey

I consent, begin the study

I do not consent, I do not wish to participate

Demographic Data: Questions about you and your construction work experience

What is your age?

- 18 to 24
- 25 to 34
- 35 to 44
- 45 to 54
- 55 or older
- Prefer not to say

What is your sex?

- Male
- Female
- Prefer not to answer

What is the highest level of schooling / degree you have completed? (Please select)

- Less than a high school diploma
- High school degree or equivalent (e.g. GED)
- Some college, no degree
- Associate degree (e.g. AA, AS)
- Bachelor's degree (e.g. BA, BS)
- Other

How many years of construction industry experience do you have? (Please select)

- Less than 2 years

2 to 5 years

6 to 10 years

11 to 15 years

16 to 20 years

More than 20 years

How long have you worked for your current company? (Please select)

Less than 2 years

2 to 5 years

6 to 10 years

11 to 15 years

16 to 20 years

More than 20 years

What is your job title?

What type of contracting does your firm do?

What is the typical project size for your firm? (please select)

Less than US $500,000

US $500,001 to US $1 million

US $1 million to US $5 million

More than US $5 million

Don't know/Can't say

How many people are there on your company payroll? (please select)

- Less than 5
- 5 to 9
- 10 to 19
- 20 to 50
- More than 50
- Don't know/Can't Say

Starting with your first (primary) language, please provide a list of languages that you can speak.

Starting with your first (primary) language, please provide a list of languages that you can read and write.

OSHA Competent Person-Part1

Do you qualify as a 'competent person' for excavation and trench work? (Note: A competent person as defined by OSHA is one who is 'capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them')?

- Yes
- No

OSHA Competent Person-Part2

If you have taken a competent person refresher course, when did you take your last one?

- Less than 2 years ago
- Between 2 to 5 years ago
- Don't know / Can't say
- Not applicable

How often do you take a competent person refresher course?

- Once every 2 years
- Once every 5 years
- Not applicable

In your opinion, the requirements of OSHA safety standard for excavation and trenching

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
are easy to understand	○	○	○	○	○
are easy to implement	○	○	○	○	○
are important for protecting the worker	○	○	○	○	○

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
do a good job of protecting the worker	○	○	○	○	○
cover all aspects of worker safety	○	○	○	○	○
are relevant and applicable in all size jobs	○	○	○	○	○

Are there any specific excavation and trenching requirements from OSHA that are difficult to understand? (please check all applicable)

- Competent person's responsibility
- Determining soil type
- Hazardous atmospheres
- Entering or Exiting trench/excavation using ramps/ ladders
- Daily inspections
- Slope and /or bench design and calculation
- Understanding Manufacturer's tabulated data
- Installation and removal of shoring/shielding systems
- Other

Worker protection systems

Which of the following systems have you used most often?

- Sloping
- Benching

Shoring

Shielding

Two or more systems together (Please use the space below to explain)

Other

In your experience, which of the above systems is most cost effective

In your experience, which of the above systems is easiest to work with

Excavation and trenching accidents / near misses

In your opinion, what factors can lead to excavation/trenching accidents?

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Lack of Training	○	○	○	○	○
No competent person on site	○	○	○	○	○

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
No protection system used	○	○	○	○	○
Incorrect equipment use	○	○	○	○	○
Language / Communication	○	○	○	○	○
Weather and/or site conditions	○	○	○	○	○
Negligence	○	○	○	○	○

In the past year, how often have you seen situations when protective systems were not used during excavation/trenching?

- Less than 2 times
- 2 to 5 times
- More than 5 times
- Don't know/Can't say
- Other

What are the reasons why protection systems are not used on sites. (please check all that apply)

- Lack of knowledge about protective equipment use
- Lack of supervision
- Protective equipment availability

Site conditions (e.g. existing utilities)

Working on a tight budget

Working on a tight schedule

Other

If applicable, please describe an instance when your job-site was cited for an excavation/trenching related violation?

If applicable, please describe an experience when you or anyone you know has been in a trenching related near-miss or accident?

Carnegie Mellon University

Informed Consent

A survey designed to collect input from **construction safety managers, construction project managers, safety experts, safety trainers, policy makers, safety equipment makers and similar designations.** . These findings will be used to design and build a smartphone based knowledge and training app for reducing the number of accidents during earthwork operations.

Invitation to participate

It is a frightful reality that in the US alone, approximately **40 workers die each year** while working in and around excavations and trenches. We know that accidents and the resulting loss of life and limb can be prevented with safe work practices as promoted by Occupational Safety and Health Administration (OSHA) and the construction industry. Correct and consistent use of safety equipment can go a long way in ensuring that at the end of a workday a construction worker returns home to his family, safe and healthy.

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smartphone-based training app to improve **access to safety related information** for excavation and trenching. The app is expected to be especially helpful for people who are new to construction business and/or require simple, accurate interpretation.

We need your help in this process. I invite you to take this brief survey based on your experiences on construction projects. The survey is divided into two sections and is expected to take 15 minutes or less. Kindly note that this is an anonymous survey and your responses will not be linked back to you. Your participation is voluntary and does not provide compensation in any form. Please do not include any private and/or personally - identifiable information about yourself or others in your answers. While there is a small chance of breach of confidentiality, we will do our best to keep this information secure. Completed surveys will provide valuable input for the app design, therefore please answer as completely as possible.

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Thank you for being a safety champion!

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I am 18 years of age or older.

I have read and understand the above information.

I want to participate in the research and continue with the survey

I consent, begin the study

I do not consent, I do not wish to participate

Demographic Data: Questions in this section are about you and your industry work

What is your age?

Less than 25

26 to 35

36 to 45

46 to 55

56 or older

Prefer not to answer

What is your sex?

Male

Female

Prefer not to answer

What is the highest level of schooling / degree you have completed? (Please select)

- Some high school
- High school degree or equivalent (e.g. GED)
- Associate degree (e.g. AA, AS)
- Bachelor's degree (e.g. BA, BS)
- Master's degree (e.g. MA, MS, MEd)
- Doctoral Degree (e.g. PhD, MD)
- Other

Which among the following best describes your current job position?

- Policy maker
- OSHA compliance officer
- Emergency responder
- Construction/project manager at a construction firm
- Safety manager at a construction firm
- Occupational safety & health (OSH) professional
- Safety trainer
- Other

How many years of industry experience do you possess? (Please select)

Less than 5 years

6 to 10 years

11 to 15 years

16 to 20 years

More than 20 years

Other

How many years have you worked in the field of safety? (Please select)

Less than 1 year

2 to 5 years

6 to 10 years

11 to 15 years

16 to 20 years

More than 20 years

Other

Please list your safety-related certification (e.g. OSHA 10, OSHA 30, CHST, CSP)

Briefly describe your experience in occupational health and safety

Block 1

NIOSH suggests that excavation and trenching hazards are well defined and preventable using 'widely recognized and established safety practices.' Yet, in the last decade alone, 392 workers have died while working in trenches or excavations. In your opinion, why are these deaths still occurring and what can be done differently to prevent them?

Analysis reveals that in the last decade about 70% of the deaths have occurred from specific NAICS : Water and Sewer-line Construction, Site Preparation, HVAC and Poured concrete contractors. In your opinion, are there any unique challenges faced by them that are not addressed by current safety measures?

Given the wide acceptance of smartphones in our lives and society, this research explores its use in improving information access by developing a training application. The objective is to facilitate reach and simplify the process of interpretation of OSHA standard especially for those with overlapping vulnerabilities (e.g. a young immigrant) Based on your expertise and experience, what aspects of safety knowledge in excavation and trenching should be covered by such a tool?

Please comment on whether the requirements of the OSHA standard (1926 subpart P (Excavations)) has kept up with the changes, if any, in work practices (e.g. trench-less techniques) and/or technological advancements in worker protection systems? What changes, if any, do you deem essential?

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