RESEARCH & DEVELOPMENT

Communicate Lessons, Exchange Advice, Record (CLEAR) Database Development

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North Carolina State University

NCDOT Project 2019-15
FHWA/NC/2019-15

July 2021

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Raleigh, NC 27699-1549

Final Report

Project: 2019-15

July 31, 2021

Technical Report Documentation Page

1. Report No. **FHWA/NC/2019-15**	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Communicate Lessons, Exchange Advice, Record (CLEAR) Database Development**		5. Report Date **July 31, 2021** 6. Performing Organization Code
7. Author(s) **Edward J. Jaselskis, Ph.D. P.E., Arnav Jhala, Ph.D., Siddharth Banerjee, Colin Potts, Abdullah F. Alsharef, Omar K. Alainieh, Sankalp S. Gaharwar**		8. Performing Organization Report No.
9. Performing Organization Name and Address **Department of Civil, Construction, and Environmental Engineering** **North Carolina State University** **Campus Box 7908** **Raleigh, NC 27699-1549**		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address **North Carolina Department of Transportation** **Research and Development Unit** **1020 Birch Ridge Drive, Building B,** **Raleigh, NC 27610**		13. Type of Report and Period Covered **Final Report** **July 2018 to July 2021** 14. Sponsoring Agency Code **2019-15**
15. Supplementary Notes:		

16. Abstract

Valuable lessons learned and best practices gleaned from construction projects often do not transfer to future generations of personnel due to the lack of a formalized process. This ongoing issue gives rise to the need to impart fresh training to new North Carolina Department of Transportation (NCDOT) employees once the aging workforce retires or in the event of turnover. In addition, a platform for personnel to record pertinent project information about projects' successes and failures is needed. Such information can help solve problems and avoid repeated mistakes. The aim of this research project is to create a new program for lessons learned/best practices called Communicate Lessons, Exchange Advice, Record (CLEAR). The North Carolina State University (NCSU) research team used a Design for Six Sigma approach to identify, define, develop, optimize, and verify lessons learned/best practices to create the CLEAR database. The database fields were selected based on end-user input as well as a review of existing data, such as claims and supplemental agreements, within NCDOT data repositories. The NC Department of Information Technology created this internal-only web-based database on its Connect NCDOT SharePoint portal with MS Access as the backend. The NCSU research team created training materials, including videos and standard operating procedures, to disseminate information about this new program. In addition, the research team developed a data dashboard and artificial intelligence (AI)-based model to improve CLEAR's workability. The data dashboard, developed in Tableau, will help to monitor the CLEAR program's impact on the NCDOT. The AI-based model will automatically suggest pertinent lessons learned and best practices to project personnel based on the project documents provided as input. The CLEAR program will help the NCDOT to institutionalize knowledge and is expected to improve project cost variability and scheduling.

17. Key Words **Enhanced communication, artificial intelligence, web-based lessons learned database, data visualization, information dissemination**	18. Distribution Statement		
19. Security Classif. (of this report) **Unclassified**	20. Security Classif. (of this page) **Unclassified**	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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ACKNOWLEDGEMENTS

The research team acknowledges the North Carolina Department of Transportation (NCDOT) for supporting and funding this project. We extend our thanks to the project Steering and Implementation Committee members:

Clare E. Fullerton, P.E.	Chair
Alyson Tamer, P.E., CPM	Vice-Chair
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Curtis T. Bradley, Ph.D.	P Member

The authors also thank NCDOT personnel who participated in this research project for their time and hospitality. Without the help of all these individuals, the project could not have been completed in such a successful manner. The active participation and resulting contributions of NCDOT personnel and the Steering and Implementation Committee were especially noteworthy and helpful.

EXECUTIVE SUMMARY

This research project was undertaken to develop and establish an internal-only Connect NCDOT SharePoint database to collect and share lessons learned/best practices about North Carolina Department of Transportation (NCDOT) projects. This database project is referred to as CLEAR (Communicate Lessons, Exchange Advice, Record). "A lesson learned is defined as knowledge gained from experience, successful or otherwise, for the purpose of improving future performance" (Construction Industry Institute, 2017). For this project, 'lessons learned' signifies the process of collating data during a project's lifecycle that may be useful for future NCDOT projects. By storing and retrieving knowledge for future projects, this repository will help the NCDOT to achieve better project control and to be better prepared to consider suggestions for innovative ideas, thereby adding value to the state of North Carolina.

Previous research efforts (e.g., CII 2017 and the International Atomic Energy Agency Construction Workshop 2011) have explored various approaches to access and utilize lessons learned experiences in the construction industry. Also, the Kentucky Transportation Cabinet funded a study to develop a constructability lessons learned tool to be used during the design phase to improve project outcomes (Stamatiadis et al., 2012). In contrast, this NCDOT research project incorporates the collection and dissemination of both lessons learned and best practices at each concurrence point during the preconstruction phase, execution phase (considering detailed design and construction), and maintenance and operations, thereby essentially covering all aspects of a project's lifecycle. North Carolina State University (NCSU) researchers have helped create the user-friendly CLEAR database to gather, record, and communicate the lessons learned and best practices. The database is sortable by major trends, such as keywords and/or by division, region, county, cost/schedule impacts, project type, and project phase, for the various groups within the NCDOT.

This report also presents a preliminary analysis of claims data that pertain to utilities. These data, obtained from the Highway Construction and Materials System (HiCAMS), are for 1994 through 2018. In its initial data gathering stages, the NCSU research team observed a frequent trend with regard to utilities claims and found from data analysis that one in every five projects is impacted by utility issues-related claims that delay the schedule by about 70 days and increase project costs by about two percent. In addition, the quality of input within HiCAMS must ensure that missing/unknown cases are addressed appropriately for better data analysis in the future. This analysis of utility claims should help the NCDOT identify avenues for improvement and generate a customized list of best management practices to handle such issues.

The success of the CLEAR program is heavily reliant on its end-users. Therefore, end-users' willingness to participate in this program and enter relevant knowledge gained at project sites is imperative. To this end, the NCSU research team developed a survey instrument to help determine the training needs and requirements of NCDOT personnel and to develop training materials that would provide the most meaningful impact and encourage participation in the CLEAR program. Based on the survey results, the research team developed training materials in the form of short videos using commercially available video-making software, VideoScribe. In addition to the video materials, the research team also prepared standard operating procedures (SOPs) for the various stakeholders in this program, i.e., end-users, the gatekeeper, and the

Expert Review Panel. These SOPs are intended to serve as a guide for entering information into the appropriate forms and searching for lessons learned/best practices based on relevant search criteria, and for the experts to review entered information.

To ensure CLEAR's proper functioning and maximum reach for NCDOT personnel, this research utilized cutting edge concepts of artificial intelligence (AI) and data visualization to encourage the process of knowledge sharing. A data dashboard tailored for the gatekeeper will provide effective means to monitor progress that relates to predetermined metrics. In addition, the data dashboard will serve as a success metric for the CLEAR program by monitoring entries based on factors such as the status of implementation of various lessons and best practices, Innovation Culture Index survey data to assess end-users' ability to innovate, and website analytics data. An AI-enabled set of algorithms will help provide useful insights about the text that is entered into the knowledge repository by effectively disseminating information, thus allowing the utilization of wisdom within the knowledge repository to be a proactive process.

The final research products are (1) a comprehensive lessons learned/best practice resource repository that can be used to improve performance for future NCDOT projects, (2) a data dashboard to enable the gatekeeper to monitor the progress of the end-users and intervene when necessary, and (3) an AI-based model to disseminate information to end-users automatically. The NCSU research team will provide these products to the NCDOT Value Management Office in conjunction with a presentation that includes demonstration of the dashboard and AI model to ensure that these products are in line with increased end-user participation in the CLEAR program. The dashboard and AI model are envisioned to provide useful insights and automatically disseminate relevant information that is best suited to stakeholders' needs. The NCDOT will greatly benefit from the CLEAR program and database as well as from applications of the data analysis-enabled products, thereby improving project management and operational performance for the long term.

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List of Definitions Related to CLEAR (Communicate Lessons, Exchange Advice, Record) Program

Accepted: A lesson learned or best practice submission that has been reviewed by an expert and, with the expert opinion applied, has been placed on the 'Accepted Submissions' list on the CLEAR SharePoint homepage for reference or next steps.

Applicable discipline: Areas of work within the North Carolina Department of Transportation (NCDOT), such as Construction, Erosion Control, Geotech, Hydraulics, etc. The applicable discipline has a specialized person or group to evaluate and review the submission. This person or group is different from the person or group who would benefit from learning from the submission. The applicable discipline selected should reflect the person or group whose expertise is required to vet the submission. The applicable discipline also can be selected by the gatekeeper. See the list of Applicable Disciplines posted on the CLEAR homepage for a description of each.

Artificial intelligence: A computational tool to support human tasks, such as searching for relevant lessons learned and best practices in the CLEAR program.

Best practice: Methods or techniques that have been found to be the most effective and practical means to achieve an objective while making optimal use of the State's resources.

Dashboard: A data-driven tool that offers a promising way to disseminate, understand, and interpret datasets quickly by facilitating evidence-driven decision-making through increased access to information.

Expert Review Panel (ERP): Experts in domains within the NCDOT who have extensive knowledge within their area of work. Whereas the CLEAR taskforce consists of experts who cover all areas of work, the ERP is selected by the gatekeeper from this pool of experts and consists of those who can offer the most relevance and expertise to the entered lesson.

Gatekeeper: The person/team that is responsible for reviewing submissions, communicating with appropriate ERP members about the submissions, and facilitating the inclusion of valid lessons learned/best practices in the CLEAR database. The Value Management Office team at the NCDOT will act as the gatekeeper for the CLEAR database.

Idea: A creative thought that can help improve processes and bring about change in routine work practices.

Innovation: The introduction of ideas, methods, devices, or emerging technologies that are new to the operations of an agency. For state DOTs, these innovations could involve the introduction of new processes, materials, methods, technologies, and/or tools to improve results and outcomes. These innovations may be entirely new and require validation and testing, or they may already have been tested or proven at other agencies or in another business unit within the agency and are ready for adoption.

Innovation Coordinator: A person who is highly motivated in encouraging his or her unit or office to participate in the CLEAR program, thereby supporting innovation.

Lean Six Sigma: A proven methodology to drive outstanding business performance by improving processes and enhancing customer value through systemically eliminating waste.

Lessons learned: The knowledge gained from one's own project experiences as well as experiences of others (Project Management Institute, 2004).

Location: Description of where the relevant issue/lesson learned/best practice took place. Possible examples could be 1 South Wilmington St., Raleigh, or Western Blvd. at Gorman St., or the mile marker in the project (if applicable), etc.

Next steps: Future course of action that possibly could bring about procedural, policy, or organizational changes within the NCDOT.

Office: The submitter's office or unit within the NCDOT.

Project: The NCDOT project in the Construction or Maintenance Division.

Rejected: A submission or lesson learned that was incomplete and the submitter did not accept or respond to the Request for Information, or the submission was deemed unsuitable for the CLEAR database**.**

Subject Matter Expert (SME): Former name for an ERP member. Some historical data may use 'SME'.

Solution Needed: Information that is solicited about how to solve problems encountered on projects and in routine work practices.

Submitter: An NCDOT employee who is willing to share lessons learned/best practices or requests a solution to a problem as part of his/her assigned tasks.

Technical Advisory Group (TAG): A group of ERP members who focus on specific topics and collectively review submissions through the NCDOT and establish goals for collecting or soliciting solutions.

Technical Coordination Committee (TCC): A group composed of upper management, multidisciplinary and multi-modal representatives, and external partners that provides guidance and reviews from a high-level/industry perspective.

1. INTRODUCTION

The need to document and institutionalize firsthand knowledge gained by construction personnel has expanded over the past several decades. The construction industry is a knowledge-based industry that relies heavily on knowledge input by various participants within a project team environment (Carrillo & Anumba, 2002). Construction project management involves coordinating teams from all phases of the project's lifecycle (i.e., planning, design, construction, and maintenance). Despite taking sound precautions, external uncontrolled factors, such as utility coordination, right-of-way acquisition, project funding, and interagency communication, can lead to delays and claims (Plotch, 2015). In fact, one in three capital projects risks being delayed, over-budget, and/or fails to achieve its profit objective (Anderson & Tucker, 1994). One of the primary reasons that organizations repeat their past mistakes is failure to document experiential knowledge (Anderson & Tucker, 1994). As a remedy, lessons learned can serve as a valuable resource for planning and design teams to help identify potential problems in advance and thus to be proactive in mitigating possible schedule and cost overrun issues.

Lessons learned is one of the 17 best practices recognized by the Construction Industry Institute (CII) for enhanced project performance. The CII report on lessons learned (Gibson et al. 2008) is an invaluable resource in the field of knowledge management. It highlights the three main phases of a lessons learned exercise as collection, analysis, and implementation. The CII report also notes that, in any organizational structure, knowing the information to document and where to document it can impact the effectiveness of a designed lessons learned tool. Therefore, lessons learned databases are an effective means to record and retrieve appropriate information to apprise users about past experiences, both good and bad. Establishing the right culture and upper management support is also essential to establishing a successful lessons learned program. Most organizations have now started to realize the full potential of a lessons learned program within their organizations.

The Value Management Office at the North Carolina Department of Transportation (NCDOT) performed a study in 2014 as an initial step towards building a lessons learned database. The intent of this exercise was to create a meaningful interface between preconstruction units and field personnel and to document useful information about previous projects to act as a reference for future project planning. The study was referred to originally as the Post Construction Assessment Program (PCAP) because its primary aim at that time was to capture information about issues that arose post-construction as well as from pre-construction phases such as planning and design. As part of the PCAP, NCDOT personnel across various divisions were asked to provide their input about the concept of a unique database that would serve as a knowledge repository of information about previous projects. The identified need was to have a simple yet robust tool that could be used for gathering data, indexing the data correctly, and retrieving the most relevant files based on key search terms and phrases.

For this research project, the North Carolina State University (NCSU) research team sought to develop a new robust tool to institutionalize construction project knowledge for the NCDOT in consultation with the North Carolina Department of Information Technology (NC DIT). This report describes the effort to assist in the design and implementation of a lessons learned/best practices database named CLEAR (Communicate Lessons, Exchange Advice, Record) for the

NCDOT. CLEAR is a Connect NCDOT SharePoint-based internal-only database that is intended for use mainly by personnel who are associated with any project phase within the NCDOT. Personnel from various project phases can now record information related to issues (both good and bad) that emerged during a particular project and avoid repeating mistakes. As an example of the need for such a database, during the data gathering phase of this project, the NCSU research team learned that no formal process was available for the design team to know if any issues or problems related to their designs had arisen during construction or whether any delays had occurred and/or additional monies were involved. The CLEAR program and database (referred to simply as CLEAR in this report) are intended to communicate experiences among personnel so that successes and failures can be shared, recorded, and hopefully addressed (Fullerton, Tamer, Banerjee, Alsharef, & Jaselskis, 2021).

The research approach used here is to utilize the rich knowledge and experiences of NCDOT personnel that can be harnessed effectively in the form of an efficient lessons learned tool (Hansen, Nohria, & Tierney, 1999). The concept that underlies CLEAR is to improve coordination among all divisions and units and act as a knowledge repository, best practices guide, and readiness indicator for future projects. The lessons learned database is intended to be used by personnel from all 14 highways divisions throughout North Carolina as well as the central units. CLEAR thus provides a platform for interagency communication and for personnel to revisit past experiences that are rich in data. The NCSU research team employed a Six Sigma approach to accomplish this goal.

Figure 1 presents a chart that can be found on the NCDOT's Value Management Office website that succinctly explains CLEAR to NCDOT personnel (Fullerton C. E., 2020). As shown, CLEAR aims to collect lessons learned and best management practices from NCDOT personnel and share that information with others. These lessons learned and practices are vetted by an Expert Review Panel (ERP) that is composed of NCDOT personnel who are leaders in their respective fields and have the ability to inform and make policy changes relevant to their units or offices. To initiate a submission of a lesson learned or best practice, an NCDOT employee would go to the Connect NCDOT CLEAR SharePoint site and fill out the necessary and relevant information online. The program can autofill some project information, and attachments such as photos or documents can be included in the submission. Once the information is complete, the submission goes to the gatekeeper in the Value Management Office. The gatekeeper reviews the submission to ensure that it is complete and relevant and then forwards the submission to the ERP for thorough review and vetting. Once the lessons learned/best practice is approved, the ERP populates the database. The database is searchable by keywords and other functions, such as filtering by county, division, project type, etc. CLEAR aims to create feedback loops within the department for all project phases, disciplines, units, offices, and locations. This program also is expected to bring organizational changes to improve processes within the NCDOT. The NCDOT will greatly benefit from this knowledge repository, thereby aiding in achieving better project performance.

Figure 1. CLEAR: 'What You Need to Know' *(Fullerton C. E., 2020)*.

The NCSU research team used cutting-edge technological tools to develop a data dashboard that enables stakeholders to utilize information in the CLEAR repository to the fullest extent possible. This dashboard, developed in Tableau, serves to enhance CLEAR's existing functionalities by helping the gatekeeper keep track of (1) the lessons learned and best practices entries in terms of their implementation path towards innovation and (2) the most impactful entries based on predefined categories that relate to CLEAR's return-on-investment. The dashboard presents visualizations of the Innovation Culture Index (ICI) survey data that are indicative of the internal innovation motivation levels by the NCDOT personnel. The dashboard also provides pertinent visuals of CLEAR website analytics to allow the gatekeeper to understand end-user usage based on factors such as location of access, time of access, and ranked order of webpages visited. A sample of these visualizations is presented within the 'Data Dashboard' section later in this report. In addition, Appendix P provides a detailed step-by-step guide to prepare these visualizations in Tableau.

2. LITERATURE REVIEW

2.1. Previous Work Regarding Lessons Learned at Other Organizations and Departments of Transportation

Numerous organizations have benefited from lessons learned tools and programs in order to tap past experiences and make informed decisions. For example, the National Aeronautics and Space Administration has both a public lessons learned system as well as an internal lessons learned system. The United States Army's Construction Engineering Research Laboratories uses

DrChecks, which utilizes client-server architecture for online comment sharing among various parties for discussions that pertain to design documents. In addition, the "CROSS-US [Confidential Reporting on Structural Safety – United States] is a confidential reporting system to capture and share lessons learned from structural safety issues which might not otherwise have had public recognition, with the aim of preventing future failures" (CROSS-US, 2020). The CROSS-US database is open-access to the public and includes a search feature that is based on a construction taxonomy that has not been shared hitherto as public knowledge. Additionally, recent research has found lessons learned to be an effective means in recording and storing knowledge while dealing with complex regulatory landscapes (Rasoulkhani, et al., 2020). Organizations can make use of past knowledge to avoid repeating mistakes to tackle the harsh regulatory environments.

With regard to transportation organizations, the Indiana Department of Transportation (INDOT) was an early adopter of a lessons learned database. McCullouch and Patty (1994), researchers at Purdue University, conducted a series of interviews with INDOT personnel to improve coordination between the design and construction teams, with the ultimate aim to achieve a better constructability review program. To this end, the Purdue team developed a windows-based constructability lessons learned software application, called Folio Views, using Visual Basic. Folio Views contains constructability lessons learned in text form and is used to store, index, and retrieve the lessons (McCullouch and Patty, 1994).

The Kentucky Transportation Center at the University of Kentucky conducted similar research to develop a web-based lessons learned database that could accept files both in text format and image format. Goodrum et al. (2003) surveyed resident engineers, contractors, and consultants to obtain an initial understanding of their vision of a perfect lessons learned database. Each user associated with the database was classified into one of three categories, i.e., end user, gatekeeper, or administrator, with each of the functions of these three roles clearly stated. The database was structured in two parts, one for users to enter new lessons learned and the other for storing and retrieving cleaned-up lessons. MS Access was implemented for data storage and retrieval and MS FrontPage was used to accept lessons learned input from users. The database also had provisions to search for specific terms within the database fields to yield specific results that would be helpful for design teams during a constructability review. However, this effort did not fulfill its intended purpose, as the lessons learned database became defunct once its 2,000-row limit was reached. The main failure to ensure proper functioning of this database was caused by not mitigating the risk of running out of space beyond the permissible 2,000-row limit.

Fong and Yip (2006) assessed the level of readiness of construction professionals in Hong Kong to implement lessons learned systems within their organizations. One of their key research findings was that construction personnel preferred not to record lessons learned while a project was ongoing, which could lead to the loss of important knowledge.

Retaining existing personnel and training new personnel have been challenging issues that most US DOTs have faced on a regular basis for several decades. For example, between 1992 and 2003, the Virginia Department of Transportation (VDOT) witnessed the departure of over 30% of its personnel, many of whom had more than 30 years of experience, which led to an increased loss of experiential knowledge (Clark & Hammer, 2008). As a result, VDOT created its

Knowledge Management (KM) division in 2003 to help retain knowledge and maintain the work culture despite organizational changes in complex environments. The KM division also was in charge of facilitating a smooth transition for VDOT personnel to find the right balance between the bureaucratic way of doing things (what worked well in the past) and a more business-oriented approach (focused on time and monetary savings).

In April 2007, VDOT implemented an agency-wide construction lessons learned initiative, Communities of Practice (CoPs), to capture lessons from previous experiences to bring about changes in processes, procedures, and contract language. VDOT commissioned CoPs as a primary tool to encourage knowledge sharing and to create networks among individuals and across silos throughout the agency. A CoP is a group of people "who share a concern, set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger, McDermott, & Snyder, 2002). VDOT's CoPs were teams of at most 15 people from varied backgrounds in terms of work expertise and geographic location. These teams convened on a schedule that was suitable for all team members, including the KM division team member, to share experiences about successes and failures and identify opportunities to improve workflow processes. The meeting notes, decisions, and actions were documented on a team website that was designated for common documents within the agency's portal. The CoPs acted as a link between personnel and upper management to articulate information to be used for reviewing and amending policy. Although this VDOT CoP effort is no longer active, it nonetheless can provide useful insights into developing strategies for effective knowledge retention within an organization.

More recently, other transportation organizations and DOTs also have developed knowledge repositories in the form of databases. For example, the Kentucky Transportation Cabinet funded a study to develop a constructability lessons learned tool for use during the design phase to improve project outcomes (Stamatiadis, Goodrum, Shocklee, Sturgill, & Wang, 2013). Also, the Federal Highway Administration (FHWA) has compiled a list of lessons learned from various transportation-related projects from DOTs throughout the United States (FHWA, 2018). This database is open-access to the public and contains lessons learned in text format from various projects as well as project phases. The USDOT has a lessons learned database for its Intelligent Transportation Systems (ITS) called ITS Lessons Learned Knowledge Resource (LLKR) (ITS Joint Program Office, 2020). The LLKR database captures knowledge from users who are involved in planning, deployment, operations, maintenance, and evaluation of ITS throughout the United States. This database is heavily reliant on gathering information from other related databases, such as ITS case studies, the ITS Electronic Document Library, the Transportation Research Board (TRB) Transportation Research Information Services, international transportation literature databases, and TRB conference proceedings. The LLKR is open-access to the public and can be searched for lessons learned using keywords or by filtering based on location and/or categories.

The Colorado DOT (CDOT) created a program called Lean Everyday Ideas to encourage users to upload innovative suggestions and adopt practices to improve existing methodologies by clicking on 'I suggest!' and 'I fixed it!', respectively. Although this database accepts information entry by authorized personnel only, the public has open access to Idea Cards that provide details about a few select innovations and how their use has helped CDOT to improve its workflow processes.

The Lean Everyday Ideas database was developed primarily using Google products, such as Google sheets and slides (CDOT, 2018).

2.2. Lessons Learned from Previous Lessons Learned Database Designs

Goodrum et al. (2003) devised a list of suggestions for successfully designing and implementing a lessons learned database, as follows.

1. Lessons learned systems require a champion. A champion should be assigned to promote and manage the system. The champion should be experienced and capable of dedicating resources when needed. Other characteristics of a champion include that he/she:
    a) Is knowledgeable about organizational work processes.
    b) Is visible at the management level of the training and orientation of the lessons learned system.
    c) Can establish accountability and authority.
    d) Has exceptional people and communication skills.
    e) Is respected in the organization for fairness and impartiality.
2. A submitter's input into a lessons learned system must be recognized. Recognition needs to be given to the submitter in the form of either a letter or email within ten days of receipt of a lesson learned.
3. Lessons learned systems should not be used to criticize mistakes.
4. Lessons learned systems should be designed for simplicity.
5. The most significant factors for the success of lessons learned systems are:
    a) Quantity of the stored lessons learned.
    b) Quality of the stored lessons learned.
    c) Diversity of the lessons learned.
    d) Availability of resources that are required to maintain and update the system.
6. The most common deficiencies of lessons learned systems include that they are:
    a) Too expensive to maintain.
    b) Too complex to be used effectively.
    c) Dependent on required skills that are beyond those available within the organization to operate and maintain.

Most of the above points were validated by a research survey conducted by Knoco, Ltd. (Knoco, 2009) whose aim was to ascertain the degree of usefulness of existing lessons learned systems within organizations. Knoco, Ltd. prepared an online questionnaire and received from organizations 74 responses that represented a wide range of functionalities. The respondents reported success factors and barriers to implementing an ideal lessons learned database, and the responses seemed to concur with the points in Goodrum et al.'s (2003) list of suggestions. The barriers were classified into the following categories: senior management, culture within the organization, lack of follow-through and application, time issues, and other barriers. Figure 2 presents the results of the survey conducted by Knoco, Ltd. where respondents were asked to indicate whether or not they implemented certain components in their lessons learned database. Few respondents stated that they rewarded/incentivized submission of lessons learned. Another significant finding from the Knoco, Ltd. study is that encouragement from senior management in

the form of nominal awards can encourage people to enter lessons learned in a positive manner and thus aid in achieving a more effective lessons learned database.

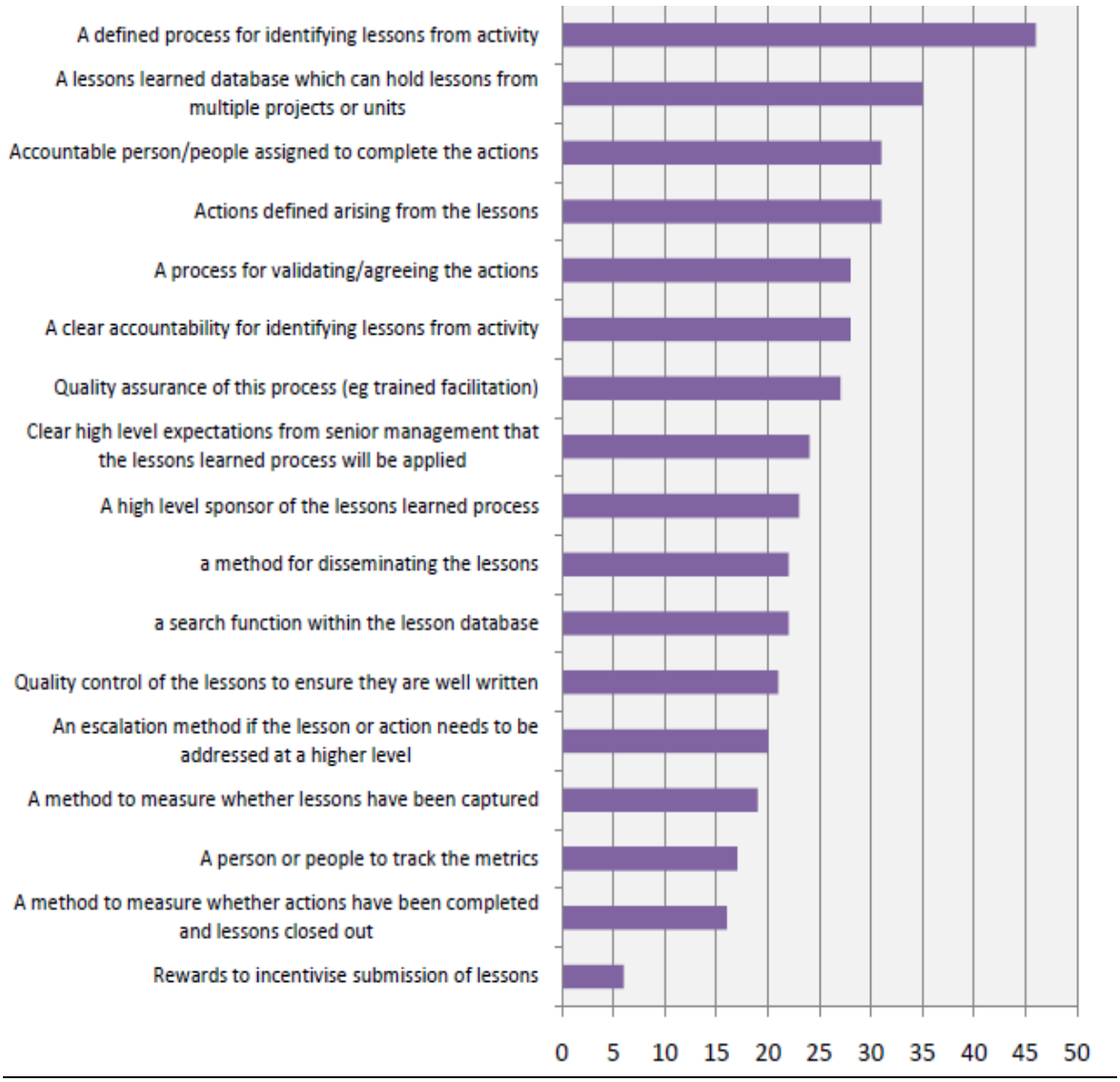

Figure 2. Preferred lessons learned components (Knoco, 2009).

3. METHODOLOGY

3.1. Introduction

The initial background study that the NCDOT's Value Management Office conducted in 2014 identified the need for a formal medium to communicate information about projects within the NCDOT. The results indicated the lack of a medium to store knowledge that was gained on project sites and led to the creation of the PCAP in 2017, which in turn led to NCSU researchers being contracted to help develop a new lessons learned database for the NCDOT. During the

ongoing research efforts, the PCAP was renamed CLEAR in 2018 because the CLEAR database was intended to ensure that content was captured from all project phases and not just the post-construction period as initially envisioned. The NCSU research team consulted the literature that focused on earlier lessons learned databases to ensure that CLEAR was user-friendly in order to ensure its longevity. The research team also took precautions to avoid the snags that had been experienced in earlier research efforts. To this end, the NCSU researchers employed a Design for Six Sigma (DFSS) approach to design and create the new and robust lessons learned database. The five stages of the DFSS methodology, i.e., identify, define, develop, optimize, and verify (IDDOV), form the basis of the final research outcomes (Banerjee, Jaselskis, & Alsharef, 2020).

3.2. Design for Six Sigma (DFSS)

The DFSS methodology is a systematic and disciplined problem prevention approach that is widely used to design robust engineering systems. Many models in addition to the IDDOV model utilize DFSS for generic technology development and include I^2DOV (invent, innovate, develop, optimize, verify), CDOV (concept, design, optimize, verify), and DMADV (define, measure, analyze, design and verify), to name a few. Although these models have their own benefits and drawbacks, the NCSU research team decided to utilize the concepts of the closed-loop IDDOV model that starts and ends with customers (or end-users in the case of CLEAR). The research team first explored various other models and then selected the IDDOV model, which appeared to be the most suitable of the various DFSS options, to design and build an error-free robust lessons learned database. In fact, the COVID-19 pandemic situation has caused huge levels of uncertainty affecting workflow processes (Alsharef, Banerjee, Uddin, Albert, & Jaselskis, 2021); thus the final product needed to be resilient against such future impacts as well. Figure 3 shows the five steps of the IDDOV model as applied to the CLEAR database. The following subsections provide brief descriptions of the five components of the selected DFSS IDDOV model.

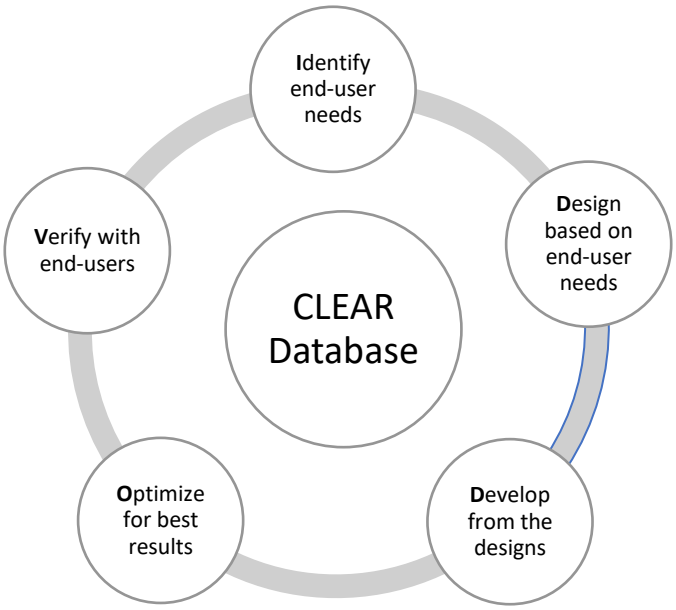

Figure 3. Design for Six Sigma model approach applied to CLEAR database.

Identify end-user needs.
The first phase of the development of the CLEAR database involved gathering end-user needs from NCDOT personnel and understanding the features that they envisaged as being incorporated into an ideal lessons learned database. The focus was to learn the current practices of sharing lessons learned and to obtain detailed information about the end-users' needs. For this purpose, the NCSU research team created an interview guide to obtain responses regarding current needs. The questions were classified into three categories: basic respondent information, current practices, and database requirements. Appendix A presents this interview guide.

Design the database based on end-user needs.
The NCSU research team performed simple qualitative analysis of the respondents' inputs, including frequently recurring trends/keywords and content analysis, to extract the most relevant information. In addition, the team prepared a risk sheet that listed possible caveats that the end-users anticipated for the CLEAR database. Based on these inputs, the research team devised three initial segments of user input for the lessons learned database: (1) a description of existing conditions, (2) lessons learned or best management practices, and (3) project information. Appendix B presents these database fields that are based on the preliminary inputs received from the respondents.

Develop the database from designs.
The final database designs were submitted to the NC DIT for database development. The CLEAR database is housed within the Connect NCDOT portal and uses SharePoint to display the lessons learned entry form and uses MS Access database as its backend. The Connect NCDOT portal covers a wide array of products used by NCDOT personnel for their daily work and hence was the natural choice to host the lessons learned database.

Optimize the database for best results.

The Value Management Office identified a select group of experts within each applicable discipline based on their NCDOT experience as well as their knowledge about addressing issues within these disciplines. These experts, also known as taskforce members, were trained both in person and via video calls to use the CLEAR database. Their feedback, including whether they felt that any features were missing and hindered the ability to record lessons learned, served both to validate the database design and development and to glean their opinions. With regard to space constraints within the database, the lessons learned should be able to be archived in an ever-expanding repository for the future. Such data would pertain primarily to obsolete technologies, implemented organizational changes, or other suitable topics determined by the taskforce.

Verify with end-users for completeness.

The final phase of the IDDOV cycle is the end-users testing the database and informing the research team about any possible modifications or additions that are needed. The Value Management Office conducted a risk assessment study of the CLEAR program to determine any potential risks and appropriate mitigation measures. The CLEAR lessons learned/best practices database was rolled out first as a pilot program to a select group of NCDOT units and divisions before expanding its reach to the entire organization in March 2020. The Value Management Office is the gatekeeper of this database and is responsible for ensuring the completeness and quality of submitted lessons learned/best practices and for the final uploading of these lessons learned into the database.

4. FINDINGS

The following Sections 4.1 through 4.5 provide insights into the findings obtained using the five-stage IDDOV approach described in Section 3. These five sections respectively pertain to ways that each of the five stages of the IDDOV approach tie in with the CLEAR program and the findings at each stage.

4.1. Identify End-User Needs: Identifying Trends and Database Fields

The first stage of the IDDOV model was to identify the end-user needs. The NCDOT Value Management Office provided contact information for potential interview respondents to the NCSU research team. The research team then sent interview requests to 66 potential respondents at the NCDOT. During this phase of information gathering, the NCSU researchers conducted 32 interviews with 46 personnel who had a total of 813 years of work experience. Figures 4 and 5 present details regarding the interview process by project phase and personnel designation, respectively. The NCSU team conducted the interviews both in person and by phone with personnel from multiple project phases, such as preconstruction, design (e.g., safety and structures), construction, and maintenance. The team also interviewed NCDOT personnel in the areas of materials, design-build, and facilities management. In addition to being in various project phases and areas, the respondents belonged to multiple categories of levels of work, starting as high as the state-level engineer to assistant resident engineers. This variety of the NCDOT workforce afforded the research team opportunities to explore diverse perspectives from within the NCDOT. Overall, this interview process helped the research team to obtain in-depth feedback about extant processes of information exchange and to determine the fields to include in the new lessons learned database.

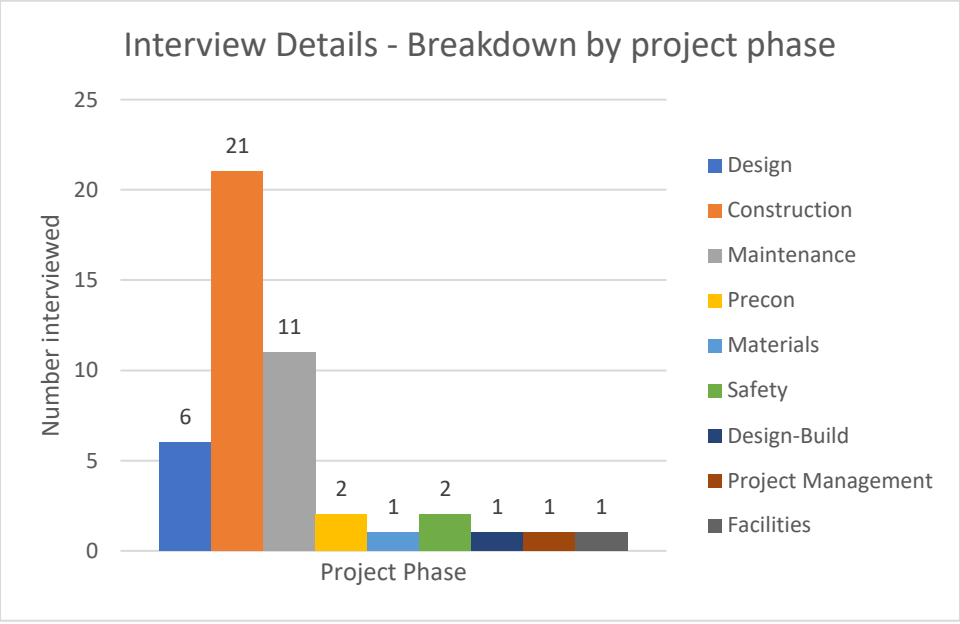

Figure 4. Interview details by project phase.

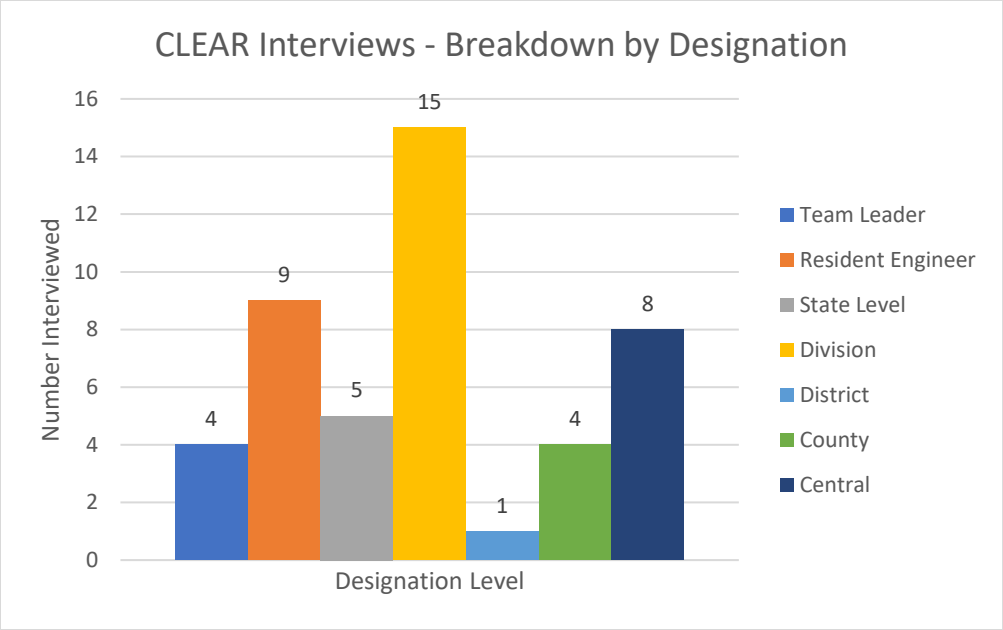

Figure 5. Respondent details by personnel designation.

The NCSU research team carefully documented the inputs from these interviews so not to miss any important piece of information. For each interview, the research team prepared at least two sets of notes and entered the information into a MS Word file for each interview, whether obtained in person or by phone. Following each interview, the notes from all the research team members were combined to prepare a comprehensive list of responses. By the end of this phase, the research team had gained a good sense of current organizational practices to communicate lessons learned within the NCDOT and had determined the proper direction to proceed with designing the lessons learned database fields. Based on the interview responses, the research team considered several points for designing the database, as presented in Section 4.1.1.

4.1.1. Database Design Considerations

- Software
    - Microsoft Access is well known but respondents had concerns that it might not function very well as the size of the database increases.
    - The database needs the capability to populate fields using data from other sources (to mitigate the double entry of data).
- Structure

In general, respondents liked the fields in the preliminary database, e.g., description of existing conditions, lessons learned/best practice, reference, project name, project number, contract number, project size, etc. Suggestions for improvements included:

- Add an impact or severity rating for each lessons learned/best practice.
- Identify the beneficiary(ies) of the lessons learned/best practice.
- Use keywords found in *Roadway Standard Drawings, Specifications, and Special Provisions*, e.g., earthworks, pipe culverts, contract time, liquidated damages, etc.

    - Design a short version rather than detailed descriptions because users will know where to go for more information.
    - Include links to standard NCDOT documents, e.g., specifications, design details, contract documents, claims, and supplemental agreements, to make it easier for users to find this information.
    - Provide the name of the unit for additional inquiries rather than the name of a contact person.
    - Provide photos or links to photos.
- Data Entry
    - For larger and longer duration projects, lessons learned should be entered during the construction phase. For smaller projects, lessons learned can be entered at the end of the project.
    - Try to make the amount of time for data entry less than five minutes, as entering data should not be a large time commitment.
    - Avoid having to enter the same data twice.
    - Use drop-down menus as much as possible to reduce the amount of manual data entry.
    - Populate certain fields automatically from other sources, e.g., the Highway Construction and Materials System (HiCAMS), where possible.
    - Start by entering the more impactful lessons learned, e.g., ones that resulted in claims and supplemental agreements.
- Search Capability
    - Provide a keyword search capability that is similar to Google searches. The current NCDOT search capability could be improved.

4.1.2. General Observations

The 'identify' stage of the Six Sigma IDDOV approach led to the following general observations:

- The current approach to sharing lessons learned/best practices from one project to another is informal (word of mouth).
- Groups tend to be in silos in that they do not communicate with those outside their division.
- The NCDOT has experienced significant turnover in all departments. A new database could help serve as a training resource for new staff.
- Better project coordination is needed. Maintenance should apprise the design team of problems faced so that such issues can be addressed during the design phase.

4.2. Design Based on End-User Needs: Database Design

The second stage of the IDDOV model was to prepare the database designs based on the end-user needs identified in the earlier stage. The initial version of the developed CLEAR database had a single lessons learned/best practices form that was based on inputs gathered during the first phase and was divided into three segments (see Appendix B). The first segment recorded basic user information such as name and division and office information including email and telephone number. This information was not intended to be displayed while showing the lesson learned in appropriate search results, but was intended only for the gatekeeper (defined in Section 5.2.1) to be able to contact the end-user in case any missing/additional information was needed. The second segment was designed to input information about the issue and solution that were entered. Users could include attachments such as pictures, PDFs, revised contract language, and other relevant files to make it contextually easy to understand. The third segment recorded project information that pertained to the lesson learned or best practice. A few fields in this segment were intended to be populated from other internally linked databases to expedite data entry and encourage participation. Based on the Value Management Office's input and other studies, such as a risk assessment study (described in Section 4.5), this initial common form for lessons learned/best practices served as the basis for the current three forms for lessons learned, best practices, and solutions needed.

4.2.1. Principal Stakeholders

The principal stakeholders involved with the CLEAR database are as follows:

End-users: End-users are NCDOT personnel who are responsible for entering useful lessons learned and best practices based on knowledge gained at project sites. They also are responsible for searching for relevant knowledge to understand previous circumstances in order to avoid repetition of problems.
Gatekeeper: The Value Management Office at the NCDOT serves as the gatekeeper for CLEAR and is responsible for checking for completeness of the submissions, forwarding the submissions to taskforce members, and subsequently approving the submissions after receiving the go-ahead from taskforce members.
Taskforce: The taskforce is composed of experts within various disciplines who are responsible for ensuring the quality of the content that is uploaded to the database. Based on its review of each submission, the taskforce will inform the gatekeeper of its decision to accept or reject the submission. Note that, whereas the taskforce consists of experts who cover all disciplines of work, the ERP is selected by the gatekeeper from this pool of experts as those who can offer the most relevance and expertise for submission.
Innovation Coordinators: These coordinators are highly motivated personnel who encourage their units or offices to participate in the CLEAR program, thereby supporting innovation.
Technical Advisory Group (TAG): The TAG is composed of taskforce/ERP members who focus on specific topics or areas and collectively review lessons learned/best practices submissions and establish goals for solutions.
Technical Coordination Committee (TCC): The TCC is composed of upper management, multi-disciplinary and multi-modal representatives, and external partners who provide guidance and

review from a high-level/industry perspective.

4.2.2. CLEAR Workflow

Figure 6 presents the basic steps followed in the CLEAR system for entering lessons learned/best practices. Once an NCDOT employee submits an entry, the gatekeeper checks for completeness of the data and forwards the submission to the appropriate ERP/taskforce member. The taskforce member then decides to accept, reject, or solicit additional relevant information regarding the entry. The stakeholders are kept informed at each pertinent stage by email so that they can keep track of the submission. One of the end-goals of the CLEAR program is to encourage organizational innovation among all units and divisions. Thus, the TAG and TCC make every effort to ensure that the lessons learned/best practices are converted into implementable innovations throughout the department. Figure 7 provides details regarding the CLEAR workflow in terms of the roles of the submitter (of the lesson learned/best practice), the gatekeeper, and the ERP (taskforce).

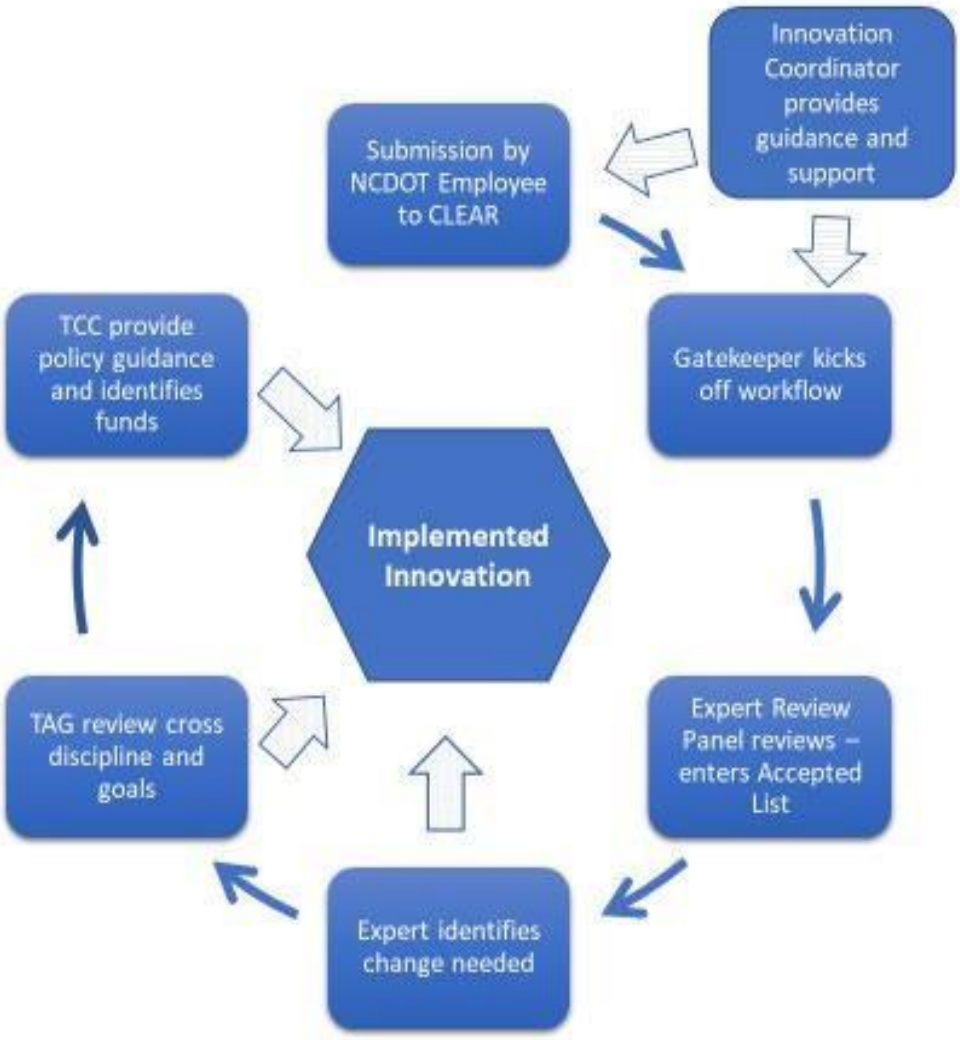

Figure 6. CLEAR steps for a lesson learned/best practice.

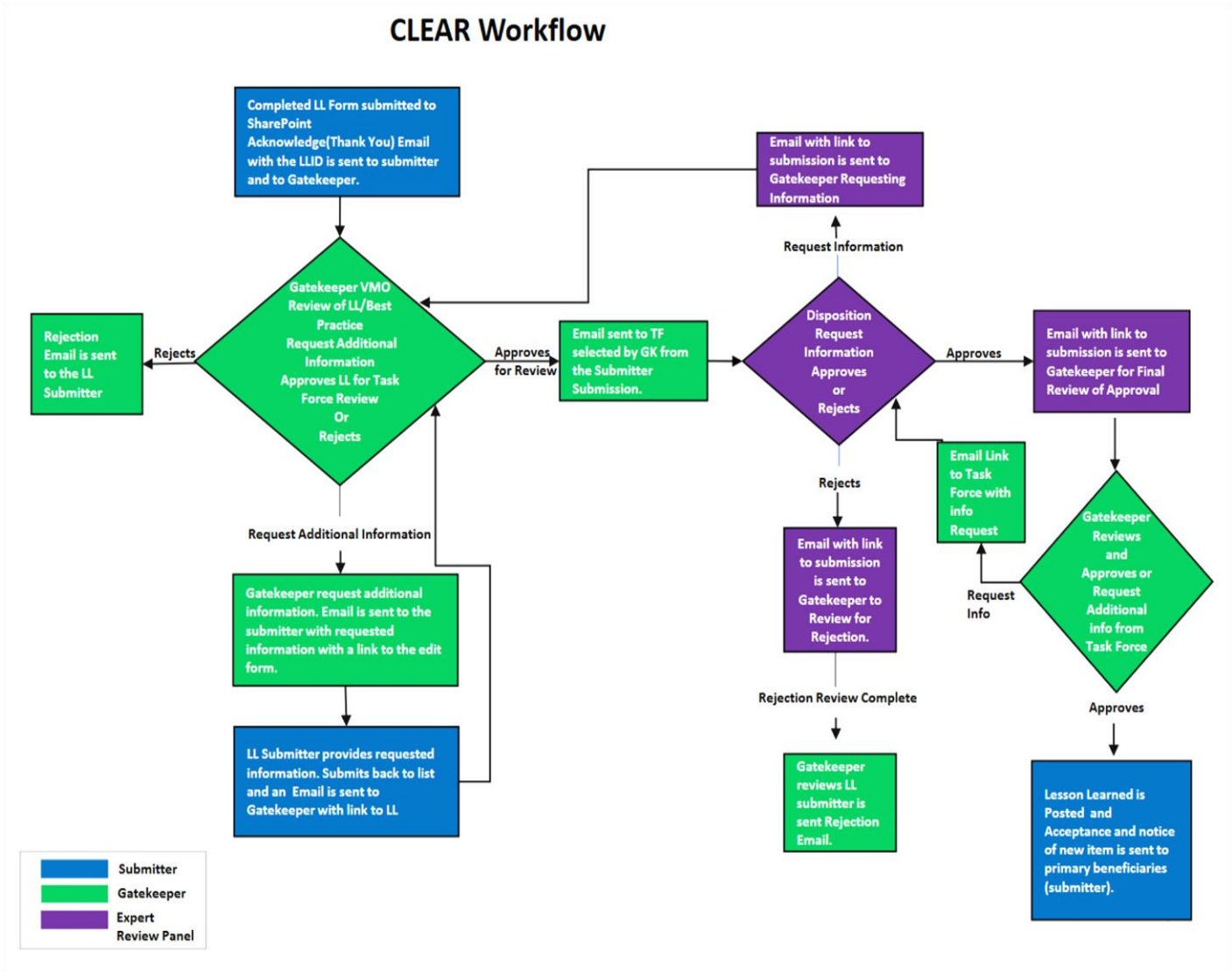

Figure 7. CLEAR workflow process.

4.3. Develop from the Design: Database Development and Respondent Feedback

Once the database designs were finalized, the third stage of the IDDOV model was to develop the database from those designs. In the initial effort, the NCSU research team gathered 42 lessons learned and best practices from 19 end-users as well as from two pilot projects. To build the lessons learned repository, the research team contacted NCDOT personnel who had participated during the data gathering phase. The 19 respondents provided their lessons learned/best practices by phone. In addition to gathering these phone data, the research team visited two pilot projects and gathered lessons learned and best practices by observing the project work and talking with site personnel. The two pilot projects were the East-end Connector project in Durham, NC and Pitt County's Resident Engineers office in Division 2. The effort to solicit as many high-quality lessons learned as possible from end-users, such as site engineers, inspectors, resident engineers, and other project personnel, is ongoing whereby users can enter information in the CLEAR database within the Connect portal.

4.3.1. General Comments Based on Project Phase

A few general trends emerged based on the project phase, risks associated with a new system, and user incentives extracted from the lessons learned and data gathering phase, as follows.

- **Preconstruction Phase**
    - Planning
        - Changes that take place after design completion and are due to scope creep indicate missing initial goals and give the perception that 'you did not deliver'.
    - Design
        - Drainage
            - Design culverts with above-grade fill that is more than 4 feet (otherwise a thicker top slab is required/grade must be raised).
        - Structures
            - Provide additional clearance to the top set of deck reinforcing bars on heavily skewed bridges to add 'a little more play' with the screed (add half-inch additional clearance).
        - Erosion Control
            - Because the design and field conditions frequently differ (more so on smaller projects), hold more face-to-face meetings and encourage field visits by designers to discuss solutions.
        - Other
            - Provide feedback to designers about how new products perform in the field.
    - Project Management
        - Improve utility (sewer, water, gas, power, communication) relocation process with third-party owners, which is a "constant battle we deal with on every project."
        - Address right-of-way issues prior to construction (timing of access and size of right-of-way).

        - Provide project management training to designers who are given project management responsibilities.

- **Construction Phase**
    - Drainage/Erosion Control
        - Ensure that inspectors perform their duties properly, especially with regard to inspecting washed-out shoulders and ditches (which perhaps were washed away because they were not compacted properly).
        - Allow grass and other vegetation to mature to prevent erosion.
    - Structure
        - Request that NCDOT personnel review current standards and specs to see if NCDOT personnel can be more flexible with contractors, especially with regard to bridge deck pours where contractors prefer to pour more at the same time and the NCDOT wants them to pour less.
    - Paving
        - Address any foreign material found in asphalt (e.g., mud flaps).
        - Provide a better way to predict actual quantities that are needed because, e.g., for bridge rehabilitation projects, often the actual quantities are greater than those specified in the design.
    - Other
        - Request inspectors to provide more detail when writing their diaries.
        - Invite the maintenance engineer to assist with the punch list.
        - Resolve issues found during construction so they do not become a maintenance problem.

- **Post Construction Phase**
    - Erosion
        - Consider extending the shoulder berm gutter to address bridge water runoff issues that lead to excessive slope bank erosion.
    - Structures
        - Address cracking in prestressed bent diaphragm girders made continuous for live loads.
    - Pavement/Subgrade
        - Require resurfacing when subgrade quality is poor.
    - Other
        - Improve continuous quality improvement (CQI) rating approach because:
            - It is subjective (e.g., what is the difference between a 4 and 5 rating?)
            - Resident engineers might be inclined to rate an item above a 6 just to avoid spending time writing a detailed report.
            - Some resident engineers have not completed a CQI assessment for projects before.
            - A binary rating might be better (needs fixing or not).
- **Other**
    - Consultants
        - Require (or consider requiring) consultants to follow an updated checklist (e.g., roadway checklist), because the NCDOT is still having problems with the quality of work performed by some private consulting firms.

        - Address the current problem of not enough consultants to deliver the amount of work required by the NCDOT ("lag in what the industry can provide").
    - Standardization
        - Provide a standard for divisions to follow, because currently each division is managing projects in its own way.
        - Provide a manual (or playbook) for Project Development to follow or a place to go to for answers to questions.
    - Knowledge Management
        - Provide training. Transferring knowledge from one project to another is important. Webinars are a good place to disseminate best practices. Having a lessons learned database is a good idea.
        - Find a better way to track the root cause of problems. The HiCAMS User Manual is good for materials data but not for integrating other data (e.g., from diaries, weather, etc.)
        - Improve communication by "going electronic" (using SharePoint) instead of relying on manual approaches.
        - Alleviate redundant work; e.g., currently, both iPad and HiCAMS data are required to be entered.
        - Provide a mechanism for passing information from construction to design teams to rectify errors.

4.3.2. Risks Associated with Database Creation

- Legal issues
    - Avoid potential increase in liability to the NCDOT for problems (identified by lessons learned) that are not corrected in a timely manner.
    - Be mindful of the types of records that can be made public (as some might be deemed sensitive).
- Willingness to participate
    - Consider that some personnel might not be willing to spend time documenting lessons learned and best practices for their projects.
    - Consider that some personnel might be more likely to provide best practices as opposed to potentially embarrassing lessons learned.
- Technical
    - Address slow performance issues; e.g., Excel files ~10 MB tend to hang up for pay items.
- Quality of lessons learned
    - Heads of units should review each lesson learned to validate its suitability and worthiness for incorporation into the database.
- Avoid creating another software maintenance requirement where additional time is needed to follow up with any software problem, which is typical with new programs.

4.3.3. Participation Incentives

- Obtain upper management support/buy-in and encourage others in the organization to use the database.
- Make the entering/submission of lessons learned and best practices part of employees' annual performance review process.
- Consider focusing initially on lessons learned/best practices that are related to claims and supplemental agreements. Consider including specific questions related to lessons learned and best practices within the HiCAMS manual.

4.4. Optimize for Best Results

The fourth stage of the IDDOV model was to optimize the developed database. CLEAR was envisioned to be "a program to support internal communication, knowledge sharing, creativity, and innovation" (Fullerton C. E., 2020). The success of this program hinges on the end-users' willingness to embrace and enter useful knowledge into the database in the form of lessons learned, best practices, or solutions needed. In order to achieve this goal, the NCSU research team devised a strategy to promote the use of the CLEAR program among NCDOT personnel. This strategy was aimed to develop the best possible ways to encourage participation by incorporating user preferences and possible incentives. With this strategy in mind, The NCSU team developed a survey that was sent to NCDOT employees. The methodology, results, analysis, and recommendations based on this survey are discussed in Sections 4.4.1 through 4.4.4.

4.4.1. Methodology: The CLEAR Program Survey

When designing this survey, the NCSU research team gave priority to minimizing the time needed to complete it. The team created the survey online using Qualtrics and sent a link to NCDOT employees through the Value Management Office. The survey started with an introduction that provided a brief description of the CLEAR program and the goal of the survey, followed by instructions, a confidentiality statement, and a consent to participate statement (see Appendix C). The survey consisted of three sections: (A) the respondent's background information, (B), the respondent's preferences for training method, and (C), the respondent's user preferences. These three sections are described in the following paragraphs.

Section A: Respondent's background

The goal of Section A was to glean a general idea about the respondent in order to link this information to the respondent's preferences later. The NCSU research team discussed the possibility of a multi-faceted strategy where different audiences were targeted by different approaches. Given the high retirement rate at the NCDOT, the research team decided to make the first question of this section about the respondent's age group. Respondents were given five options for a range of birth dates: 1945 and before, 1946 to 1964, 1965 to 1980, 1981 to 1997, and 1998 and after. The second question inquired about the number of years of experience the respondent had with the NCDOT. The third question was about the respondent's current job function. The next three questions were aimed at understanding the respondent's work-hour distribution (jobsite vs. office), types of devices used during work hours (laptop, phones, PCs,

etc.), and how much time the respondent has access to the internet during work hours.

Section B: Training preferences
The goal of Section B was to determine the NCDOT employee's preferences for ways to learn about new technologies, applications, and services. In the first question, the respondent was given five options and asked to rate them on a scale from 1 (least favorable) to 5 (most favorable). A write-in option also was available for this question. The options were devised based on a review of common training solutions and were checked with the NCDOT Value Management Office for approval. The next three questions focused on the characteristics of videos that might be used to train employees to use the CLEAR program.

Section C: User incentives
The goal of Section C was to discover possible ways to create incentives and motivations for the employees to contribute knowledge and retrieve lessons learned from the CLEAR database. The first question was: "During work, how often do you face a problem, situation, or opportunity for improvement that you think having previous knowledge about would have helped save time, money, or generally improved the outcome?" Respondents were given five options: (a) daily basis, (b) weekly basis, (c) monthly basis, (d) when starting a new position or job function, and (e) when starting a new project. The goal of this question was to identify possible times when use of the CLEAR program could be mandated or highly recommended. The last question of this section (and the entire survey) was: "You would most likely provide input and retrieve data and experiences from the knowledge sharing program if…." This question was open-ended and without options in order to provide space for respondents to suggest possible incentives or identify factors that were important to them and that would impact their utilization of the CLEAR program database.

4.4.2. Results

The survey was sent out to NCDOT employees through the Value Management Office. Each respondent's anonymity was guaranteed and no identifiers were collected. Answers were recorded between May 25, 2019 and August 21, 2019. The total number of responses was 58. The respondents were given the option to skip questions they did not wish to answer. On average, each question was answered 49 times.

Figure 8 presents the results from the age group question: 46% of respondents were 39 to 54 years old, 28% were in the millennial age group of 22 to 38 years old, and 26% were 55 to 73 years old.

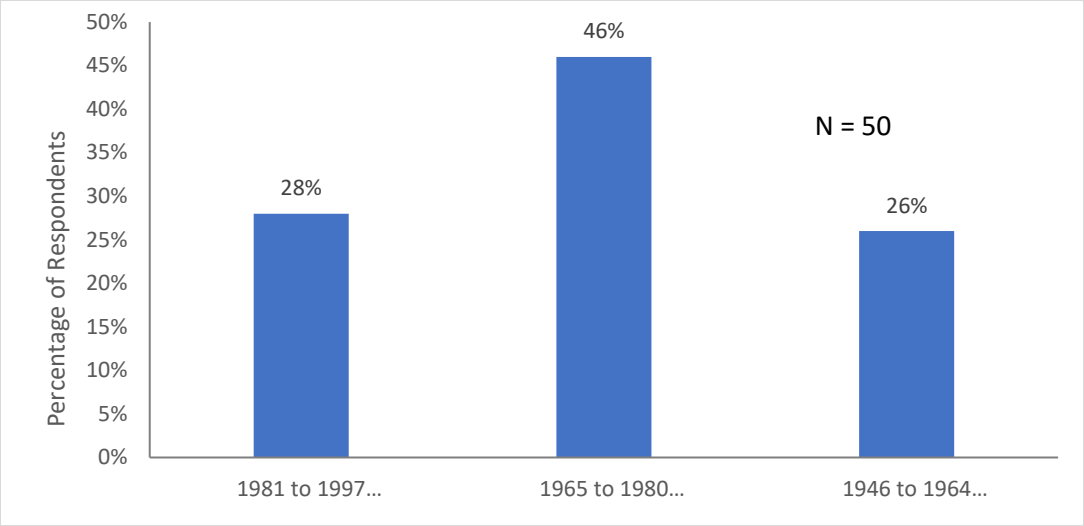

Figure 8. Age group distribution within NCDOT.

In terms of experience, 34.8% had 5 years or less experience with the NCDOT, 13% had 25 years or more experience, and 19.6% had 21 to 25 years of experience. Figure 9 shows all the results.

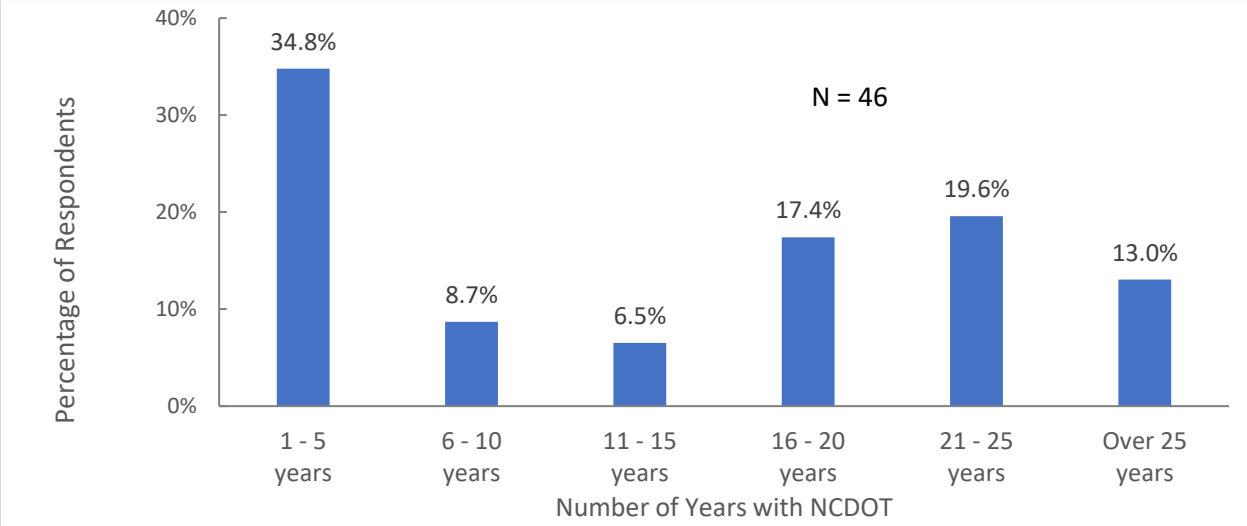

Figure 9. Years of experience with NCDOT.

Figures 10 through 13 show the current job functions, work-hour distribution, types of devices used during work hours, and access to the internet during work hours, respectively.

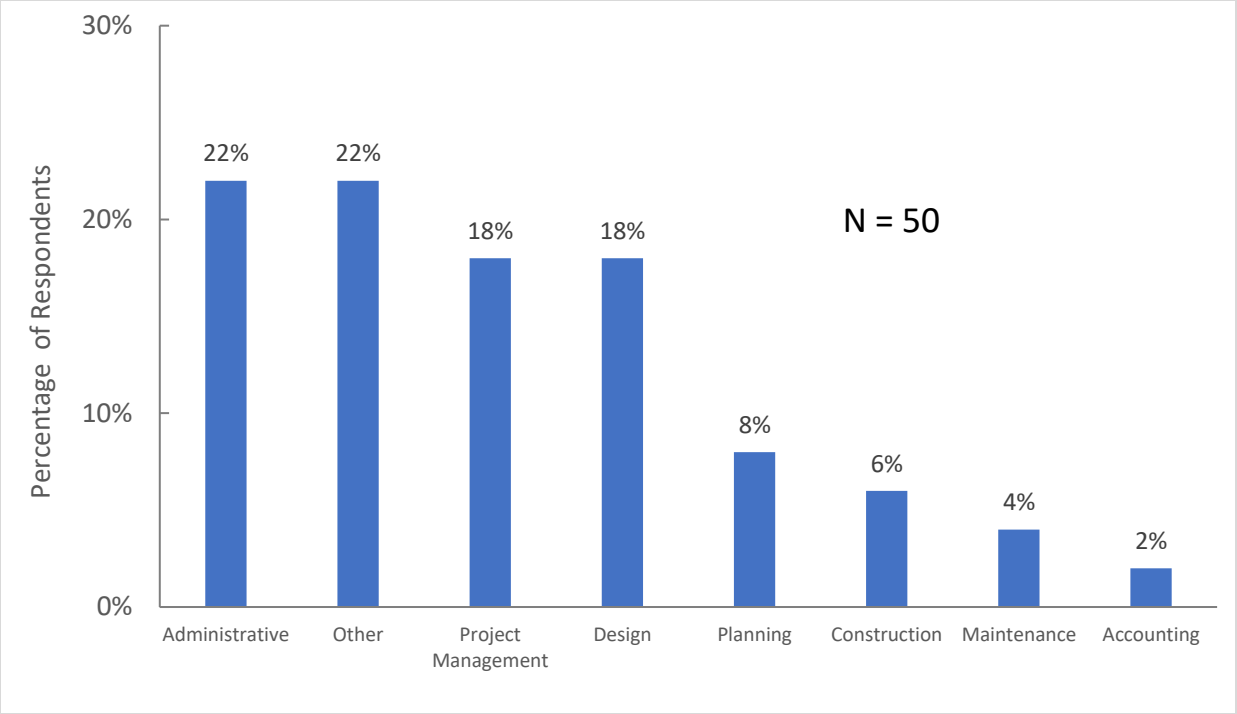

Figure 10. Current job function distribution within NCDOT.

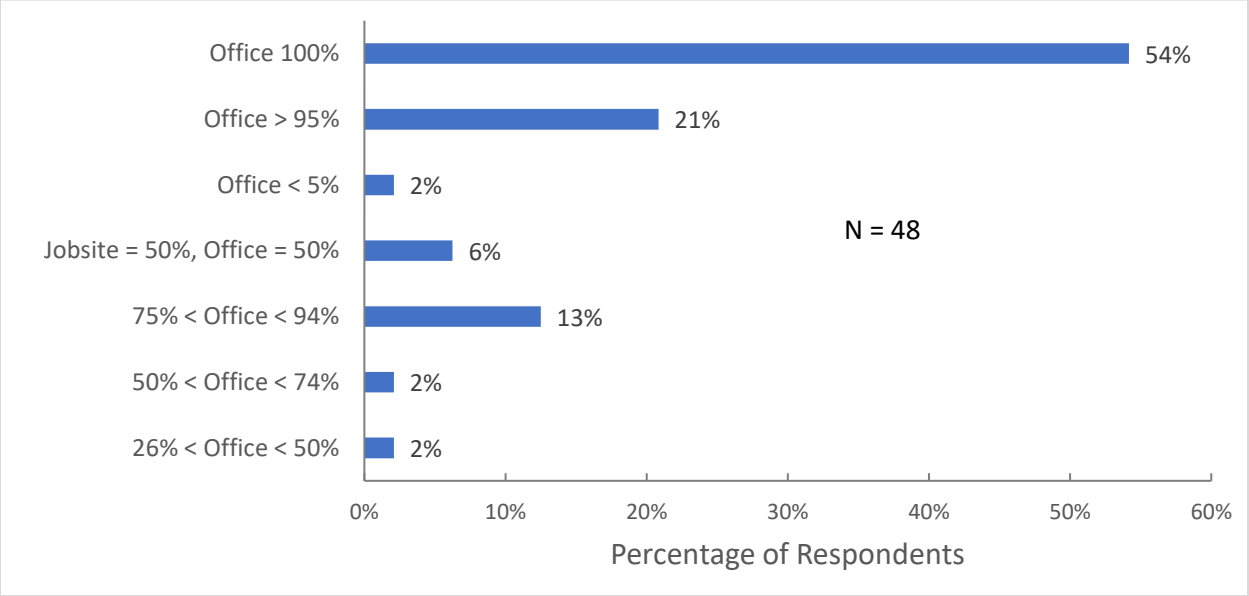

Figure 11. Work-hour distribution within NCDOT: Office vs. job site.

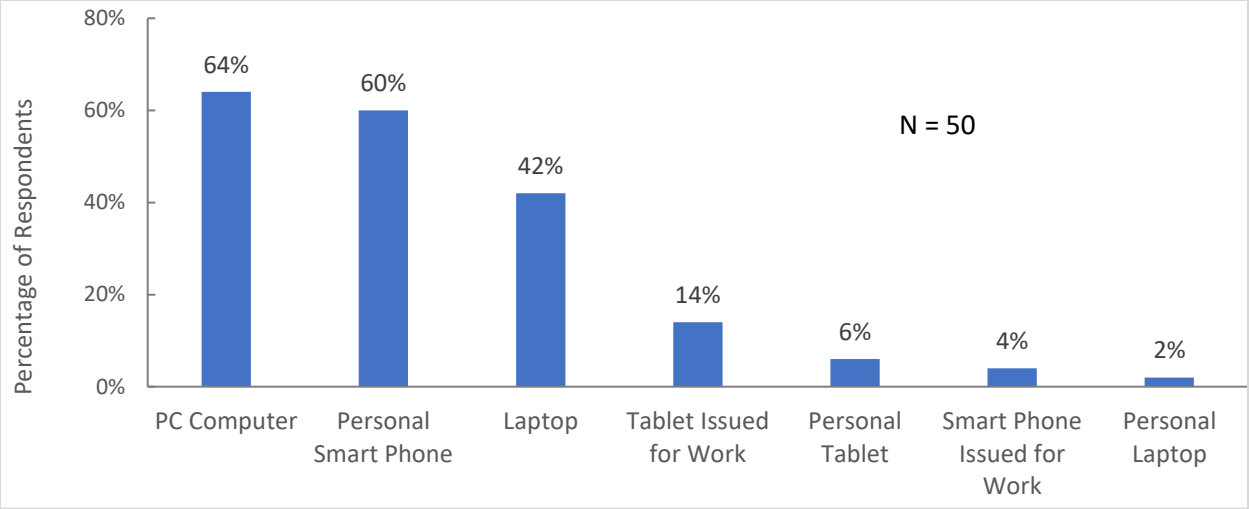

Figure 12. Types of devices used during work hours at NCDOT.

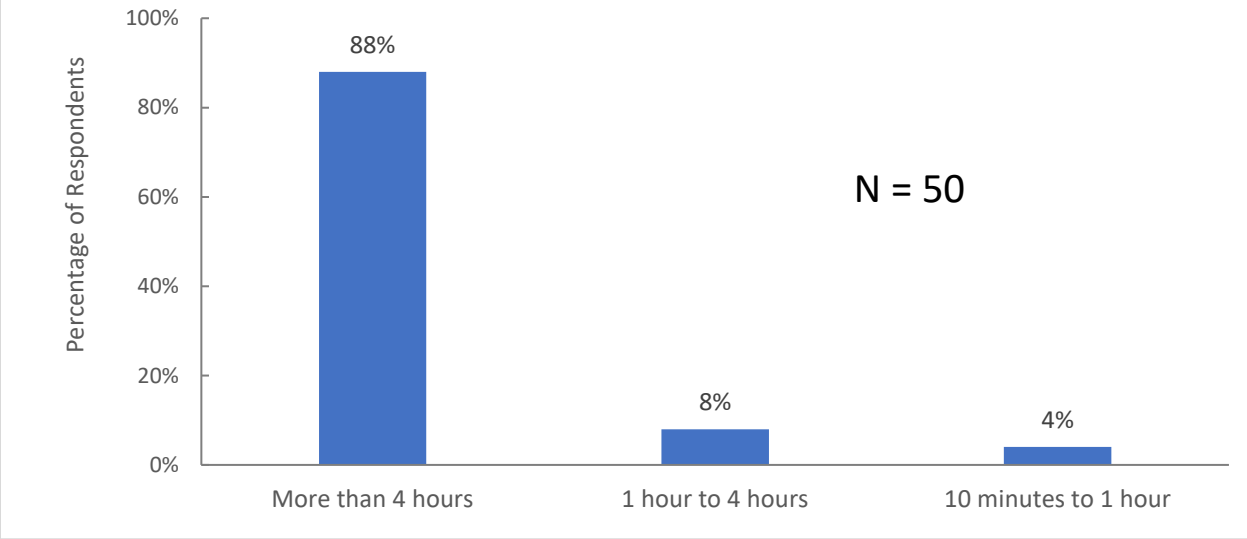

Figure 13. Time of access to the internet during work hours at NCDOT.

In terms of learning preferences, the overall majority of respondents gave high favorability scores to 'Combination of practical training and online videos'. Figure 14 presents the overall scores. The research team performed further analysis to link the training preferences to age group but was unable to establish any significant correlation. The 'Combination of practical training and online videos' and 'Video or series of videos' remained the highest scoring options across categories. Figures 15 through 20 show the distribution of scores across the three age groups and three job functions, respectively.

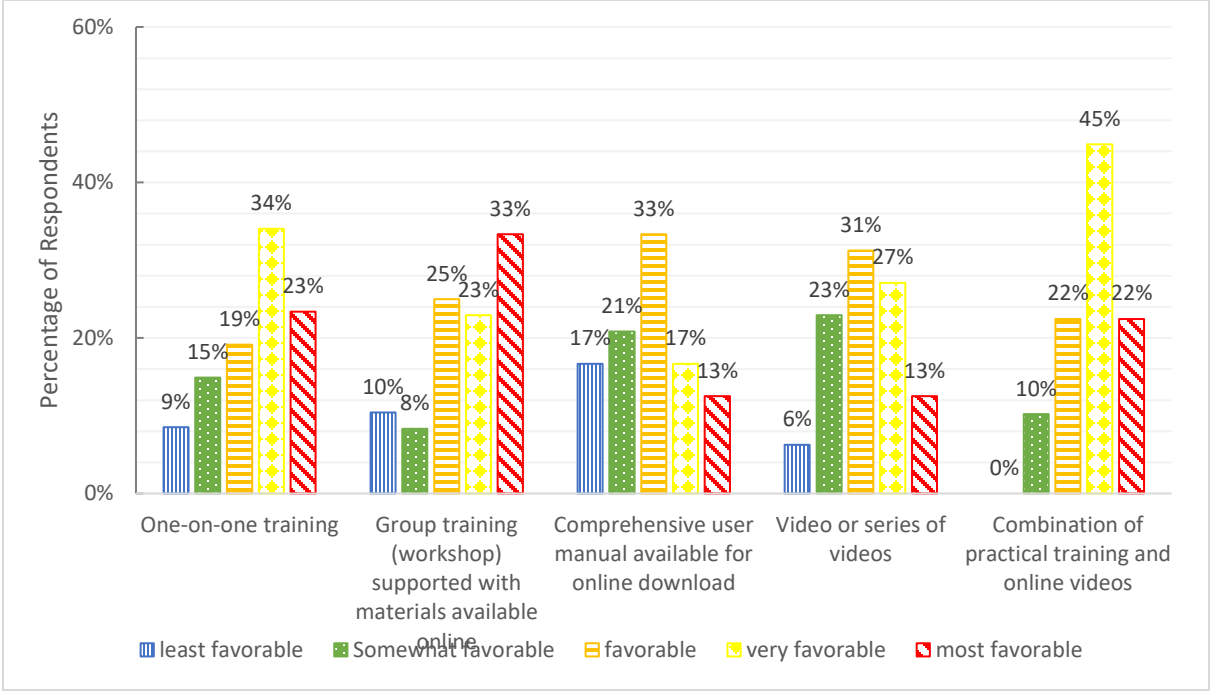

Figure 14. Overall learning preferences of NCDOT employees.

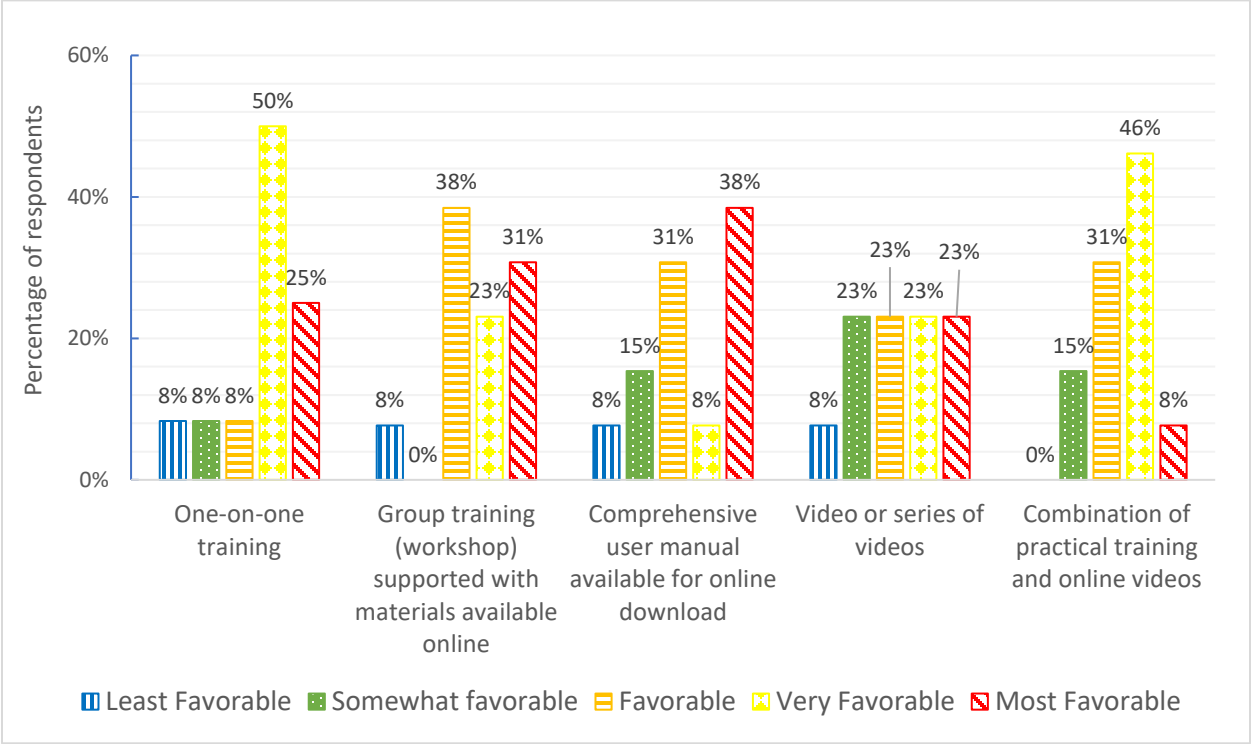

Figure 15. Preferred learning approaches in the 55- to 73-year-old age group.

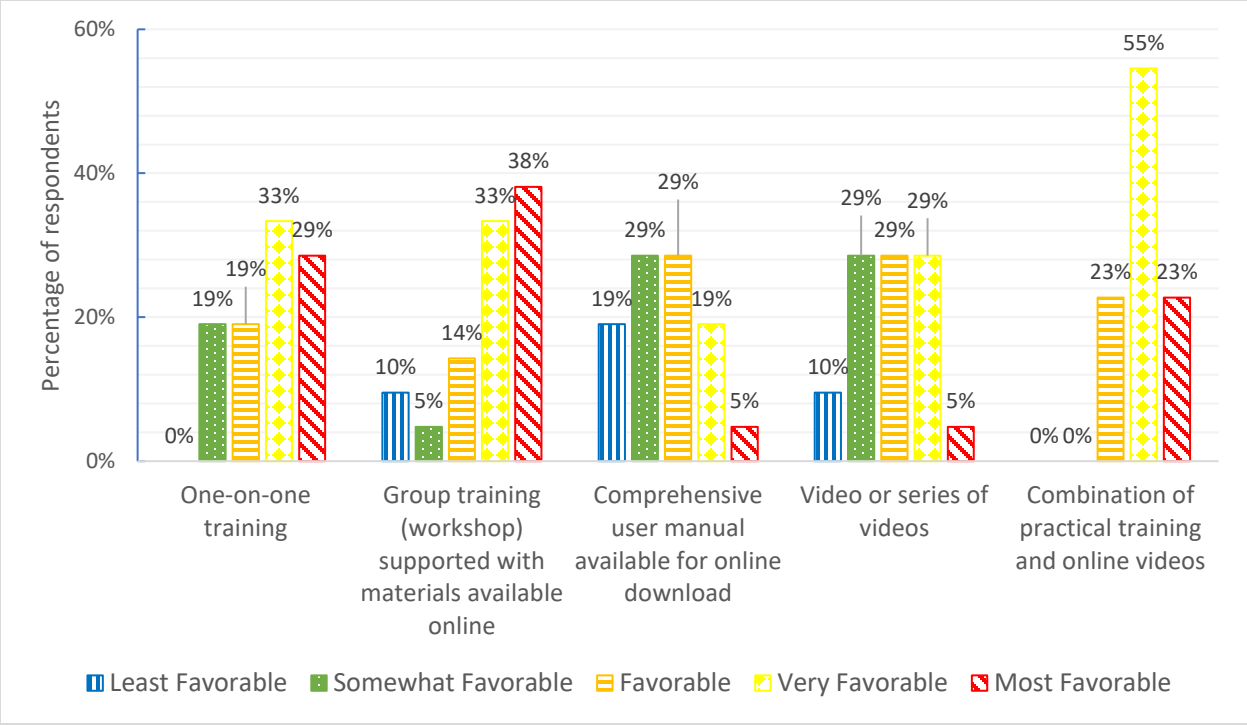

Figure 16. Preferred learning approaches in the 39- to 54-year-old age group.

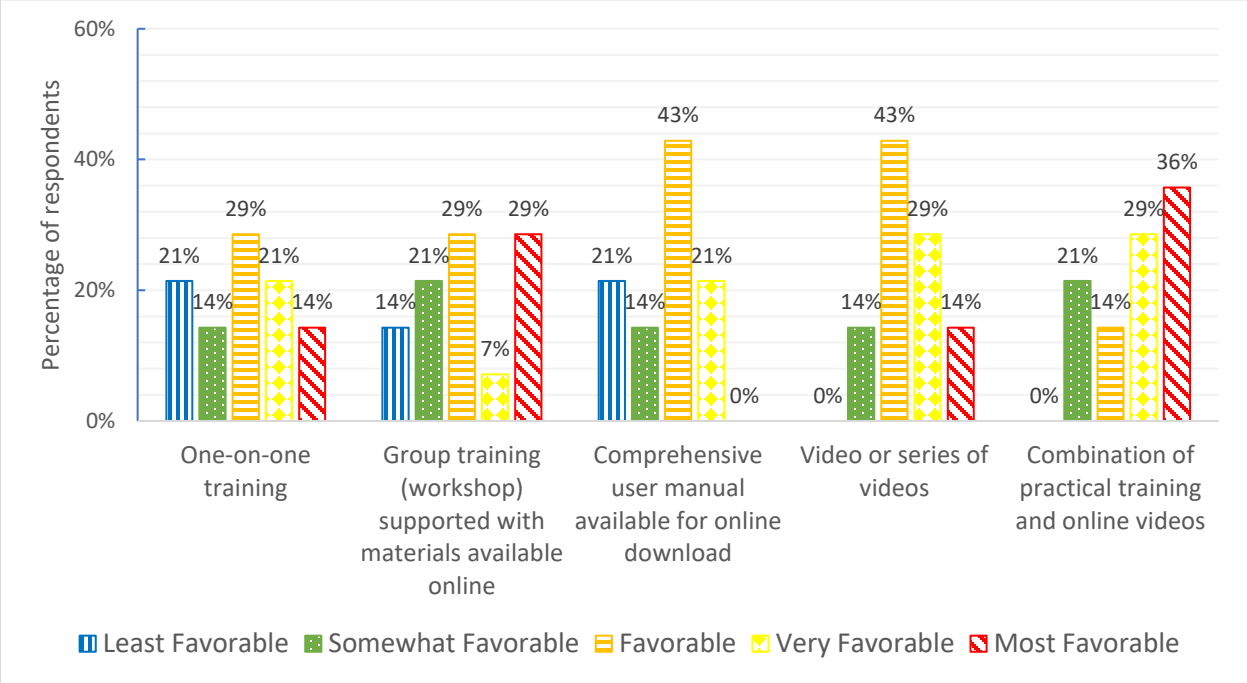

Figure 17. Preferred learning approaches in the 22- to 38-year-old age group.

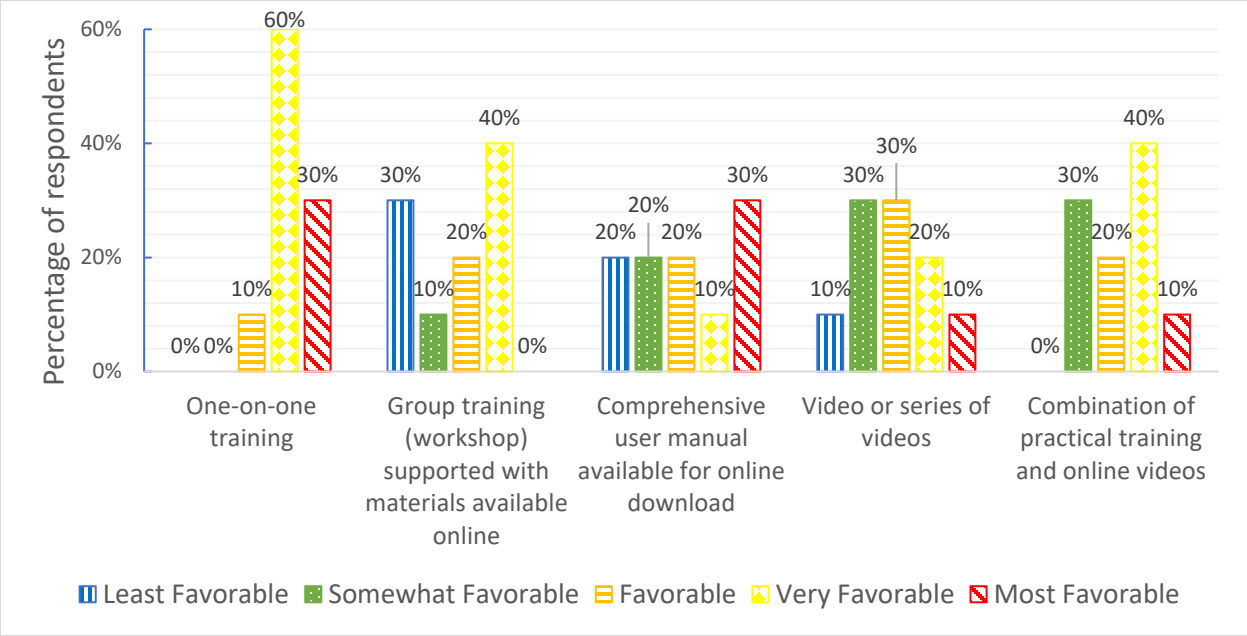

Figure 18. Preferred learning approaches in the administrative job function.

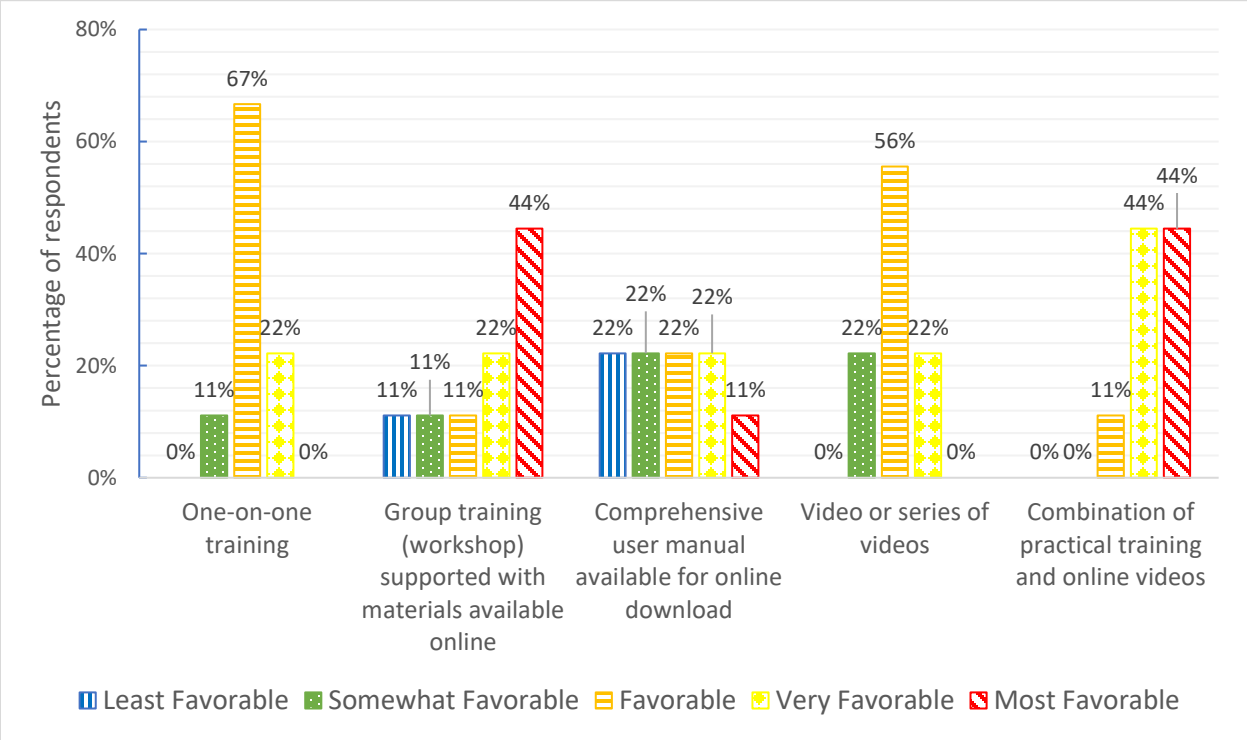

Figure 19. Preferred learning approaches in the project management job function.

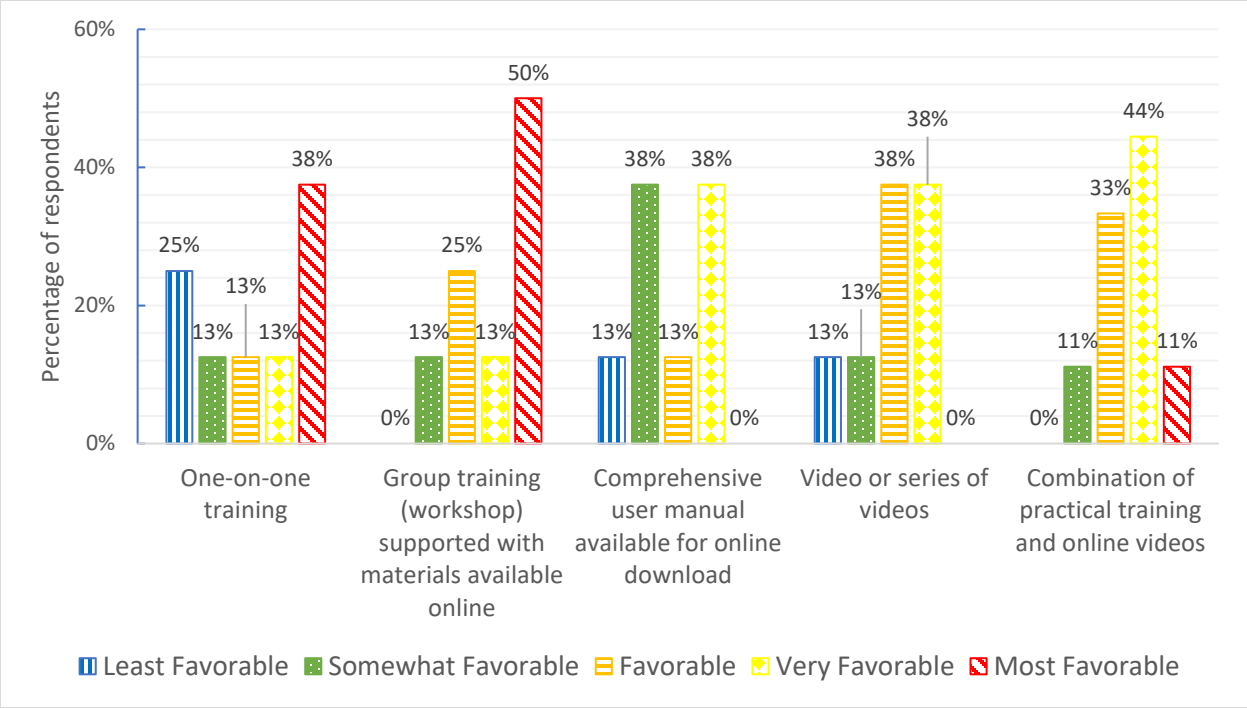

Figure 20. Preferred learning approaches in the design job function.

No clear majority of responses was evident in terms of type of training video or type of instruction in the video. Figures 21 and 22 indicate that the percentages were close.

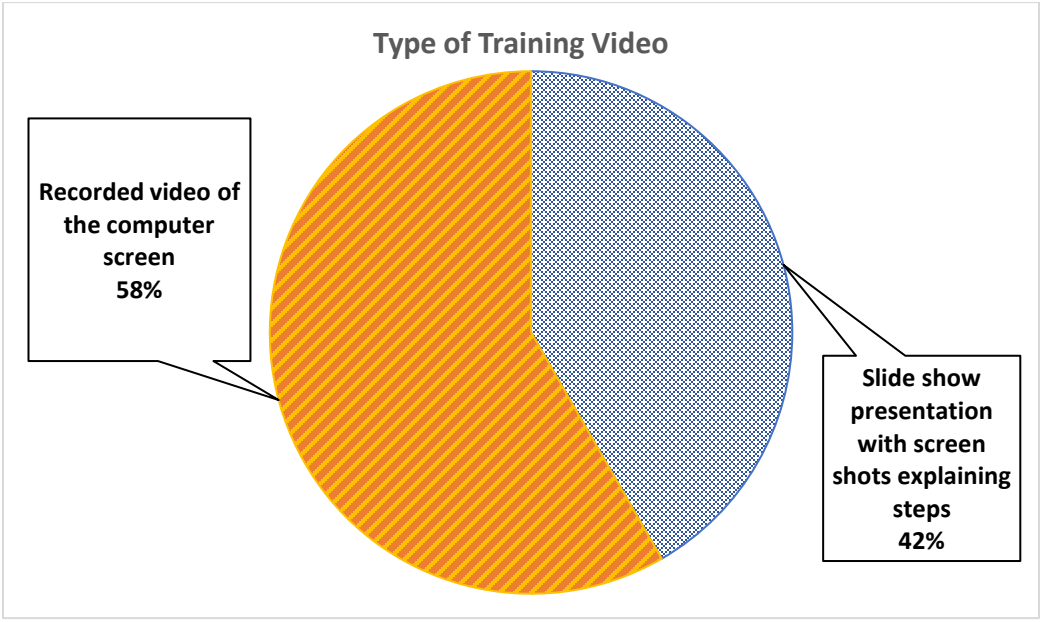

Figure 21. Preferred type of training video.

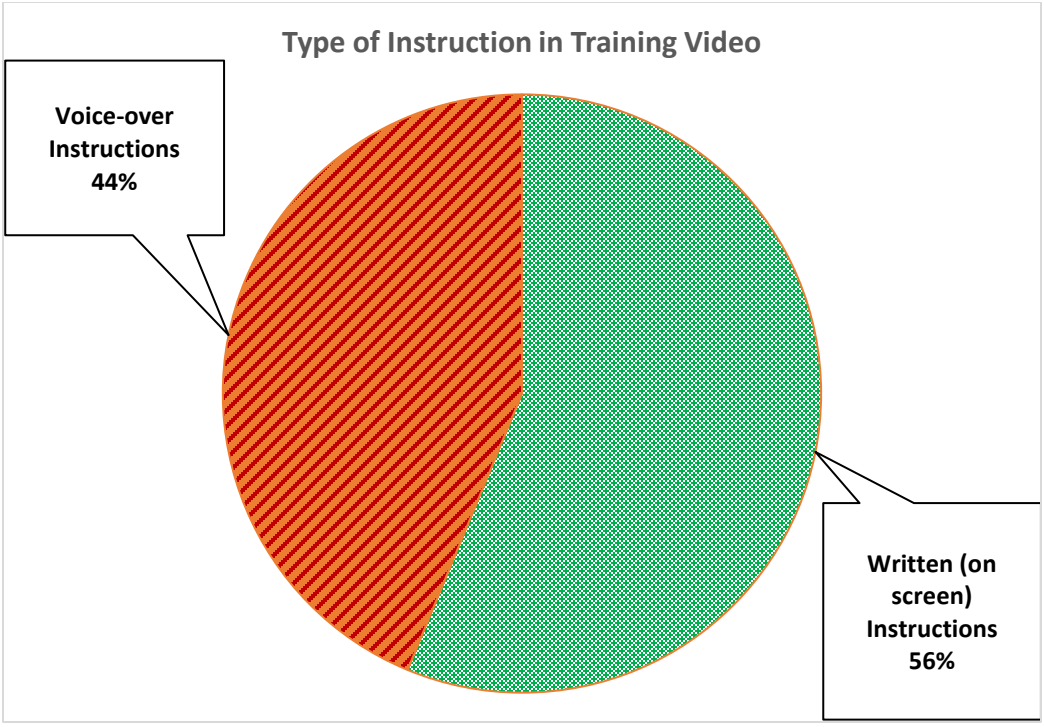

Figure 22. Preferred type of instruction in training video.

Finally, more than 70% of respondents reported that they had faced a problem or had an opportunity for improvement on a weekly or monthly basis that they think having previous knowledge about would have helped save time, money, or generally improved the outcome. Figure 23 shows that 29% of respondents reported that they faced such issues at the beginning of a new job function, position, or project. The answers to the last question, 'You would most likely provide input and retrieve data and experiences from the knowledge sharing program if . . .' included a variety of factors and suggestions. The research team reviewed and classified these factors into categories, some of which are shown in Figure 24.

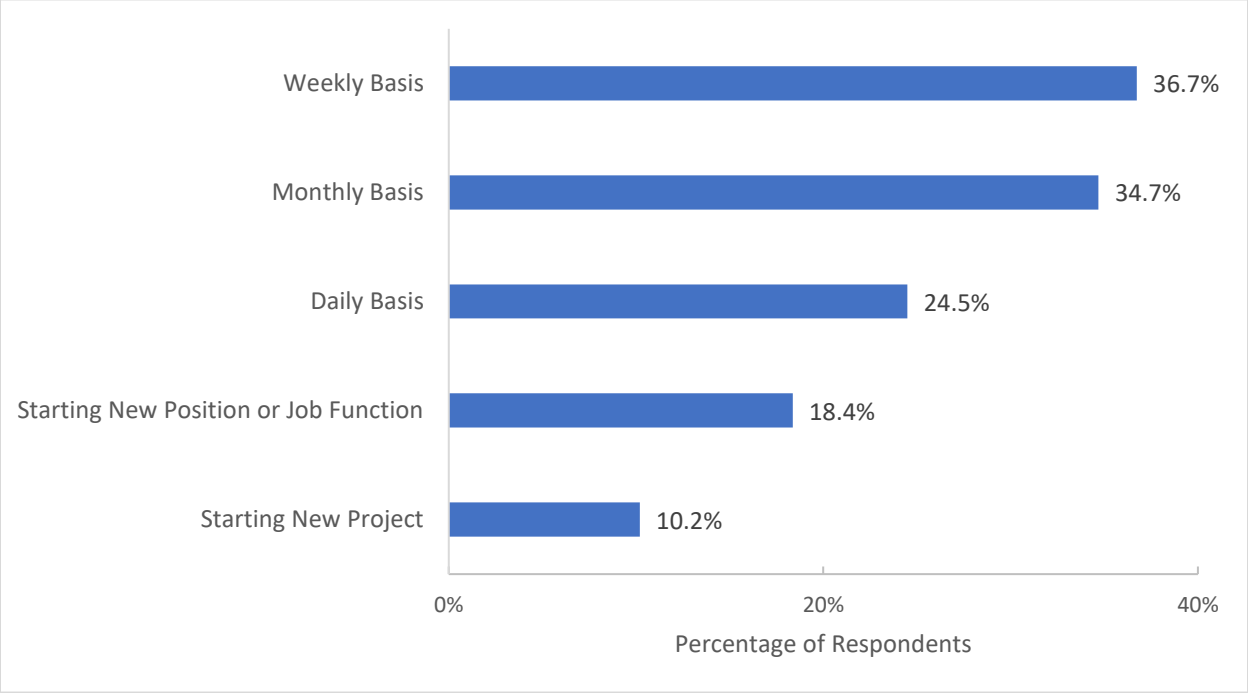

Figure 23. Frequency of encountered issues that CLEAR might be able to help address.

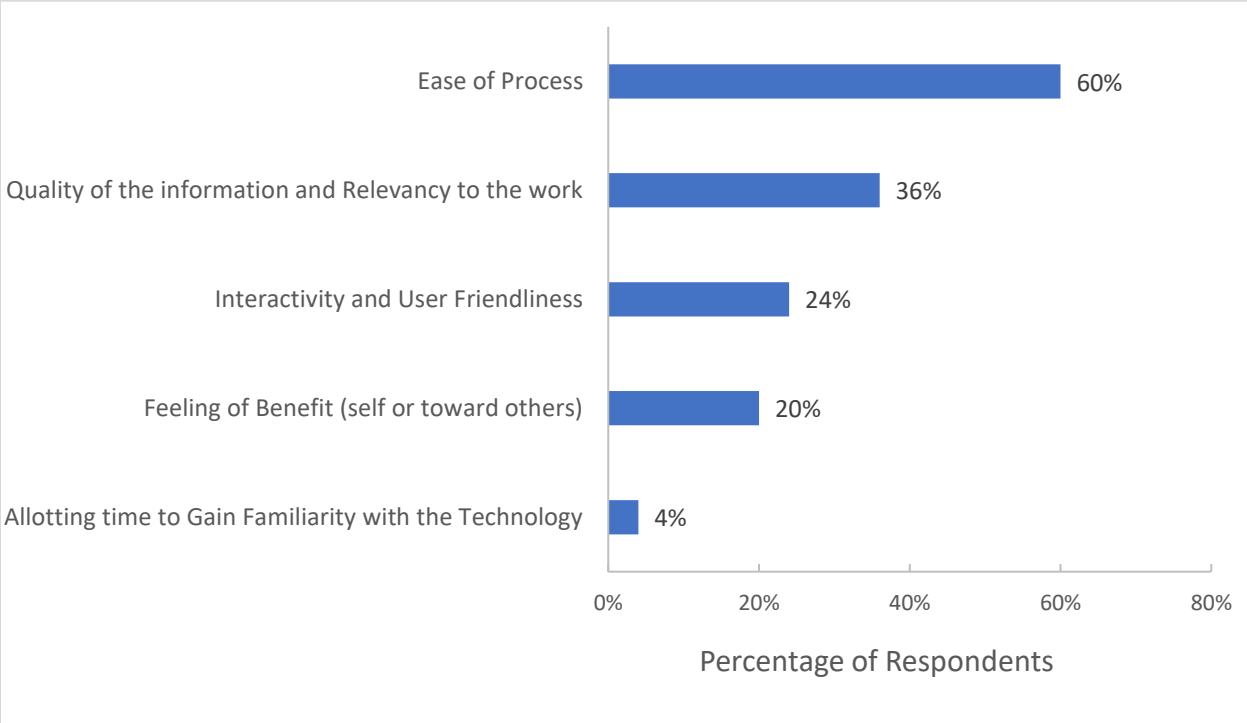

Figure 24. Possible factors that might encourage personnel to use the CLEAR database.

4.4.3. Analysis

As Figure 2 suggests, the percentage of respondents with less than five years of experience with the NCDOT (34.8%) is comparable to those with more than 20 years of experience (32.6%). In terms of age groups, the percentage of respondents between 55 and 73 years old (26%) who are nearing retirement is close to the percentage of respondents 22 to 38 years old (28%). The CLEAR program, among its other objectives, was designed to facilitate the sharing of knowledge and practical experience between the most and least experienced groups. With regard to training preferences, overall, 'Combination of practical training and supporting videos to be available online' is shown as the most preferred approach for the 22- to 38-year-old and 39- to 54-year-old age groups. The 55- to 73-year-old age group preferred group training supported by material available online. Based on these results, and given that most of the respondents spent a large portion of their work hours in an office with access to a PC and to the internet, the CLEAR program was recommended to be promoted through a series of online videos. The series includes an introductory video about the CLEAR program and its objectives and benefits to the NCDOT and its employees. The NCSU research team also created other videos that demonstrate how to access the database, submit lessons, and troubleshoot. Videos longer than five minutes were not preferred by respondents.

Previously, Zou (2007) had tested an online education approach for construction management education. Zou found that the advantages of this approach are efficiency and flexibility as well as the ability to cater to large numbers and allow part-time students to be enrolled. At the end of Zou's three-year study, 67% of the students surveyed after enrolling in an online construction class showed preference for a combination of face-to-face and online learning (Zou, 2007). These findings in the field of construction management academic education concur with the findings of this study as they pertain to the professional environment at the NCDOT.

4.4.4. Recommendations

By far the most important feature of the CLEAR program that respondents reported in the incentives section of the survey was ease of process. Respondents recommended that the CLEAR developers keep all the submission and retrieval processes as simple as possible.

The respondents also recommended creating a series of videos that describe the CLEAR program and explain how to submit and retrieve lessons as well as to troubleshoot. The NCSU research team made a special effort to keep the 'how-to' videos short and simple based on the users' preferences and recommendations. At the time of the data analysis for this survey, the research team had created four videos that were planned to be shown at workshops and NCDOT divisional meetings. Appendix D presents screenshots of these videos. The topics of the four videos are:

1. How to submit a lesson learned to the CLEAR program database.
2. How to submit a best practice or an idea to the CLEAR program database.
3. How to request a solution to an issue or challenge faced on projects using the CLEAR program database.
4. How to submit a solution to a problem or a best practice using the kiosk form.

In addition to videos, respondents suggested workshops to introduce the CLEAR program to employees across the NCDOT divisions and central unit. These workshops could be held as part of regular meetings or conferences.

4.5. Verify with End-Users: Verify Database Based on User Feedback

The fifth and final stage of the IDDOV model was to verify the newly created database by the end-users.

4.5.1. Risk Assessment Study

Once the NC DIT had set up the CLEAR database in the SharePoint portal, the database needed to be validated by end-users. For this task, the Value Management Office at the NCDOT conducted a one-day risk assessment study of the CLEAR program in November 2019. The aim of this study was to understand the possible risks that could arise out of this program and possible mitigation measures. The study had 21 participants who identified 65 risks, of which 51 risks were deemed to require mitigation. Figure 25 provides a breakdown of the severity of the risks.

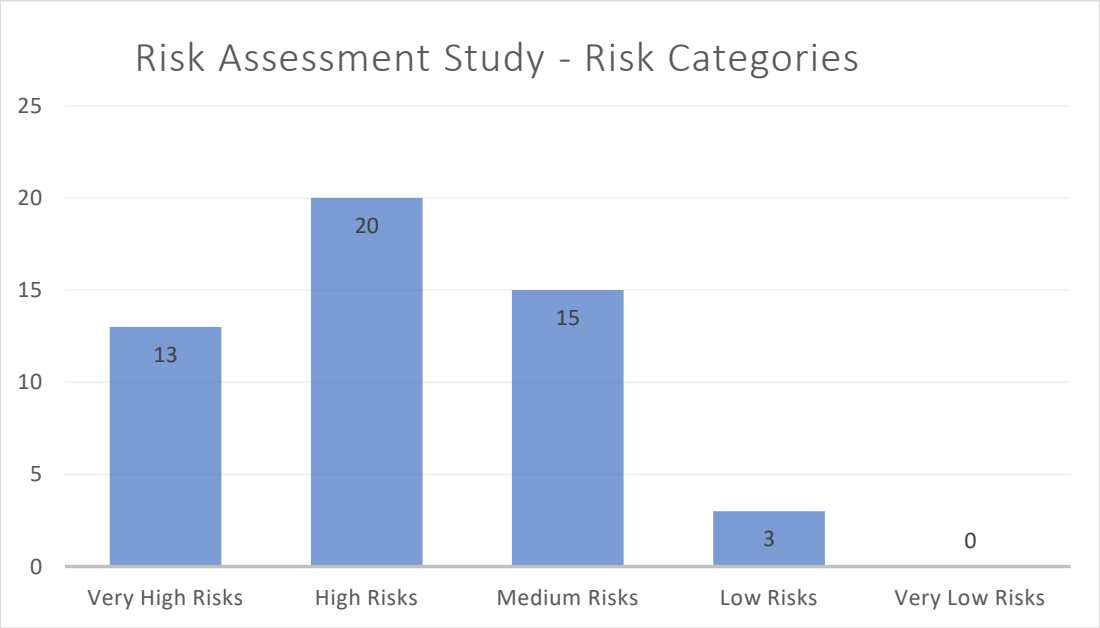

Figure 25. Risk classifications identified from CLEAR risk assessment study.

All the identified risks were categorized based on topics such as search, collection, integration, sharing, and recognition. The Value Management Office, in consultation with the study participants, devised proposed mitigation strategies for these risks and subsequently delegated these risks to the appropriate authorities to implement proper mitigation measures. More information on this risk assessment study and the identified risks can be found on the NCDOT website (Fullerton C. E., 2020).

Based on the risks identified from the risk assessment study and work done by other DOTs, such as CDOT, the NCSU research team developed three forms (presented in Appendices E, F, and G, respectively) to replace the existing single form in CLEAR. These three forms are used to input information about (1) lessons learned, (2) best practices/ideas, and (3) solutions (or control measures) that are needed to address obstacles/challenges faced at project sites. The research team also developed sets of standard operating procedures (SOPs) for end-users and for taskforce members that provide information about how to use the appropriate functionality (see Appendices H-K). For end-users, the SOPs explain how to enter information in the Lessons Learned, Best Practices, and Solution Needed forms and to search for content in the database. In addition to these forms, the research team developed 'how to' videos that describe the steps needed to enter information in the CLEAR database (see Appendix D). These videos are intended to act primarily as a training resource for first-time users of this database, although users also can use them as reference material when using CLEAR. For taskforce members, the SOPs detail the steps to provide a suitable disposition to entries made within CLEAR. Steps to create personalized views for the taskforce members to customize the workflow is also provided. The NCSU research team, in consultation with the Value Management Office, also prepared a list of definitions (presented at the start of this report) and frequently asked questions (FAQs) (see Appendix L) to be uploaded on the CLEAR website. All stakeholders involved with the CLEAR program can use these documents to familiarize themselves with relevant terminology and to obtain information from the FAQs.

4.5.2. Lessons Learned to Lessons Remembered

In line with the organizational goal of the CLEAR program to institutionalize knowledge, the NCSU research team devised a sequence of steps to make the lessons learned easy for users to remember. The data-gathering phase analysis results revealed that utilities-related issues are the problems that most affect NCDOT personnel. Therefore, the research team developed possible interventions that are based on the literature, personnel responses obtained from interviews, and HiCAMS data provided by the Value Management Office regarding utilities claims. Appendix M provides an example of these steps to remember for lessons learned with regard to utilities claims, and Section 5 is focused exclusively on information regarding utilities claims.

4.5.3. Training Materials

The NCSU research team developed training videos using the video-making software VideoScribe (see Appendix D). The team created a video for each of the three forms that describes how an end-user can enter information in the appropriate form(s). The research team also prepared training materials as 'kiosk' forms that are designed for maintenance personnel who do not have access to the Connect NCDOT portal to enter information. All the training materials, including the videos, have been uploaded to the CLEAR portal so that end-users can become familiar with ways to share information via CLEAR.

4.5.4. Online Training

The Value Management Office organized the first online training session using Microsoft Teams

for participants from Wake County in the Hydraulics and Aviation divisions. This session was planned initially to be a face-to-face gathering, but due to the COVID-19 situation, the training session was converted to an online format. The purpose of this training session was to introduce CLEAR to a pilot group of NCDOT employees (approximately 30 participants) and to explain CLEAR's potential benefits to both the participants and the NCDOT as a whole. The research team worked closely with the Value Management Office in preparing the training materials and providing support in order to obtain feedback about the presentation materials. A feedback form (see Appendix N) provided at the end of the presentation allowed the participants to share their opinions about the CLEAR program and the efficacy of the presentation.

Data analysis of the feedback survey revealed the following information:

- 16 valid responses were received, of which 15 were complete in all aspects.
- The total NCDOT work experience of the users was 187.5 years, which is an average of ~11.72 years.
- The users ranked the order of usage preference for the CLEAR forms as Lessons Learned, Best Practices, and Solutions Needed, as indicated in Figure 26.
- Most of the respondents strongly agreed that the training met their needs and that they would be willing to contribute to the CLEAR program.

Figure 27 presents the data analysis results for the various questions in the feedback survey.

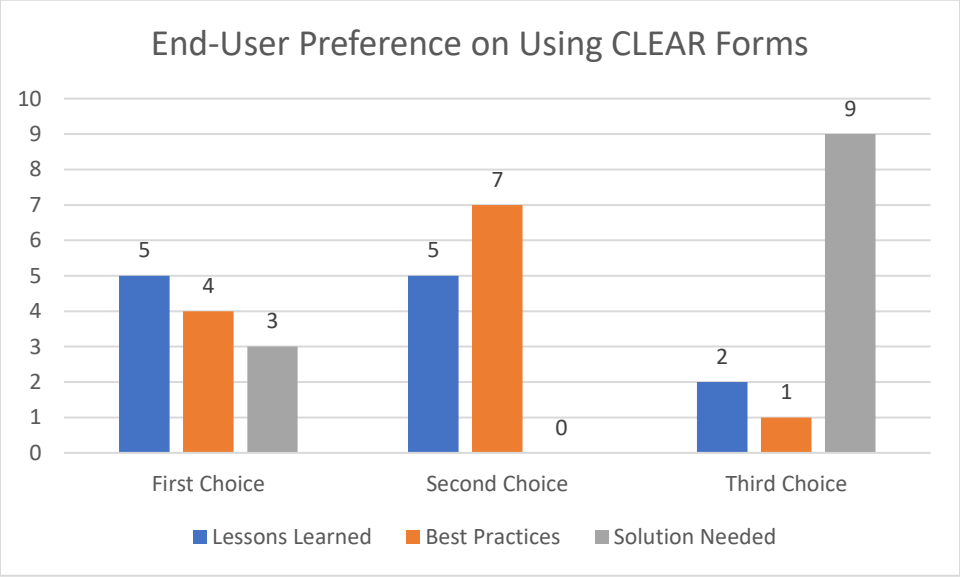

Figure 26. Ranking of three CLEAR forms based on user feedback.

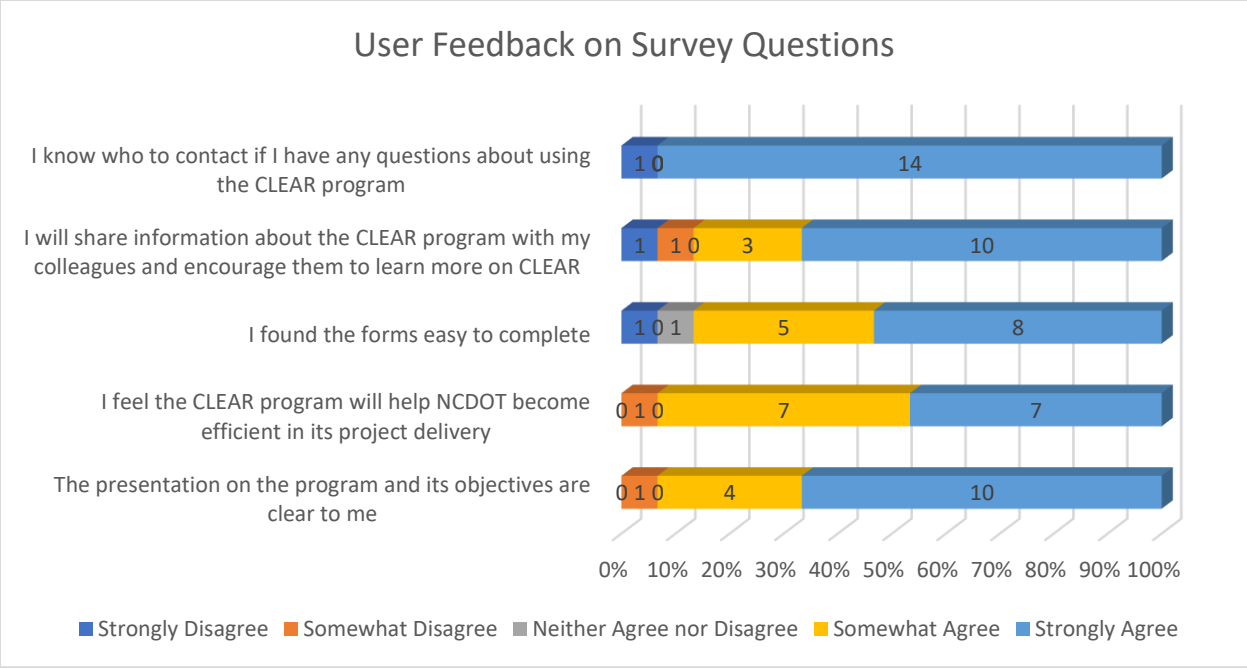

Figure 27. Data analysis of user feedback obtained from survey questionnaire.

5. ANALYSIS OF NCDOT CLAIMS RELATED TO UTILITIES

This section presents analysis of a sample of NCDOT utilities-related claims. The NCSU research team conducted this analysis because NCDOT survey respondents and personnel consistently reported several problems related to utilities. Dealing with utilities seems to be one of the most challenging and ongoing issues for the survey respondents.

5.1. Introduction

Transportation projects share the right of way with utilities-related infrastructure. Therefore, transportation agencies must coordinate with several different utility agencies to accommodate different types of utilities, such as electricity, water, telecommunications, and gas. The space-sharing of public roads and bridges with utilities often complicates the efficient delivery of transportation projects and increases the risk of utilities conflicts (Goodrum et al., 2008; Quiroga et al., 2019). According to Quiroga et al. (2011), transportation agencies often lack adequate and updated information about their facilities, which can lead to damage to existing utilities during construction and create environmental and safety incidents as well as time and cost overruns. In short, managing utilities and transportation projects is extremely challenging.

Transportation agencies have investigated best management practices for dealing with utilities and utilities providers. For example, the Illinois Department of Transportation (IDOT) surveyed other state DOTs and IDOT districts about top effective best management practices and found that coordination, cooperation, communication (or ‘CCC’) and subsurface utility engineering (SUE) are among the most utilized practices to manage utilities in the context of transportation

projects (El-Rayes et al., 2017). The Kentucky Transportation Cabinet also assessed risks associated with utilities and investigated best practices to minimize those risks. Mitigation strategies include early utilities involvement in the design phase (30% or earlier) and effective utilities investigations that utilize SUE.

Nonetheless, utilities continue to impact the performance and outcomes of transportation projects. Past research efforts identified numerous reasons for disruptions caused by utilities-related issues and dealing with utilities providers, including design and communication issues (El-Rayes et al., 2017; Quiroga et al., 2011, 2019; Sturgill Jr, 2018). However, no comprehensive assessment was undertaken in those earlier studies to target the impacts of utilities on transportation projects by investigating construction claims records. Construction claims data provide rich information that can be leveraged for this purpose. The objectives of this study of NCDOT utilities claims are to:

- Assess the impact of utilities-related claims on construction costs.
- Assess the effect of utilities-related claims on construction schedules.
- Assess the characteristics of utilities-related claims in terms of project type, project size, and utility type.
- Understand the sequence of events that led to a utilities-related claim.
- Report the relevant lessons learned that have been collected for the CLEAR database.

The following sections review the research methodology and present the findings.

5.2. Utilities Claims Database and Research Methodologies

The research methodology used for this investigation followed qualitative and quantitative approaches to studying claims associated with utilities. The analyzed utilities claims database includes a total of 1,144 valid claims related to utilities in North Carolina. These claims occurred on 707 NCDOT projects that were let between 1994 and 2018. Figure 28 shows the number of projects that were impacted by utilities claims across the years in which the studied projects were let.

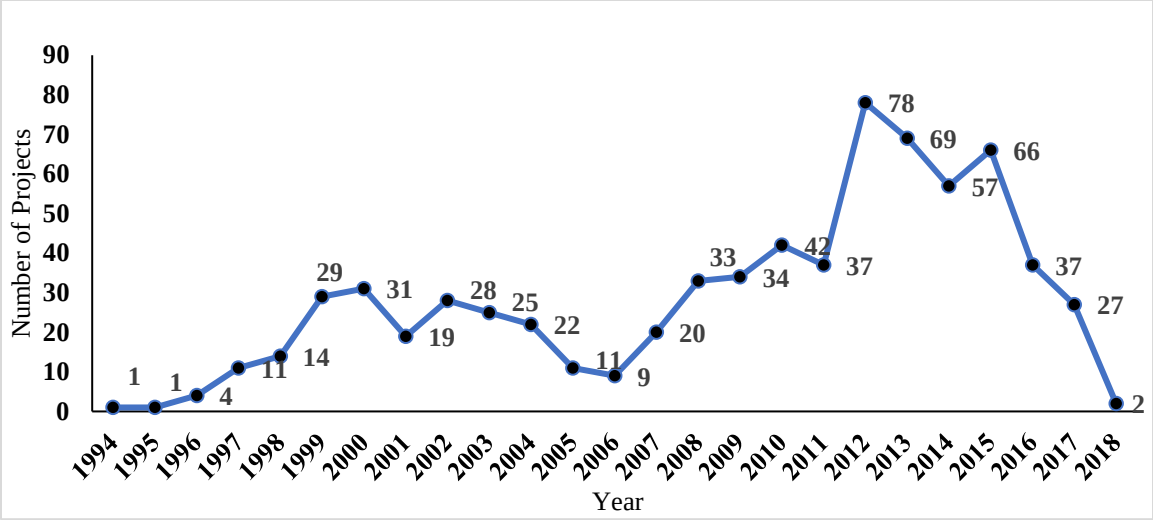

Figure 28. Number of NCDOT projects influenced by utilities claims, by letting year.

The database of claims that are related to utilities is part of a massive database of overall construction claims and supplementals. The claims data were obtained by utilizing search word capabilities in the 'claim description' field. Each claim description provides a narrative of the reason(s) for submitting the claim. The searched keywords include 'utility', 'lane', 'sewer', 'power', and 'utility providers'. The NCSU research team manually inspected the returned results to access the claims that were associated specifically with utilities and to discard the claims that were not related to utilities. The claims associated with utilities represent nearly 13% of the construction claims database. These claims occurred in 707 out of the total 3,335 projects. That is, almost 21% of all projects were affected by at least one utility claim.

The claims descriptions provide a rich source of unstructured data and help to explain the events that led to submitting the claim as well the utility type (e.g., electricity, water, gas, or telecommunications). The research team conducted comprehensive content analysis of the claims narratives to structure and summarize the reports. Content analysis is a common qualitative research approach that categorizes unstructured text into structured categories (Neuendorf & Kumar, 2015; Saldana, 2015). Following this approach, the research team obtained the following information from the claims data: (1) utility type, (2) utility location (e.g., underground or above-ground), and (3) the scenario in which the utility claim occurred. In coding the scenarios, the research team followed the domino effect coding approach suggested by Saldana (2015). The premise of the domino effect approach, as the name suggests, is creating a flow of events that would lead to the utility claim. Figure 29 describes this method using an example from the claims database.

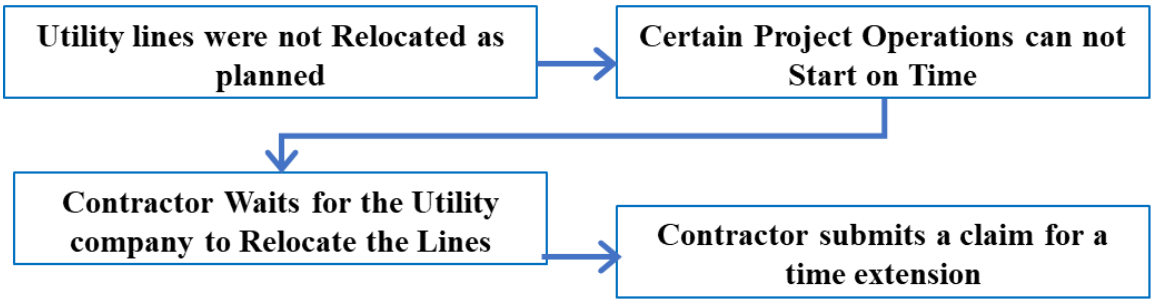

Figure 29. Example of domino effect coding approach using claims data.

Next, the NCSU research team established frequency and descriptive statistics for the following attributes:

- Project location (by division)
- Project size
- Project type
- Number of utilities claims for each project
- Cause(s) for delay (labeled in the database by NCDOT project managers)
- Delays due to utilities claims
- Cost increase due to utilities claims
- Utility type
- Utility location
- Events that led to the claim

Note that, in numerous cases, the provided claims descriptions lacked some substantial information about the events that occurred before submission of the claim(s). Also, the research team encountered claims records with missing data. Lastly, the research team reported the utilities-related lesson(s) learned that had been submitted to the CLEAR database.

5.3. Analysis Findings

This section presents the frequency and statistical analysis of the utilities claims records. The subsections report the findings.

5.3.1. Number of Projects Affected by Utilities Claims, by Division

Figure 30 shows the distribution of the studied affected projects that had utilities claims. These results indirectly suggest the divisions where the agency should focus on managing and controlling utilities-related issues. Most of the projects that were impacted by utilities claims are in Division 10, which includes projects that were let in Mecklenburg County, the largest county in the State in terms of population.

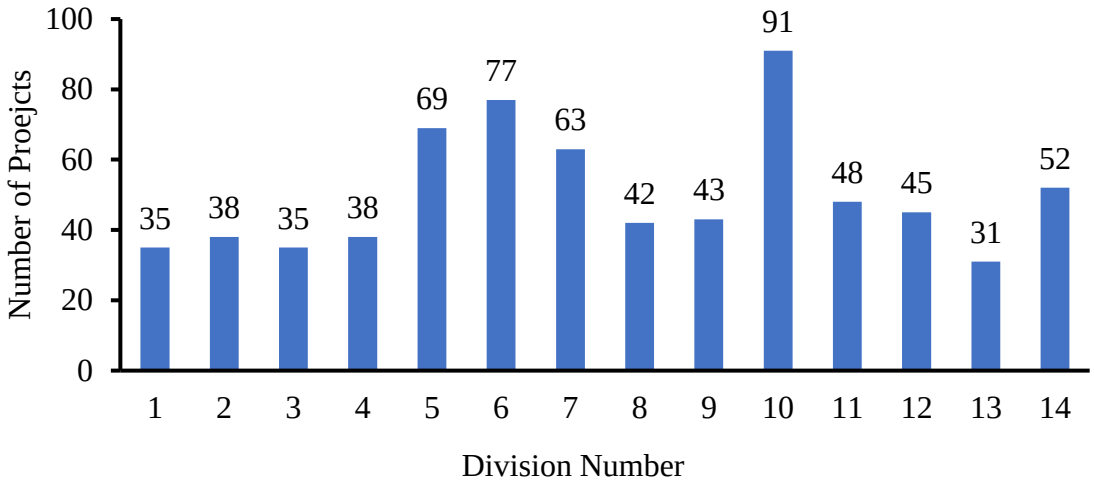

Figure 30. Number of projects affected by utilities claims, by division.

5.3.2. Size of Projects Affected by Utilities Claims

The bid amount determines the size of the project. Alsharef (2015) classified transportation projects into the following categories (in USD): less than $1 million, $1 to $5 million, $5 to $20 million, and above $50 million (the latter known as megaprojects) (Alsharef A. F., 2015). Figure 31 shows the frequency of projects impacted by utilities claims clustered by project size. Most of the projects impacted by utilities claims tend to be small. One possible explanation for this finding is that smaller projects tend to have fewer coordination efforts compared to larger projects.

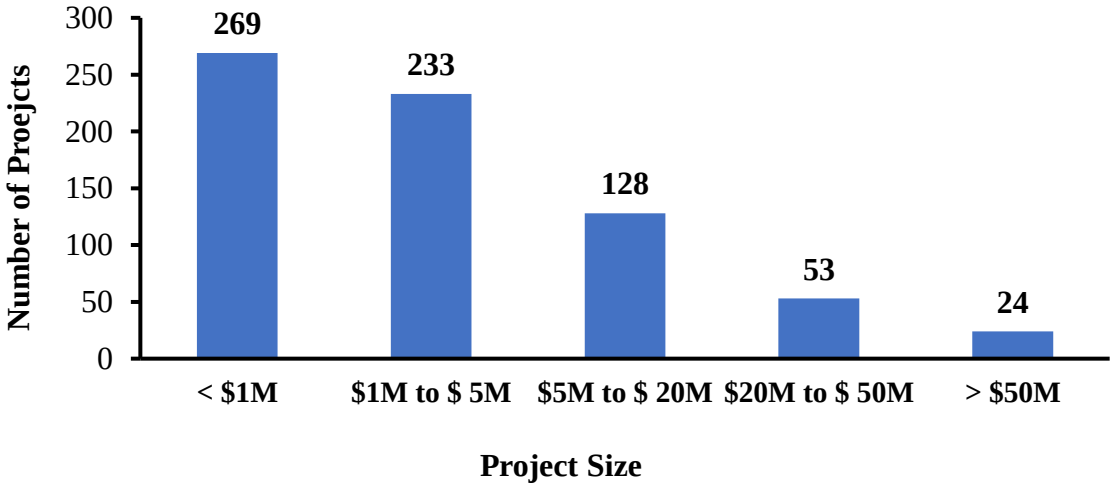

Figure 31. Number of projects with utilities claims based on project size.

5.3.3. Project Type

Figure 32 reports the number of claims related to utilities for each project type. The analysis is for 907 out of the total 1,144 claims records because the project type is missing for 234 utilities claims. Not surprisingly, the highest number of claims occurred in urban projects, followed by bridge projects. The reason for this outcome might be that urban areas are characterized by congested and intertwined utilities infrastructure (Quiroga, et al., 2019).

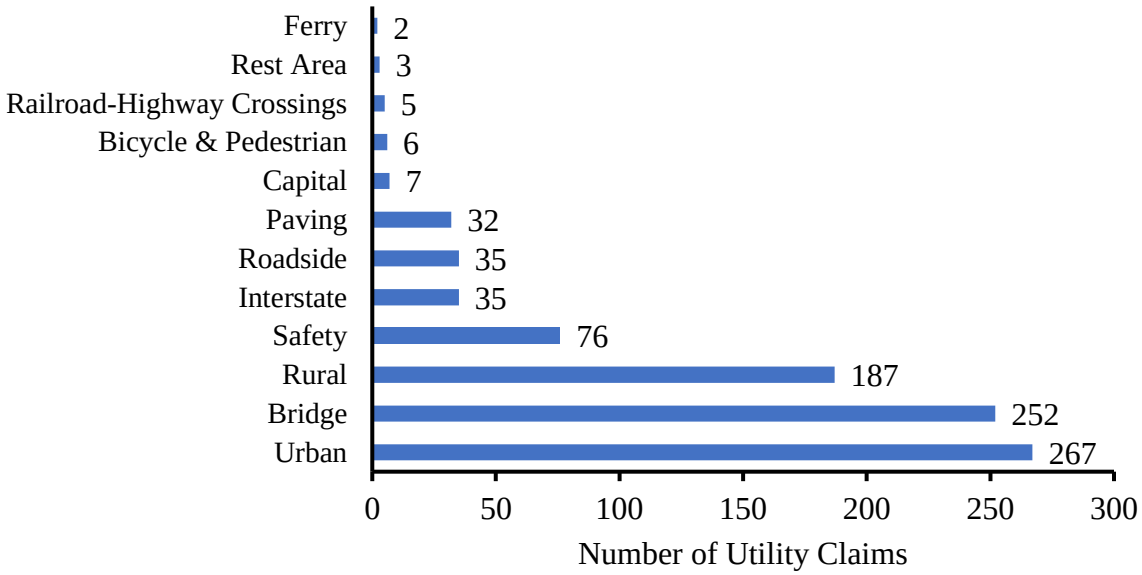

Figure 32. Number of utilities claims per project type.

5.3.4. Number of Utilities Claims per Project

Figure 33 reports the number of utilities claims per project. The figure shows that 492 projects had one utility claim and one project had 19 utilities-related claims. The one project with 13 utilities claims and the one project with 19 utilities claims are both megaprojects (projects with bid amounts greater than $50 million). Table 1 presents summary statistics for the number of claims per project.

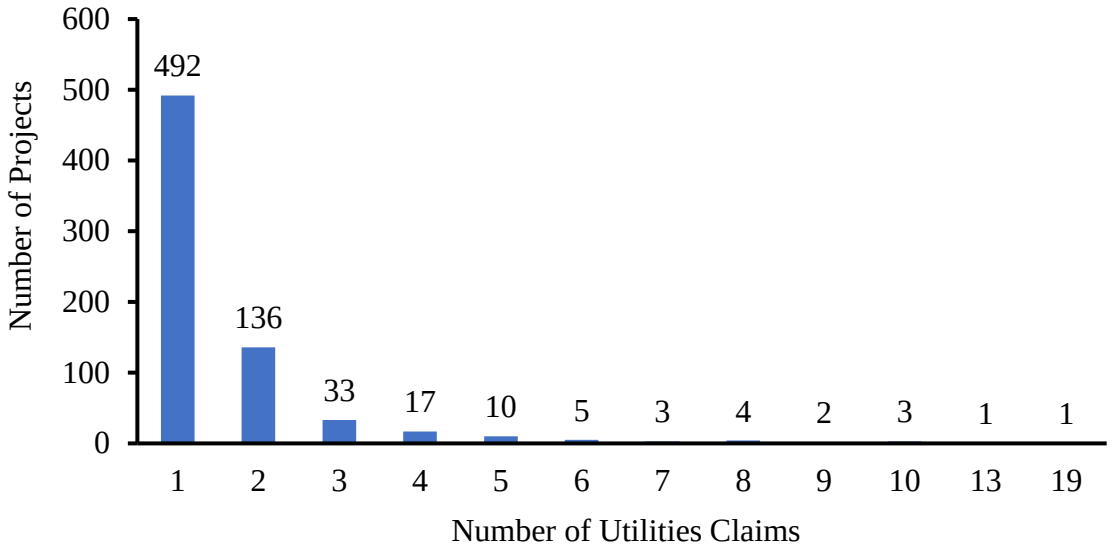

Figure 33. Number of utilities claims per project.

Table 1. Summary Statistics for Number of Utilities Claims per Project

Number of Projects	707
Average	1.62
Median	1
Standard Deviation	1.5
Mode	1

5.3.5. Analysis of Project Delays Due to Utilities Claims

The goal of this analysis was to assess the impact of claims related to utilities on the project's duration/schedule. In many cases, the contractor requested an extension of time due to a utility conflict that impeded the construction progress. Figure 34 shows the frequency of the time extensions that resulted from utilities-related claims. On average, such claims would extend the project completion by nearly 70 days. Table 2 provides summary statistics for delays caused by utilities claims.

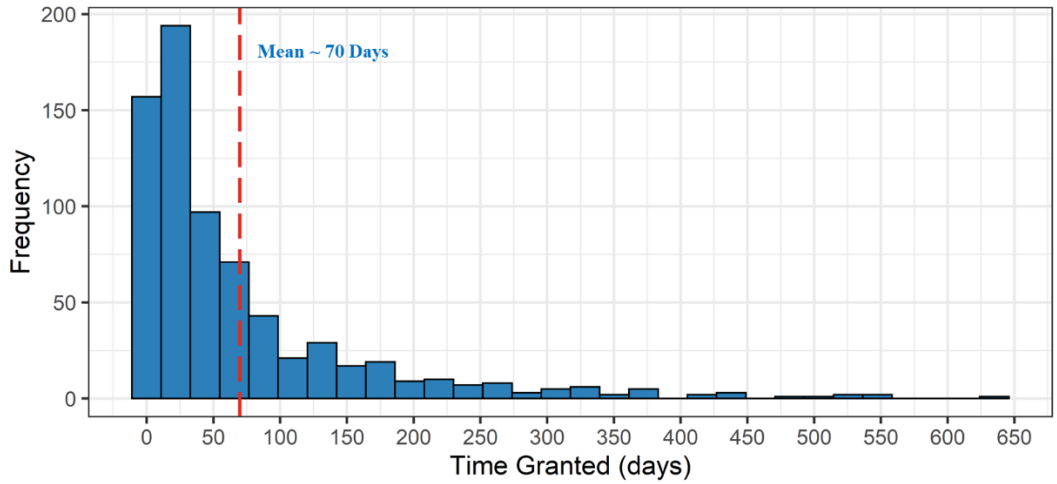

Figure 34. Frequency of delays due to claims associated with utilities.

Table 2. Summary Statistics for Number of Utilities Claims per Project

Number of Claims	715
Average	69.75
Median	34
Standard Deviation	92.45
Mode	7

5.3.6. Causes of Utilities Claims Delays

In the utilities claims database, each cause for delay is labeled by the person who entered the claims record. Out of 931 utilities claims, nearly 57% of the delays were caused by utilities-related conflicts (see Figure 35). In one claim, the contractor requested a time extension due to delays associated with relocating utilities. The contractor mobilized to the job site and was not able to start the project because the relocation work had not been completed in a timely manner. Design issues also seem to cause project disruption. In one project, the contractor attempted to install the proposed sewer and water lines. However, an unknown underground utility was encountered that halted the construction progress and resulted in submitting a claim.

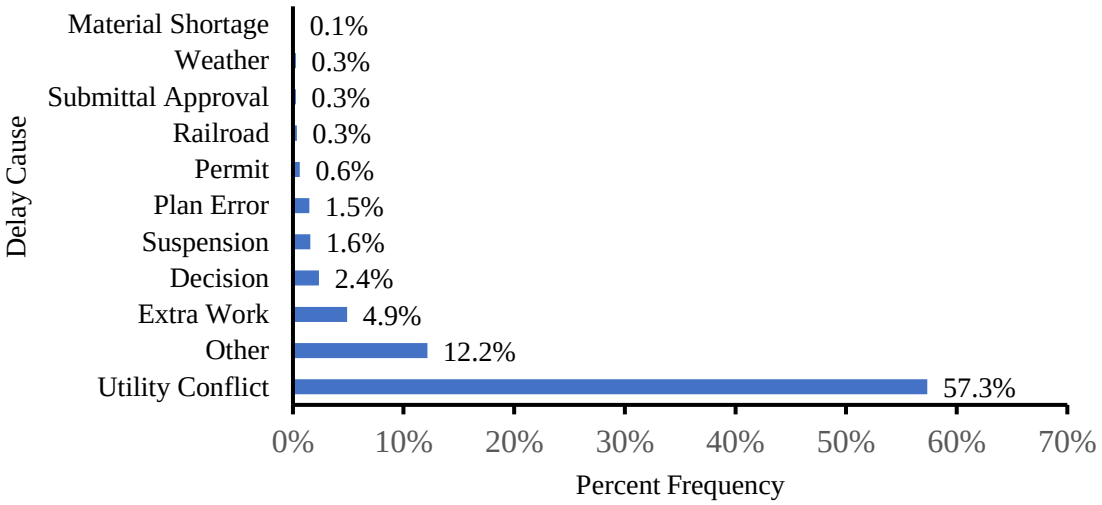

Figure 35. Percentage frequency of causes of utilities claims delays.

5.3.7. Cost Increase Due to Utilities Claims

Projects can vary in size, and thus, the cost of claims related to utilities can be normalized based on the bid amount, as shown in Equation (1).

$$Utility\ Claim\ Cost\ (\%) = \frac{Claim\ Amount\ Granted\ (\$)}{Bid\ Amount\ (\$)} \qquad (1)$$

The claims database contains 125 records of the amount granted that was due to claims related to utilities. Table 3 reports the statistics of these records and indicates that the associated cost of a utilities claim would increase the project's bid amount by 2.4% on average. Nevertheless, the standard deviation is around 10%, which indicates a broad spread of data with several outliers. In one claim, the contractor requested compensation due to additional work. The contractor had constructed a detour and installed additional traffic control and safety items, including sandbags. In another claim, the contractor was delayed due to a utility conflict and requested a time extension. The contractor also asked for additional compensation for idle equipment and laborers during the utility relocation period.

Table 3. Cost Increase Due to Utilities Claims

Number of Claims	125
Average	2.4%
Median	0.26%
Standard Deviation	10.27%
Mode	0.005%

5.3.8. Utility Type Analysis

The NCSU research team investigated utility type (i.e., power, gas, water, or electrical) via content analysis. Figure 36 shows the percentage frequency for each utility type. Water-related utilities are the most frequent type of utility involved in claims. In many instances, water line utilities are not shown on the construction drawings and are encountered during project execution. For example, a contractor was performing earthwork when the contractor encountered a water line. While the conflict was being investigated, the contractor was delayed from completing the remaining work and submitted a time extension claim. In numerous cases, however, the claim description lacks information about the utility type. For instance, one claim stated that the project completion date was extended by 228 days due to an availability date delay as a result of several utility conflicts. In this claim, the availability date was delayed because of utility conflicts, but the utility types were not specified.

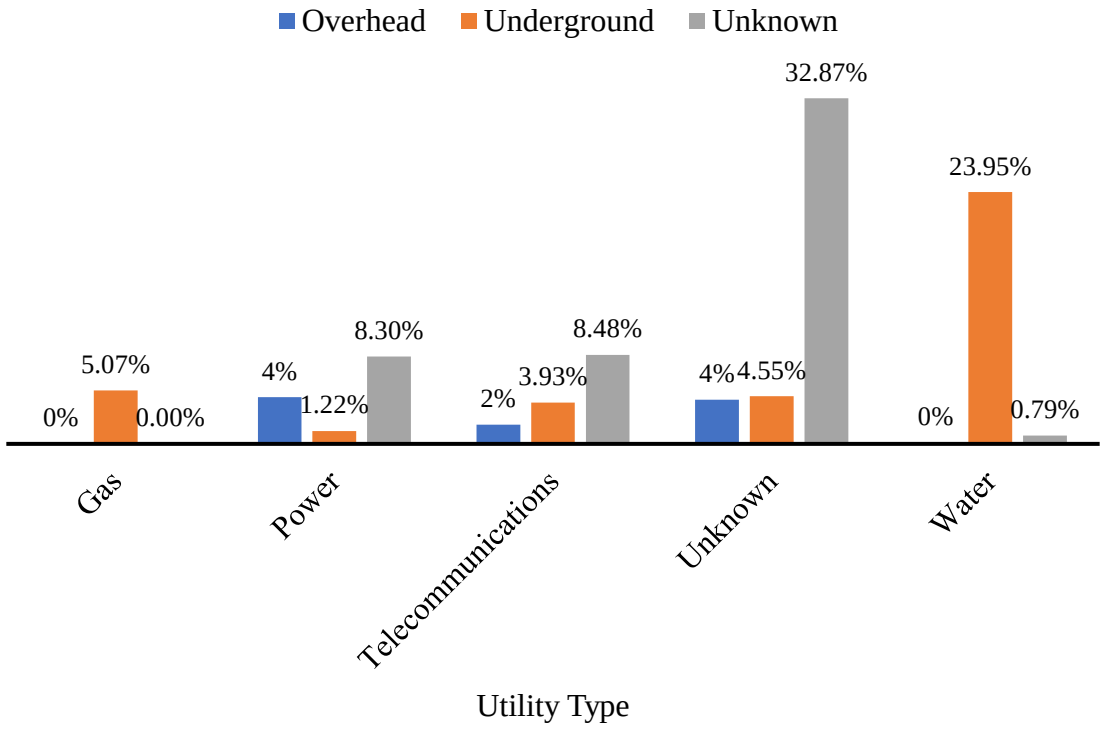

Figure 36. Percentage frequency of utility type, by location.

5.3.9. Utilities Claims Scenarios

In order to understand the events that led to utilities-related claims, the research team classified the claims into four categories: (1) expected, (2) no physical conflict, (3), unforeseen, and (4) unspecified. The ‘expected’ claims group includes delays due to utility relocation or improper relocation. The ‘no physical conflict’ category includes delays that were not due to physical issues but were caused by, for example, waiting for a new design or permit issues. The ‘unforeseen’ category includes cases where the existence of the utility infrastructure was not known or included in the project’s scope or drawings. Lastly, ‘unspecified’ includes claims records with limited or no information about the events that led to the claim. Figure 37 presents

the proportions of the utilities claims categories. Table 4 presents the most frequently reported scenarios that led to utilities-related claims.

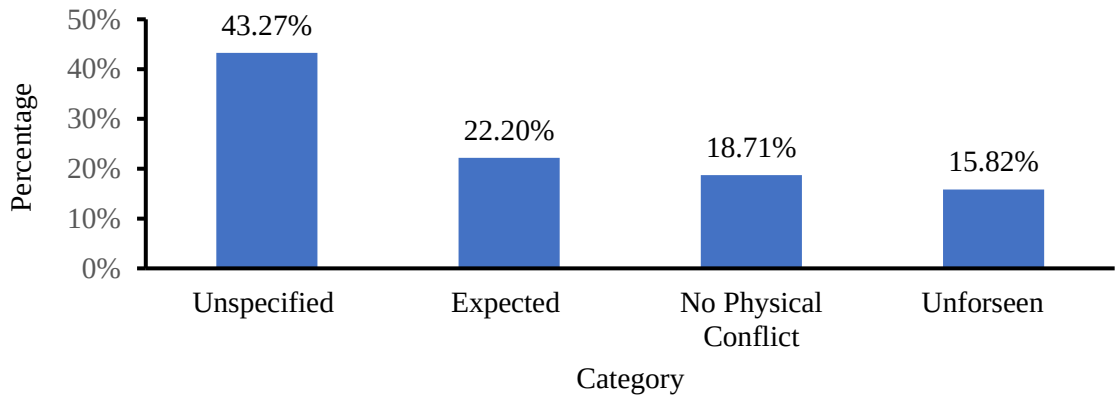

Figure 37. Proportions of utilities claims categories.

Table 4. Frequency of Events Leading to Utilities-Related Claims

Scenario	**Frequency**
Expected	
Delayed or Improper Relocation of Utility Lines → Delay in Project Availability/Mobilization	36
Delayed or Improper Relocation of Utility Lines → Delay in Project Availability/Mobilization → Delay in Structure Construction	20
Delayed or Improper Relocation of Utility Lines → Delay in Project Availability/Mobilization → Delay in Earthwork	17
Delayed or Improper Relocation of Utility Lines → Work Suspension → Delay in Earthwork	17
Unforeseen	
Design Error/Change → Work Suspension → Delay in Earthwork	14
Design Error/Change → Extra Cost/Overhead Cost	10
Design Error/Change → Work Suspension → Delay in Structure Construction	10
Design Error/Change → Work Suspension → Delay in Utility Construction	10
No Physical Conflict	
Delay in Connecting Utility Lines by the Provider → Work Suspension → Delay in Sign Installation/Activation	32
Concurrent Utility Project by Different Entity → Work Suspension → Delay in Paving/Resurfacing Operation	20
Permit Issues → Work Suspension → Delay in Utility Construction	10

5.4. Recommendations

This study of utilities-related issues and resultant claims provided an opportunity for the NCSU research team to investigate the causes of claims that often arise due to utilities-related problems and to provide insights to the Value Management Office and top personnel in the Utilities unit. The research team was unable to analyze many claims because the utility type was either unknown or unspecified. Efforts should be made to encourage submitters to provide adequate information because more data can help provide better analysis results in the future. In addition, the NCDOT could consider implementing some of the best management practices and incentives that are reported in the literature. Finally, the NCDOT can partner with the NCSU research team to conduct a thorough study to develop a list of tailored best practices and incentives to aid in better utilities coordination and improve project success where utilities are involved. Appendix O lists a few sample lessons gathered from end-users that relate to utilities issues.

6. DATA DASHBOARD

Lessons learned databases can have limitations despite having robust knowledge management practices in place. For instance, a lessons learned database can run the risk of becoming obsolete if the end-users do not find much use for it or find it cumbersome owing to the additional burden it places on their daily activities (Ganopol, et al., 2017). Technology can play a vital role in ensuring that organizations can obtain end-users' buy-in to use knowledge management sources (Rezaei, Khalilzadeh, & Soleimani, 2021). Organizations increasingly rely on business intelligence tools to keep track of resource usage in terms of maintaining the continuity of end-users' contribution to innovation. Visual data representations of such information derived from commercially available tools such as Tableau, Power BI, or Microsoft Excel can yield the real-time status of a database for storing, retrieving, and reusing knowledge regarding construction projects. Most of the extant literature about the use of such robust visualization tools for construction projects focuses on improving communication among stakeholders by visualizing project control data using 'building information modeling' (Ho, Tserng, & Jan, 2013) (Mehrbod, Staub-French, Mahyar, & Tory, 2019) (Li, Shen, Wu, & Yue, 2019) (Lin & Golparvar-Fard, 2020).

The NCSU research team used a novel technique to create a web data dashboard using Tableau, a commercially available and popular data visualization tool, to monitor the status of the newly developed knowledge repository program, CLEAR. The dashboard's designs were mapped out through extensive consultation with the key stakeholder of the CLEAR program, i.e., the gatekeeper. Key dashboard visualizations include the display of top-rated lessons learned and best practices, NCDOT's Innovation Culture Index data, and the CLEAR website analytics data, such as most visited page views and temporal aspects of webpage usage. This real-time information display helps to disseminate useful information to facilitate decision-making and execute appropriate interventions in addition to encouraging end-user participation in the CLEAR program. In addition, this data dashboard is anticipated to foster enhanced knowledge sharing among end-users and encourage internal organizational innovation.

This Section 6 describes the effort to develop the data dashboard specifically to enable the gatekeeper to monitor several key components, viz. lessons learned/best practices information, an organizational culture index, and website analytics. These key components are described according to visualizations created using Tableau Desktop. With regard to end-users sharing knowledge via CLEAR, the data are stored using Microsoft Access as the back-end database and SharePoint as the front-end. This set-up allows the gatekeeper to pull up information contained within the MS Access database in Microsoft Excel format to be input into Tableau. This functionality also helps to update the Tableau visualizations dynamically in real time with appropriate changes of user inputs into CLEAR.

Figure 38 shows the visualization that details the number of lessons learned recorded from the 14 NCDOT divisions, which are color-coded. A similar visualization is also available for the number of best practices recorded. An open-source .json file that contains the NCDOT divisional boundaries has been added to the Tableau data source to represent accurate boundary separations between any two NCDOT divisions. This visualization of the number of submissions based on divisions will help the gatekeeper to keep track of high- and low-performing divisions in terms of submissions and help to determine if any additional training resources are needed to increase submissions from those divisions that submit few submissions. In addition, as of the time of this writing, two of the 14 divisions have yet to record a single submission; thus, these two divisions have been left blank in Figure 38.

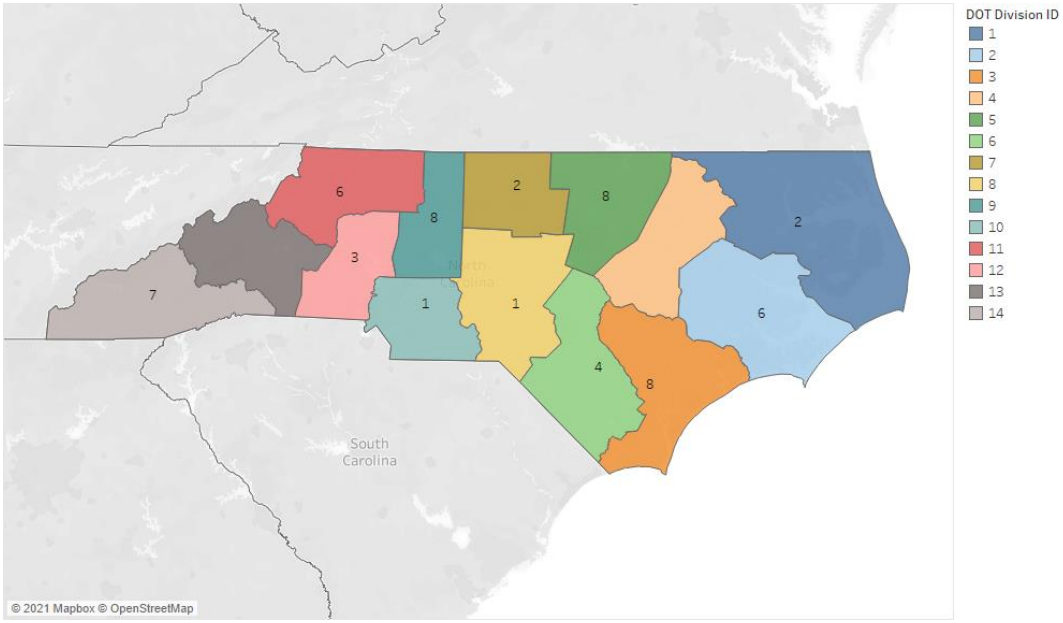

Figure 38. Division-wise distribution of lessons learned.

6.1. Innovation Culture Index (ICI) Data

The primary objective of CLEAR is to bring about organizational innovation. Extant research lists organizational culture as an important factor to sustain successful knowledge management efforts (Rezaei, Khalilzadeh, & Soleimani, 2021). Moreover, in non-profit governmental

agencies such as state DOTs, overcoming the general knowledge sharing barriers can be challenging but rewarding at the end (Henard, 2020). To this effect, the NCSU research team prepared a short anonymous survey (which took about two minutes of the respondents' time) to gauge NCDOT personnel's perception of the current culture of innovation (NCDOT Survey, 2020). The survey had 22 questions that covered a variety of topics about how the respondents felt about the culture of innovation within the NCDOT. Most questions were rated on a Likert scale, with 1 being the lowest and 5 being the highest. The gatekeeper is able to keep track of the mean values for such Likert-scale based questions to identify the bottom three questions with the lowest mean responses. This information will help the gatekeeper make appropriate interventions, including possibly organizing training sessions to improve the culture perception among end-users. Figure 39 shows a sample representation of a few questions in this survey.

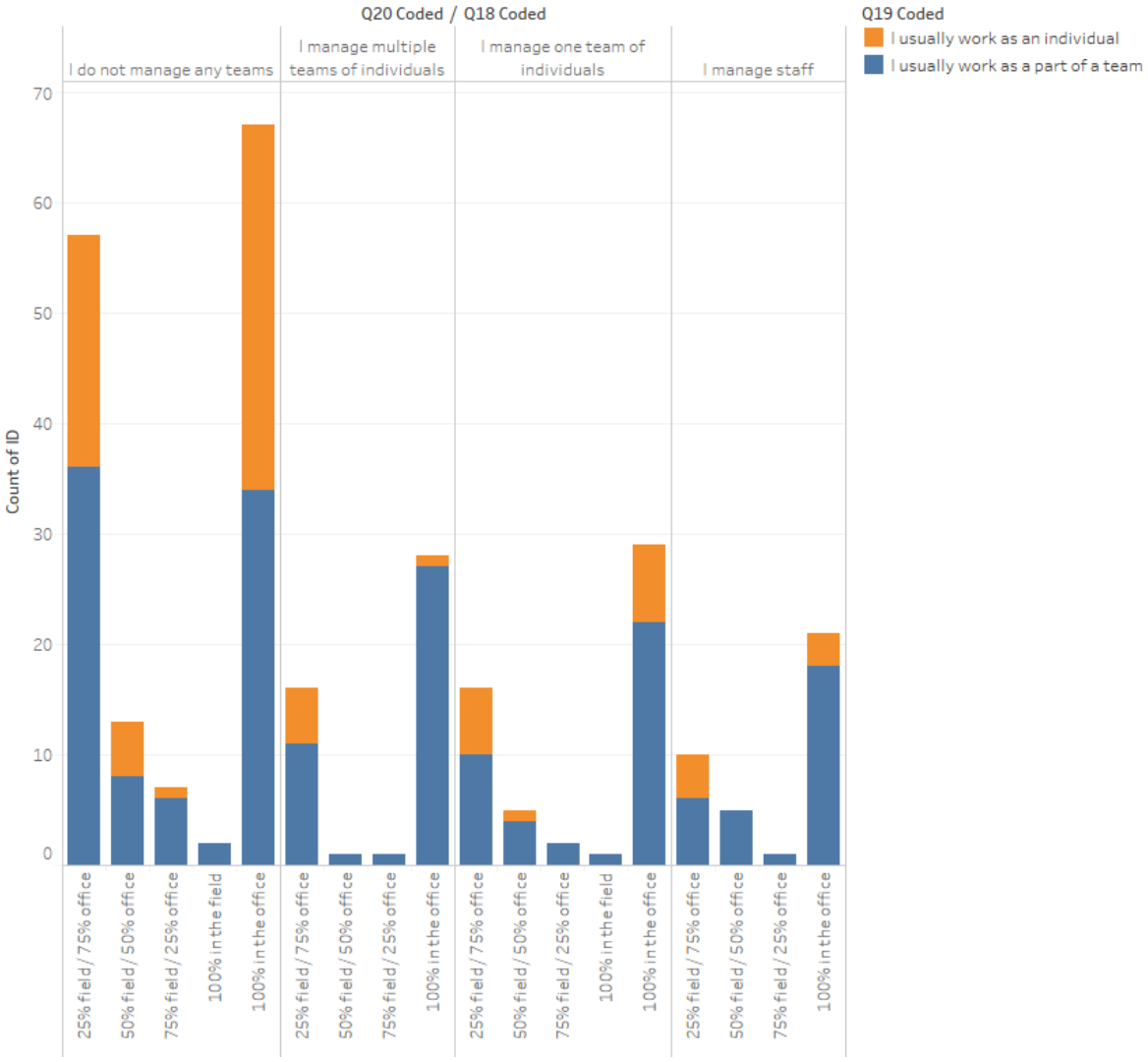

Figure 39. Typical job responsibility data obtained from Innovation Culture Index survey *(NCDOT Survey, 2020)***.**

6.2. Website Analytics

Monthly data about website traffic that detail the number of visits to CLEAR pages, time of day, and location of access can be obtained from the NC DIT. Based on this information, the data dashboard displays information about end-users' usage of the CLEAR program so that the gatekeeper can make any necessary interventions. For example, Figure 40 shows the mean hourly usage of CLEAR website data. As shown, the maximum website traffic is recorded between 9 AM and 10 AM. Thus, this window would be an appropriate time for the gatekeeper to upload any relevant files for end-users to access in order to maximize its viewership. Conversely, 3 PM has the lowest traffic during regular work hours, so this time would be appropriate for the gatekeeper to perform any necessary cleaning or modifications to the CLEAR data.

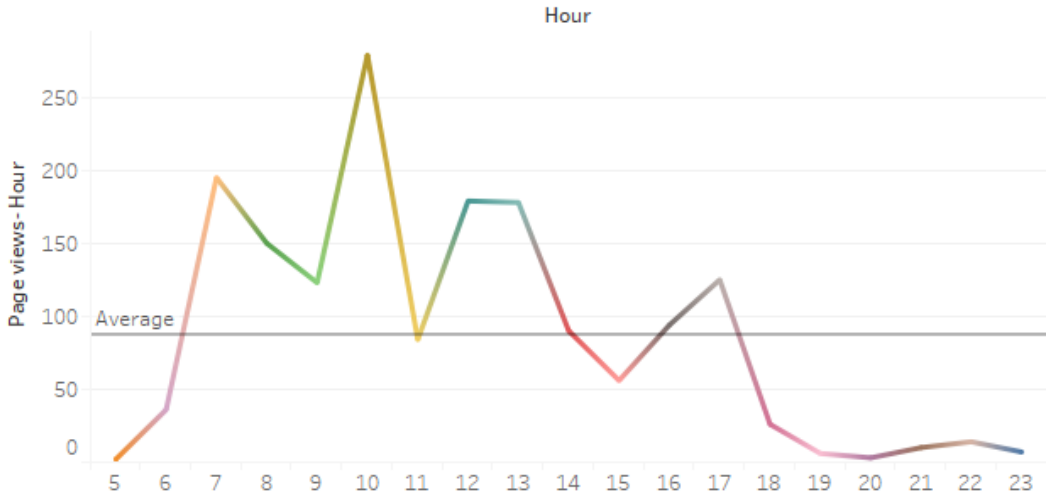

Figure 40. NCDOT website data based on mean hourly trends.

Appendix P provides a detailed record of the visualizations generated for the gatekeeper and serves as the data dashboard SOP. To ensure the longevity of CLEAR, this data dashboard will help the gatekeeper of the program, viz. the Value Management Office within the NCDOT, to periodically monitor the CLEAR data using effective data visualizations. In addition to helping to institutionalize knowledge, this data dashboard also will play a crucial role in identifying and reducing repeat mistakes on projects, thereby leading to enhanced organizational workflow processes.

7. ARTIFICIAL INTELLIGENCE (AI) MODEL

A successful lessons learned program is one where end-users are able to make effective use of the knowledge stored within the repositories for future projects. Numerous databases have become defunct for want of end-users to embrace and use them. Dalton (Dalton, 2013) (2013) states that organizations find it increasingly difficult for end-users to look into and extract knowledge from these lessons learned databases and analogizes the situation as a black hole where information is lost forever, rendering all previous efforts useless and risking repeat

mistakes over extended periods of time, thus causing financial loss. The dominant mode for knowledge extraction from lessons learned databases is a keyword-based search. This method requires exact words to be specified in the lessons learned narrative for extraction. The choice of keywords is up to the user and determines the quality of relevant retrieved lessons learned. Lessons learned do not directly incorporate the entire context of the project, which includes a variety of factors (location, environment, materials, timeline, resources, etc.). This research used the latest advances in computational language models to address this challenge.

Machine learning systems in general, and natural language processing in particular, require a vast amount of input data in order to train effective models. The NCSU research team curated a collection of transportation construction texts from a variety of sources. This collection of texts contains over four thousand documents and over one and a half million words. The texts come from the CLEAR database (both lessons learned and best practices), a sample of eight NCDOT projects, the NCDOT construction manual, several textbooks, and several thousand claims and change orders for NCDOT projects. This methodology allowed the NCSU research team to train a Doc2Vec model (Le & Mikolov, 2014), which is a statistical language model that has a basic understanding of the nuances of transportation construction text via the statistical co-occurrence of terms learned from the training corpus of relevant documents in a given domain.

In order to process all the documents, the NCSU research team used Google's Tesseract optical character recognition software (Smith, 2007) in order to parse text out of PDFs that had been scanned or otherwise missing the markup needed to extract text directly. The team then used a custom tokenization run-time to parse the results into a stream of tokens (words) per document. For other sources, the researchers used a combination of loading directly from the CLEAR database and scripts to crawl manuals from NCDOT web pages. Figure 41 shows the methodology adopted to suggest the ranked list of lessons learned/best practices (LL/BP in the figure) from the corpus of NCDOT project documents.

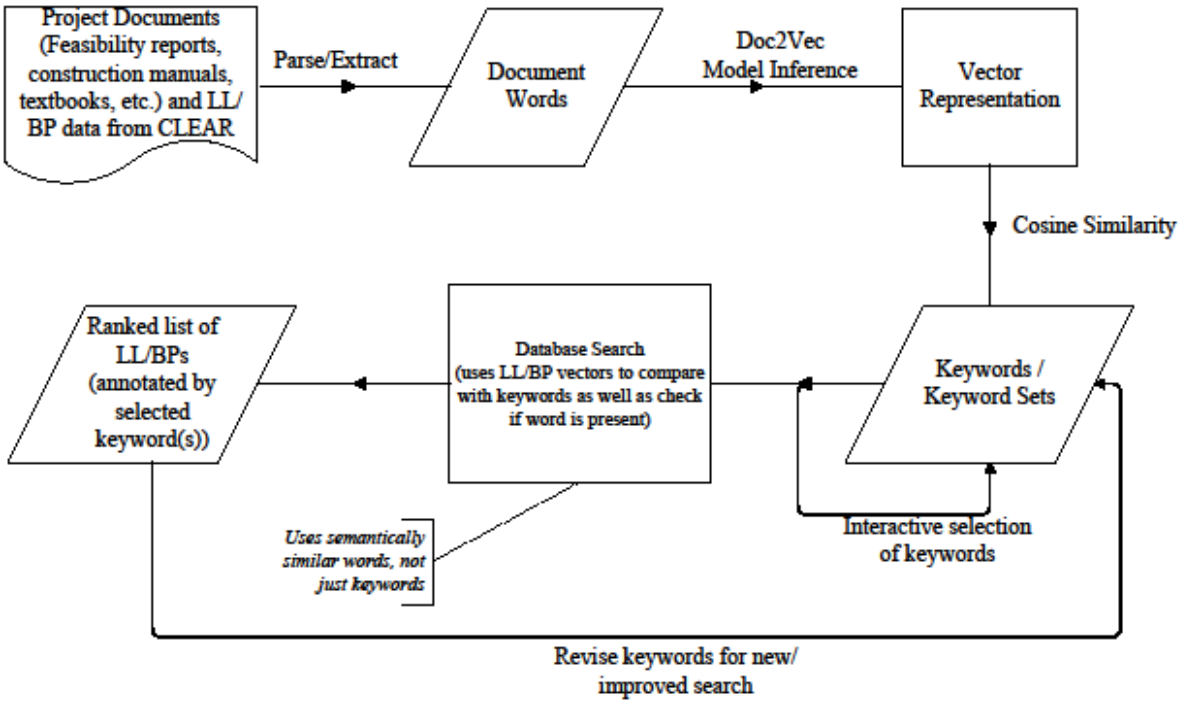

Figure 41. Steps involved in creation of artificial intelligence model.

Doc2Vec simultaneously trains continuous vector representations of documents and words. The resulting vector space has useful semantic properties, such as a measure of similarity that uses cosine distance. In addition, vector addition and subtraction yield intuitive semantics. One of the canonical examples is *Paris* is to *France* as *Berlin* is to *Germany*, which can be computed using vector arithmetic.

$$V_{Paris} - V_{France} + V_{Germany} \approx V_{Berlin}$$

The developed artificial intelligence (AI) model contains transportation construction-specific information, such as *Power* is similar to *Transmission*, *Copper*, *Storing*, and *Energy*. Using the vector addition, *Power* and *Overhead* combine to be similar to *Powerline* and *Transmission*.

$V_{Power} + V_{Overhead} \approx V_{Powerline}$ or $V_{Transmission}$

Using subtraction shows that the sense of *Transmission* without the context of *Power* is more similar to *Axle*.

$$V_{Transmission} - V_{Power} \approx V_{Axle}$$

These examples help illustrate that the AI model understands the different contexts of common words found in transportation construction text. This feature is one of the advantages of curating a corpus instead of using a more generic pretrained model. Other semantic examples would be

the model's ability to understand that *Interchanges* and *Intersections* are related and that *Fiberoptics* is related to *Roadways*.

The NCSU research team tagged documents in the Doc2Vec model both uniquely and by their source. This effort led to vector representations for a project and the individual documents that the project contains. For example, a project's feasibility study can be distinguished from its environmental impacts.

As the goal of this project is to facilitate access to lessons learned and best practices, the NCSU research team utilized the developed AI model to facilitate the process of identifying which lessons learned and best practices are relevant to a project. The general flow of the system is to upload the documents (primarily the feasibility study) for a project. Next, the system extracts text from the documents and uses the language model to generate vector representations for each document and the overall project. This representation is used to generate a set of keywords based on cosine similarity. Each keyword corresponds to a larger set of similar words, such as *Utility*, *Utilities*, etc., which are specifically tagged if they are present in a document, or merely inferred as being related. A prime example would be the model understanding the semantic similarity between *Interchanges* and *Intersections*. This ability allows far larger relevant sets to be detected than a manual keyword selection approach, or an approach that only returns keywords that are present in a document. This process is interactive where the user (typically a project manager or other staff) can add or remove keywords based on the user's understanding of the project and goals for using the system. Table 5 provides word similarities that can be used for keyword sets. Note that both the keywords and notable similar words exclude morphological variants, which the model also marks as similar.

Table 5. Word Similarities Used for Keyword Sets

Keywords	**Notable Similar Words from Model**
Resurfacing	Grading, Widening, Pavement, Reclamation, Undercut
Power, Powerlines	Transmission, Copper, Energy, Storing, Electricity, Overhead
Underground	Leaking, Tunnels, Powerlines
Water	Sewer, Agitator, Discharges
Water, Sewer	Leaking
Soil, Contamination	Unstabilized, Toxic, Siltation, Hazardous
Widening	Roundabouts, Interchange, Improvements, Resurfacing
Road, Roadway	Avenue, Rd, Roadbed, Vehicles
Fiber, Fiberoptic	Cable, Utilities, SCP (fiber technology), YAGI (brand of cable), filtering, roadways

Beyond its ability to identify similar words, the model is robust in finding common misspellings. Consider, for example, the word *Utility*. Documents may contain the misspellings *Utilitiy*,

Utiltiy, and *Utlility*, but because these words are all used in the same context and manner as the correct spelling, *Utility*, the model correctly infers that these words are semantically the same.

In the final step, the system automatically searches the lessons learned database for the selected keyword sets. This step returns a ranked order of lessons learned and the respective relevant keywords. This automatic search allows the user to determine quickly which keywords are the most relevant, ideally making for a better user experience. The user is also free to revise selected keywords and see updated results. The database search utilizes the same language model that is used to generate the keywords, which allows the lessons learned to be matched to projects/keywords even if the specific word is not present. An example is a lesson learned about *Power* and *Powerlines* that potentially matches with the keyword *Utility* because these words are related terms in the language model, even if none of these words is present in either the project documents or a particular lesson learned. This increased flexibility greatly enhances the ability of the AI model to make accurate recommendations without the writers of the lessons learned having to identify keywords or the users having to fine-tune keyword searches. These improvements and reductions in user burden will make CLEAR more intuitive and thus increase the likelihood that project teams will find pertinent information, thereby saving money and time for the NCDOT.

7.1. Significance of the Artificial Intelligence Model Applied to CLEAR

The research team used both the trained model and a more traditional string search algorithm for searching the lessons learned database. The researchers reviewed the search terms entered and first scanned the entire collection of lessons learned/best practices for exact word and phrase matches. Next, they loosened the criteria and searched for substring matches. These cases are important to distinguish, particularly in a technical language context, because, for example, an exact match for *Road* is significant but a substring match for *Road* in *Railroad* would yield incorrect results. At this stage, the language model begins to plays a role. After prioritizing exact matches to match the expected behavior for users, the researchers used the language model to look at the sense of each word individually, which allowed the distinction to be made between *Road* matching *Roadway* (relevant) and *Road* matching *Railroad* (not relevant). The research team also took advantage of the Doc2Vec model's ability to model documents to compare the semantic meaning of the input search phrase with the semantic meaning of the lessons learned/best practices. For example, consider that *Wet Utilities* has a more specific meaning than *Utilities* by itself. In this example, matches for *Utilities* only would not correspond to the semantic intent of a search for *Wet Utilities*. In the end, a final list of results can be derived from the combined ranking of exact, partial, and language model scores (Banerjee, Potts, Jhala, & Jaselskis, 2021).

8. CONCLUSIONS

Lessons learned can be an effective mechanism to document and retrieve wisdom gained from

previous projects and to apply this knowledge to future projects to attain best practices and find solutions. The CLEAR lessons learned/best practices database will facilitate improved coordination between inter- and intra-departmental personnel within the NCDOT. The overall aims of CLEAR are to achieve superior design performance and thus reduce the frequency and impacts of change orders, enhance cooperation, and ultimately accomplish improved operational performance. Two important considerations here are that (1) project teams are dynamic and are seldom composed of the same individuals for different projects and (2) the aging workforce will retire before their knowledge can be documented. In either case, a significant amount of wisdom would be lost if this information were not documented in a proper lessons learned/best practice database. The CLEAR program will provide scope for the next generation of NCDOT personnel to implement these lessons learned/best practices to realize desired project goals.

This research effort resulted in an internal-only web-based database that is housed within the Connect NCDOT SharePoint portal and contains information about lessons learned and best practices from ongoing or previous projects. Authorized personnel now have the ability to input data as well as search for information through this web-based database. The CLEAR training materials, including SOPs and training videos, will assist NCDOT personnel to contribute effectively to the database. The CLEAR program is expected to encourage end-users to share knowledge gained on projects and search for relevant lessons using the search function.

In addition to creating and maintaining the database, the data dashboard and AI model are expected to augment the end-user's willingness and desire to contribute to this knowledge repository program, thereby leading to the ultimate success of the CLEAR program. The data dashboard will play a crucial role in identifying and reducing repeat mistakes on projects by visually displaying the status of preselected metrics. The AI model will map the essential keywords/sets to document text and suggest the most relevant and necessary documents that are semantically related to such automatically detected keywords extracted from these project documents. In the long run, this automated approach is expected to reduce the burden on the end-users to look for relevant content because it automatically suggests the most relevant documents and sources to peruse the knowledge stored. Likewise, project teams across divisions, units, and departments at the NCDOT will greatly benefit from this rich and robust knowledge database. Importantly, the CLEAR program will help the NCDOT to achieve enhanced organizational workflow processes and promote internal innovation to maintain its competitive edge.

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10. LIST OF APPENDICES

Appendix A. Interview Guide to Identify Trends and Database Fields

North Carolina Department of Transportation Post Construction Assessment Program Data Collection Guide

Introduction: The purpose of this data collection guide is to gather information that pertains to trends, lessons learned, and end-user preferences for the design of a lessons learned/best practices database for the North Carolina Department of Transportation (NCDOT). The ultimate goal of this database, referred to as CLEAR (Communicate Lessons, Exchange Advice, Record), is to improve future project design, construction, and maintenance performance. The information provided in this database will be used to adjust future cost estimates, update standards, and change policies in an effort to improve the NCDOT as an effective and efficient organization to serve the public.

Confidentiality Statement: This research strictly follows North Carolina State University's (NCSU's) policy for data confidentiality. All data provided to NCSU in support of research activities by participating organizations are to be considered confidential information. The data provided by participants will not be communicated in any form to any party other than the NCSU researchers affiliated with this project.

Consent: Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate, or to stop participating at any time. You can choose to skip any question that makes you feel uncomfortable. Minimal risks are associated with participation in this research. The results of this interview guide will be kept confidential. Your participation will give the NCSU research team valuable information that will help the team identify key trends and lessons learned that will be helpful in improving the performance of future NCDOT projects. By providing answers, you are consenting to be a part of this research project.

☐ I agree

Contact information for follow-up questions: If you have any questions or require further information about this questionnaire or the research project, please contact one of the academic researchers: Dr. Edward Jaselskis (ejjasels@ncsu.edu) (Principal Investigator), Siddharth Banerjee (sbaner22@ncsu.edu) (NCSU doctoral student), or Abdullah Alsharef (afalshar@ncsu.edu) (NCSU doctoral student).

Definitions:

- **Gatekeeper:** The gatekeeper is the person who is responsible for reviewing and approving valid lessons to be included in the lessons learned/best practices database. For this project, the Value Management Office at the NCDOT will serve as the gatekeeper.
- **Administrator:** The administrator of the database is responsible for uploading the verified lessons learned files from the Value Management Office into the database and periodically removing unnecessary information.
- **End-user:** An end-user is responsible for making use of the lessons learned and providing perspectives on the new lessons learned based on experience.

- **Lessons learned:** Lessons learned is the knowledge gained from one's own project experiences as well as the experience of others (Project Management Institute, 2004).
- **Lessons learned database:** A lessons learned database is a comprehensive collection of lessons learned data that is organized for convenient access for improving future project performance (Dictionary.com--partial).
- **Trends:** Trends are used to identify potential areas where process improvements would be beneficial (NCDOT Post Construction Assessment Program document).

I. Respondent Background

1. Please identify yourself as an NCDOT employee or Consultant.
2. If you are an NCDOT employee, please provide your title (name not required) and Division.
3. How many years have you been working with the NCDOT? Non-NCDOT?
4. Which department are you affiliated with? What is your role within this department?
5. Have you worked in other departments within the NCDOT?
6. Which County, Division, and District have you worked with?

II. Trends and Lessons Learned

1. Please identify any trends or recurring issues within your specific area of responsibility that, if addressed, could improve NCDOT project performance.
2. Are there any best practices that you would like to share that could improve planning, design, construction, or maintenance procedures?
3. In order for the research team to explore trends and lessons learned, we would like to review documentation from past projects that include, but are not limited to, construction quality index reports, claims, supplemental agreements, pay items/quantities, diaries, and monthly project reports. Would you be able to provide the research team with such information? Specific information to be collected includes the following:
    a. Continuous quality improvement: Rating and comments for all parameters.
    b. Claims: Claim Description, Claim ID, Claim Status, Claim Type, Contract Bid Amount, Contract Number, Contract Status, Contract Type, Delay Cause, Federal Highway Administration (FHWA) Authorized Representative, FHWA Date, Issue Description, Issue ID, Issue Reason, Issue Specification, Issue Status, Issue Type, Resident Engineer, Time Granted, Time Requested, Time Unit.
    c. Supplemental agreements/contract adjustments: Contract Number, Contract Status, Contract Type, Deciding Job Title, Deciding Staff, Decision, Decision Comment, Decision Date, Description, FHWA Authorized Representative, Justification, Resident Engineer, Status, Total Amount, Type of Work.
4. Would your department or unit effectively use information obtained from similar completed projects?
5. What is your department's current practice for obtaining best practices regarding previous projects?

6. Is the current practice for obtaining useful information from similar completed projects effective? If not, how would you recommend improving the current practice for capturing information from completed projects?
7. Please share any additional thoughts regarding trends and lessons learned that could improve NCDOT project performance.

Lessons Learned Database End-User Preferences

Note: To facilitate the identification of preferences, the research team plans to show examples of other lessons learned databases (e.g., USDOT and Kentucky DOT).

1. The proposed lessons learned database is intended to capture and store lessons learned information and to allow NCDOT employees and consultants to search various lessons learned from the perspective of planners, designers, construction engineers, contractor engineers, and maintenance engineers.
    a. Please provide comments regarding your preferences for a lessons learned database to maximize its use.
    b. What would you like to see included that would increase your participation and use of a lessons learned database?
    c. What information that describes the lessons learned would be helpful (e.g., type and size of project, short or long version of the lessons learned, etc.)?
    d. What level of detail should be provided?
    e. The research team proposes to have searchable lessons learned displayed in a manner such that the end-user will be able to read through multiple initial descriptions based on search criteria (e.g., project size, location, trends, etc.). Once the end-user feels that a particular lesson is relevant, he/she will have the option to explore the full content. Does this approach seem appropriate or should the research team consider another approach?
    f. Would you prefer to arrive at lessons learned using drop-down menus under each category? If so, what categories or filters should be used? Alternatively, would you prefer another method (e.g., select project size → select project location → trends → and so on…)?
2. Please provide any other ideas or suggestions for creating the lessons learned database.
3. How familiar are you with MS Access and SharePoint? Do you find these platforms easy to use? What are some of the drawbacks of these platforms?

Information Technology (IT) Department

- Database specifications
    - What is the most appropriate software to use to develop the lessons learned database?
    - What are the steps involved in developing and implementing such a software application for the NCDOT website and server implementation? How long does this process usually take?
    - If photos or videos are used in the lessons learned database, would the user be restricted to an upper limit for the size of images that can be uploaded?

    - Could hyperlink text within entries be provided for users entering lessons into the lessons learned database?
    - Has the IT Department built and published similar databases?
    - Are these databases still functioning? If not, what are the reasons?
- Access for non-NCDOT employees
    - How will design consultants and other non-NCDOT personnel, including contractors, be able to gain access to this database?
    - How can outside consultants enter their own lessons learned to the database?
- Support
    - What kind of support can the NCDOT Value Management Office team expect from the NCDOT IT Department during the development phase, piloting phase, and long-term implementation phase?
    - What kind of assistance can the research team expect from the IT Department as the lessons learned database is developed and piloted?
    - What level of training support can the IT Department provide?
    - What are the procedures for upgrading the platform for the database after a certain number of years (e.g., upgrade to a new version of a software product)?

Appendix B. Initial CLEAR Program Data Entry Fields

The initial information gathered from end-users helped the North Carolina State University research team prepare the first draft of database fields to collect information about lessons learned/best practices. These fields are as shown.

CLEAR Lessons Learned/Best Practices

Date Observed

If occurred multiple times, choose one date of occurrence

Calendar Date

Location *

(Example: Intersection of HWY109 and US14 or 1 South Wilmington Raleigh NC or Near Exit 70 on I-85)

Division

Populated based on the Division Selected above

County

Office *

Name *

Email *

(Name, Phone, Email id) – For Gatekeeper to get back in case of needing additional information. Contact information will not be shared.

Phone *

Description of Existing Condition

Description of Issue (what was discovered – unforeseen condition?, key factors involved, uniqueness of the situation) – 200 characters. Add photos describing the existing condition

Attach Issue Reference Documents and Photos

Reference documents: pertinent drawing standards, plan details, correspondence, contract language, etc. (important to tie this description to tangible project documents)

Issue Details - Provide more details and any project cost/schedule impacts

Lessons Learned or Best Management Practice

Solution to Solve Issue - Short description of the solution used to solve the problem - 200 characters. Add photos describing the lesson learned/best practice/solution to the problem

Attach Solution Reference Documents and Photos

Reference documents: pertinent revised plan details, correspondence,
Revised contract language, etc.

Select Disciplines (Check box to select Applicable Disciplines)

Applicable Disciplines

- ☐ Business Opportunity & Workforce Development (BOWD)
- ☐ Construction
- ☐ Design-Build
- ☐ Aviation
- ☐ Division of Motor Vehicles (DMV)
- ☐ Environmental Analysis
- ☐ Erosion Control
- ☐ Facilities Management
- ☐ Ferry
- ☐ Geotech
- ☐ Hydraulics
- ☐ Information Technology (IT)
- ☐ Local Projects
- ☐ Location & Surveys
- ☐ Materials & Tests
- ☐ Pavement Design & Collection
- ☐ Photogrammetry
- ☐ Procurement
- ☐ Project Management

- ☐ Public Transportation
- ☐ Rail
- ☐ Right Of Way
- ☐ Roadside Environmental
- ☐ Roadway Design
- ☐ Safety & Risk
- ☐ Maintenance
- ☐ Structures
- ☐ Transportation Mobility and Safety
- ☐ Turnpike Authority
- ☐ Utilities
- ☐ Equipment
- ☐ Project Development

Occurrences encountered
(Approximate number of occurrences or frequency this problem was encountered earlier)

Select Rating - Check box for Impact Rating

Impact Rating COST-Percentage of initial authorized amount

- ☐ A - Financial Loss > 50%
- ☐ B - 25%<Financial Loss>50%
- ☐ C - 10%<Financial Loss>25%
- ☐ D - 1%<Finaicial Loss>10%
- ☐ E - No change in Finances
- ☐ F - Financial Gain> 50%
- ☐ G - 25%<Financial Gain>50%
- ☐ H - 10%<Financial Gain>25%
- ☐ I - 1%<Finaicial Gain>10%

Impact Rating SCHEDULE-Percentage of initial schedule

- ☐ a - Schedule Addition > 50%
- ☐ b - 25%<Schedule Addition>50%
- ☐ c - 10%<Schedule Add>25%
- ☐ d - 1%<Schedule Add>10%

☐	e - No change in schedule
☐	f - Schedule Improvement >50%
☐	g - 25%<Schedule Improvement>50%
☐	h - 10%<Schedule Improvement>25%
☐	i - 1%<Schedule Improvement>10%

Qualitative Impact	☐	negative press
	☐	community impact
	☐	safety issues
	☐	innovative idea
	☐	third party impact
	☐	MPO/RPO impact
		Other

Check all that apply.
If Other selected fill in response below.

Other Qualitative Impact - Please fill this box

Project Information

Project Number	Dropdown list
Project No. If Not Available	
Contract Number	Dropdown list
Contract No. If Not Available	
Project Name If Available	Dropdown list
Project Name If Not Available	
Project Delivery	
Central Let or Division Let design?	

Supplementary Agreement Involved (If yes, please enter amount in terms of additional time and cost – obtain from supplementary agreement form)	
	Supplementary Agreement Form Info- Please fill details if Yes
Specification Year	
Mile Marker	
If applicable. If not, type in N/A. Project Type *e.g. bridges, road widening, maintenance, DOT Facilities etc.*	
Project Phase *Planning, Design, Bid letting, Construction, Maintenance etc.*	
Project Cost *Initial authorized $ amount.*	
Project Size *Initial number of miles*	
Project Schedule *Initial number of months*	
Claim Involved (if yes, please enter amount in terms of cost and schedule - determine from Active Claim Resolution Form.)	
	If Yes, please enter Active Claim Resolution Info

Appendix C. CLEAR Program Survey Questionnaire: Promoting the Use of the NCDOT CLEAR Lessons Learned Program

Introduction

The North Carolina Department of Transportation's (NCDOT's) Value Management Office is developing a knowledge and experience-sharing lessons learned database through the CLEAR (Communicate Lessons, Exchange Advice, Record) program that will allow you to provide input and retrieve valuable lessons and experiences from past projects. The purpose of this survey is to determine how best to prepare training materials for this new application and understand your motivation to use such a database. This survey is part of a research project collaboration between the NCDOT and North Carolina State University (NCSU).

Instructions

This survey is divided into three sections: (A) Respondent Background, (B) Training Preferences, and (C) Incentives to Use and Contribute to This Database. The survey is estimated to take approximately 5 to 10 minutes to complete. If you have any questions, please contact Omar Kadour Alainieh (okadour@ncsu.edu) or Dr. Edward Jaselskis (ejjasels@ncsu.edu).

Confidentiality statement

This research strictly follows NCSU's policy for data confidentiality. All data provided to NCSU in support of research activities by participating individuals are considered confidential information. The data provided by participating individuals will not be communicated in any form to any party other than NCSU authorized academic researchers and designated NCSU staff members.

Consent

Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate, or to stop participating at any time. You can skip any question if you so choose. Minimal risks are associated with participation in this research. The results of the survey will be kept confidential. Your participation will give the research team valuable information and the results will help the team address your training needs and long-term use of this program. By clicking 'I Agree', you consent that you are willing to answer the questions in this survey.

Section A: Respondent Background

A.1 In what year were you born? Please select from the following ranges:

a) 1945 and before
b) 1946 to 1964
c) 1965 to 1980
d) 1981 to 1997
e) 1998 and after

A.2 How many years have you worked for the NCDOT? Please type in this information.

A.3 What is your current job function?

a) Project Management
b) Design
c) Construction
d) Maintenance
e) Planning
f) Accounting
g) Administrative
h) Other (Please specify)

A.4 What is your current work-hour distribution (jobsite vs. home office)? Please select one response.

a) Office 100%
b) Office > 95%
c) 75% < Office < 94%
d) 50% < Office < 74%
e) Jobsite = 50%, Office = 50%
f) 26% < Office < 50%
g) 6% < Office < 25%
h) Office < 5%

A.5 What type of devices (if any) do you use during work hours? Select all that apply.

a) Smart phone issued for work
b) Tablet issued for work
c) PC computer
d) Laptop
e) Personal smart phone
f) Personal tablet
g) Personal laptop
h) None

A.6 How much time during the work day do you have access to the internet?

a) Less than 10 minutes
b) 10 minutes to 1 hour
c) 1 hour to 4 hours
d) More than 4 hours

Section B: Training Preference

B.1 What is your preferred approach to learn about new technologies, applications, or services? Rate the following approaches on a scale of 1 (least favorable) to 5 (most favorable).

a) One-on-one training
b) Group training (workshop) supported with materials available online
c) Comprehensive user manual available for online download
d) Video or series of videos
e) Combination of practical training and online videos
f) Other (please specify)

B.2 What is your preferred length of time when watching instructional videos online? Please select one response.

a) Less than 2 minutes
b) 2 to 10 minutes
c) 10 to 20 minutes
d) As long as it takes to cover the topic

B.3 For a training video, which option would you prefer? Please select one response.

a) Slide show presentation with screen shots from the program that explain the steps or different components
b) Recorded video of the computer screen as the steps are being applied

B.4 For the instructions in the training video, which option would you prefer? Please select one response.

a) Written (on screen) instructions
b) Voice-over instructions

Section C: User Incentives

C.1 During work, how often do you face a problem, situation, or opportunity for improvement that you think having previous knowledge about would have helped save time, money, or generally improved the outcome?

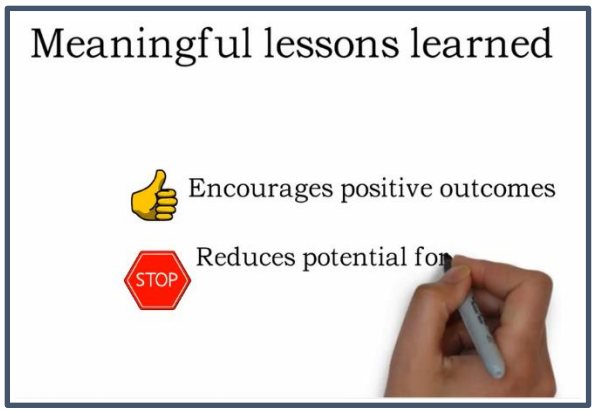
a) Daily basis
b) Weekly basis
c) Monthly basis
d) When starting a new position or job function
e) When starting a new project

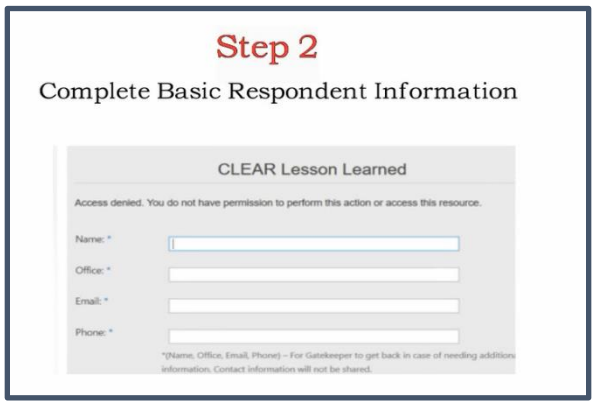
C.2 You would most likely provide input and retrieve data from the knowledge sharing program if. . . ..:

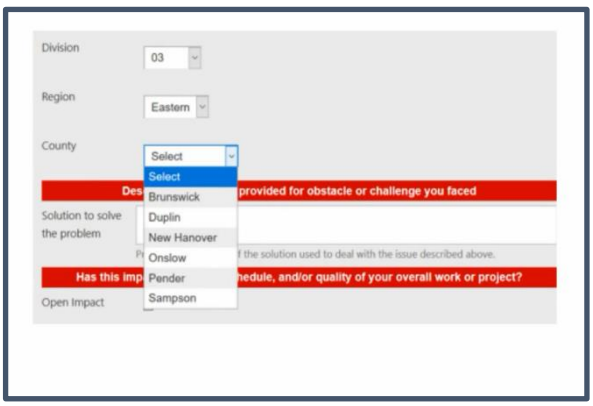
Thank you for completing this survey.

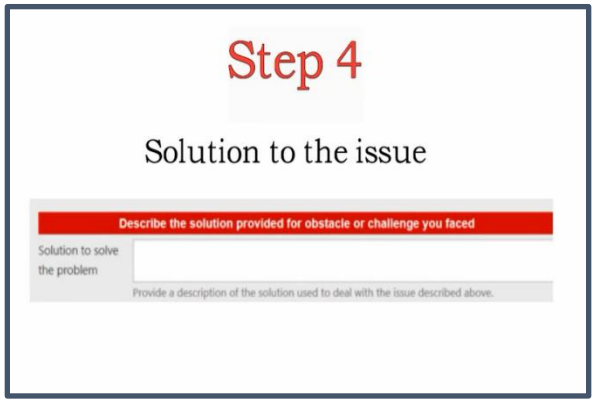
Appendix D. Screenshots from the CLEAR Program 'How-to' Videos

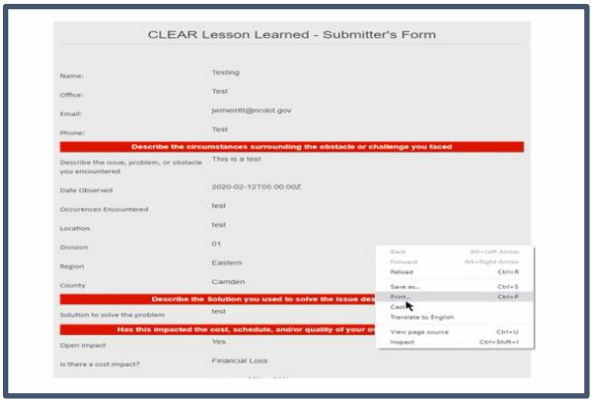
From the video 'How to submit a lesson learned to the CLEAR program database':











From the video ‘How to submit a best practice or an idea to the CLEAR program database’:

Best Practice/Idea

Effective procedure to obtain optimal results

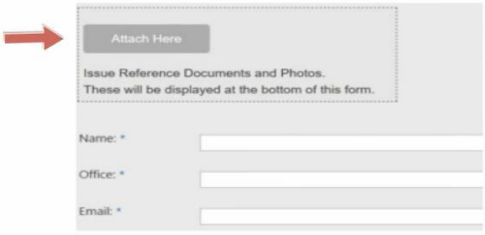
Cost/Schedule savings adopting innovative strategies

Step 1: Login

https://connect.ncdot.gov/site/lessons-learned/Pages/default.aspx

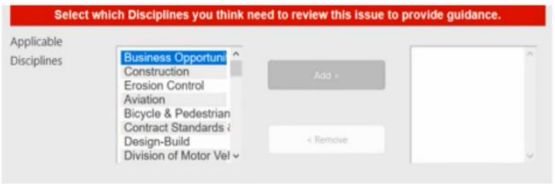
Step 2

Attach Supporting Documents



Step 5

Identify Applicable Disciplines



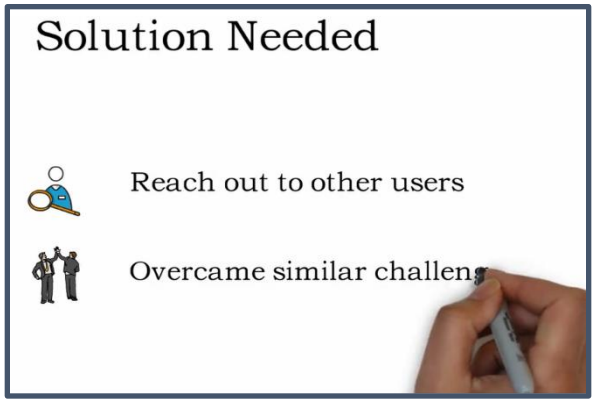
Step 6

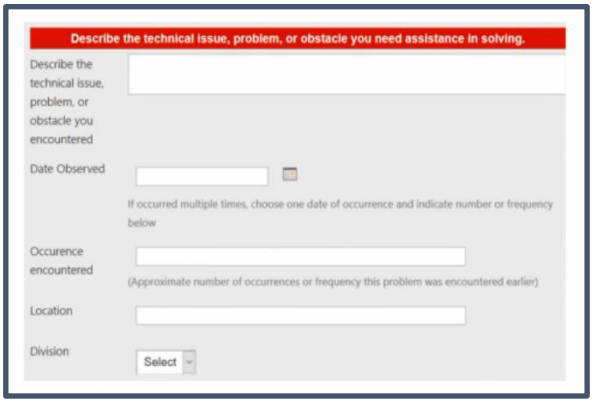
Next Steps

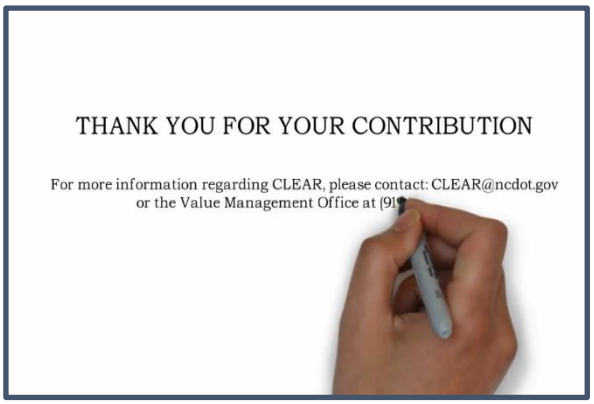
Step 7

Do you wish to be involved in further development (if needed)?

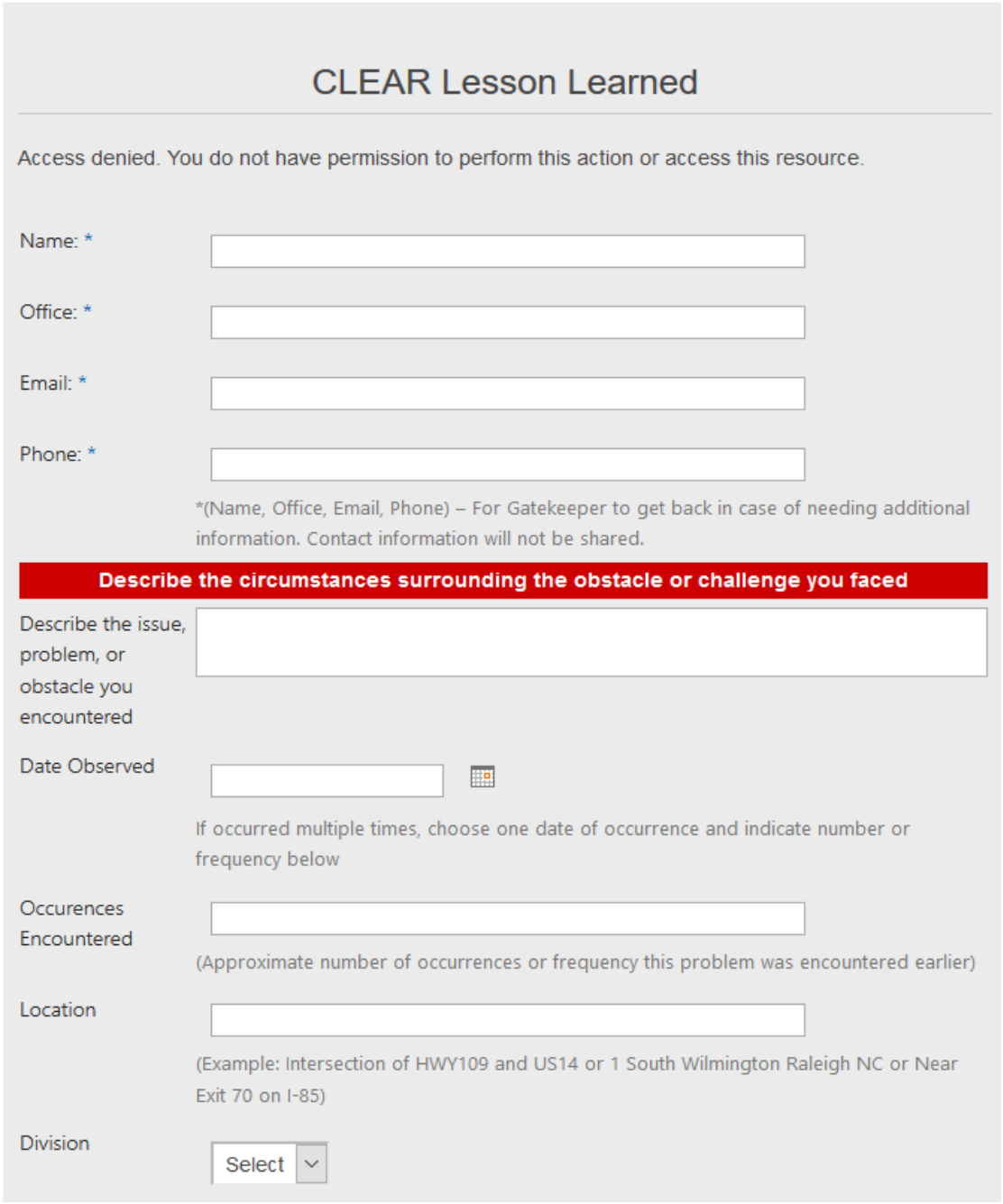
From the video ‘How to request a solution to an issue or challenge faced on projects using the CLEAR program database’:







Appendix E. Final CLEAR Lessons Learned Data Entry Form



CLEAR Lesson Learned

Access denied. You do not have permission to perform this action or access this resource.

Name: *

Office: *

Email: *

Phone: *

*(Name, Office, Email, Phone) – For Gatekeeper to get back in case of needing additional information. Contact information will not be shared.

Describe the circumstances surrounding the obstacle or challenge you faced

Describe the issue, problem, or obstacle you encountered

Date Observed

If occurred multiple times, choose one date of occurrence and indicate number or frequency below

Occurences Encountered

(Approximate number of occurrences or frequency this problem was encountered earlier)

Location

(Example: Intersection of HWY109 and US14 or 1 South Wilmington Raleigh NC or Near Exit 70 on I-85)

Division

Select

Describe the solution provided for obstacle or challenge you faced

Solution to solve the problem

Provide a description of the solution used to deal with the issue described above.

Has this impacted the cost, schedule, and/or quality of your overall work or project?

Open Impact ☐

Is this issue related to a construction or maintenance project?

Open related issue ☐

Select which Disciplines you think need to review this issue to provide guidance.

Applicable Disciplines

Business Opportur
Construction
Erosion Control
Aviation
Bicycle & Pedestria
Contract Standards
Design-Build
Disaster Recovery

Add >

< Remove

Do you have an idea on what next steps the Department should take to implement this submission?

Open next steps ☐

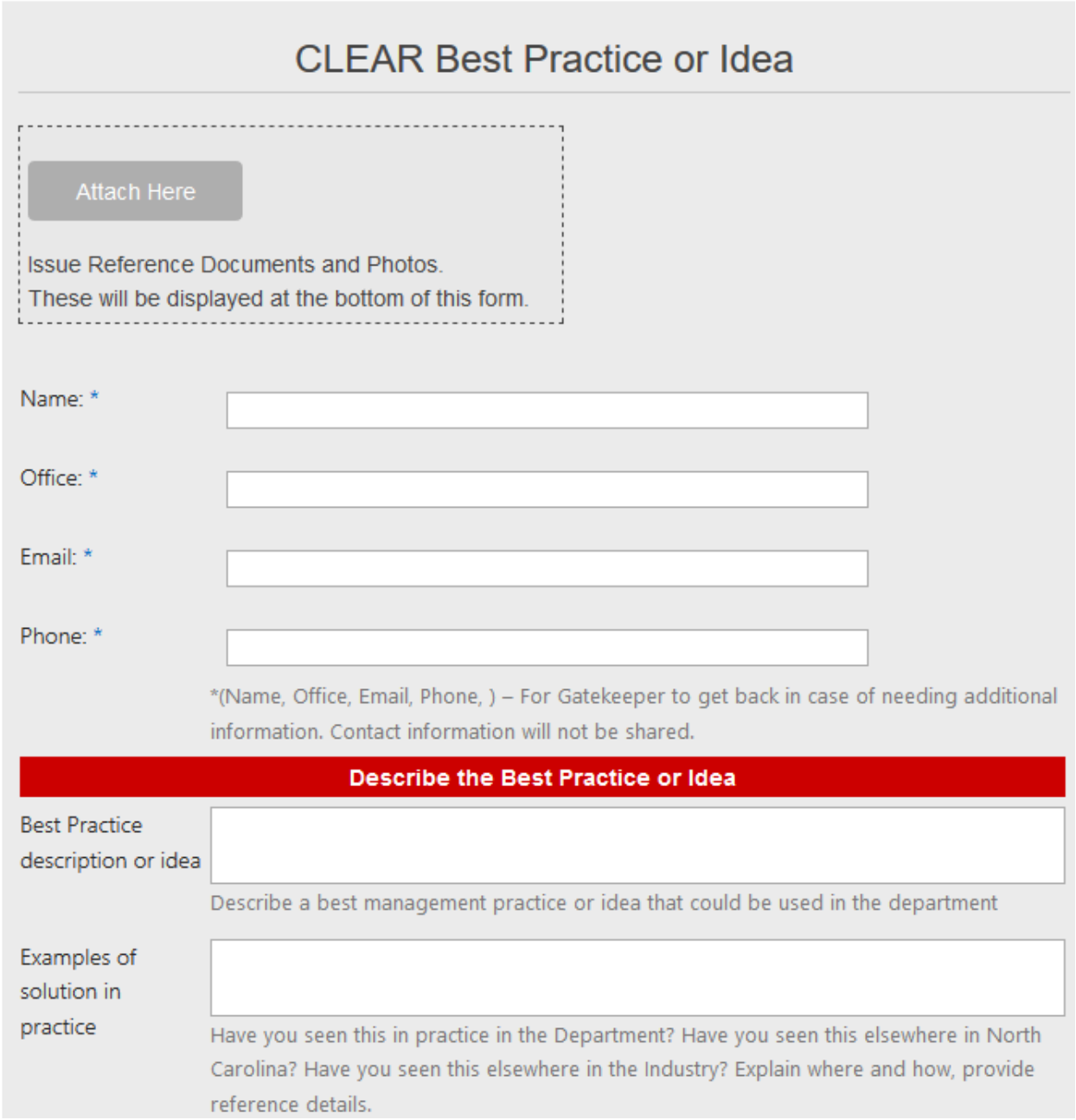
Should this lesson require additional development and implementation - do you wish to be a part of this effort?

Do you wish to be a part of this effort? Select

Title Lessons Learned

Submit

Appendix F. Final CLEAR Best Practice/Idea Data Entry Form



CLEAR Best Practice or Idea

Attach Here

Issue Reference Documents and Photos.
These will be displayed at the bottom of this form.

Name: *

Office: *

Email: *

Phone: *

*(Name, Office, Email, Phone,) – For Gatekeeper to get back in case of needing additional information. Contact information will not be shared.

Describe the Best Practice or Idea

Best Practice description or idea

Describe a best management practice or idea that could be used in the department

Examples of solution in practice

Have you seen this in practice in the Department? Have you seen this elsewhere in North Carolina? Have you seen this elsewhere in the Industry? Explain where and how, provide reference details.

Select which Disciplines you think need to review this issue to provide guidance.

Applicable Disciplines

Business Opportur
Construction
Erosion Control
Aviation
Bicycle & Pedestria
Contract Standards
Design-Build
Disaster Recovery

Add >

< Remove

Next Steps Results

Next Steps

- [ ] May result in a policy update;
- [ ] May require Specification Change or Special Provision;
- [ ] Possible New Product;
- [ ] Could be developed with a Lean Six Sigma Project;
- [ ] Additional research would further develop this submission;

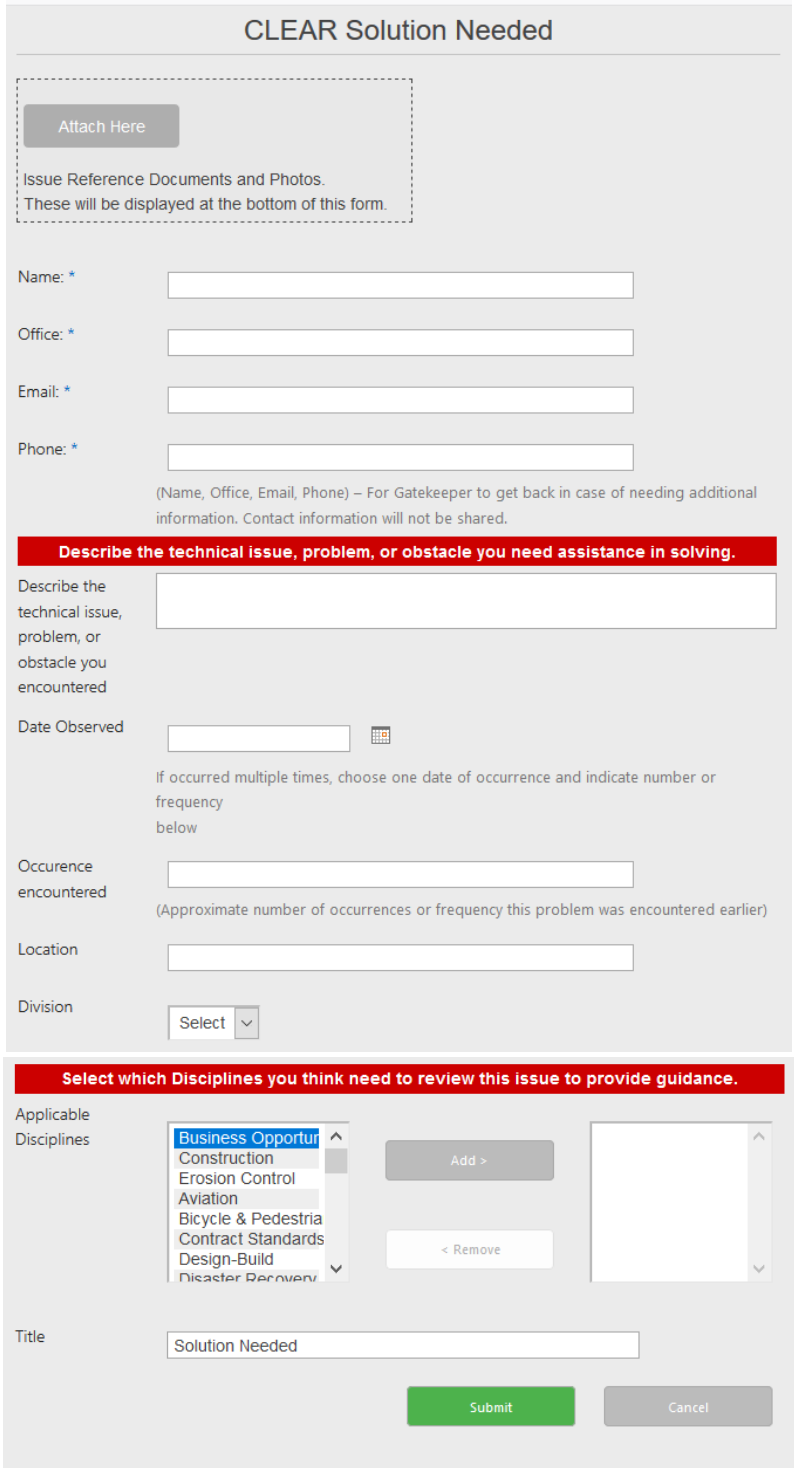
Other [ ]

Should this lesson require additional development and implementation - do you wish to be a part of this effort?

Do you wish to be a part of this effort? Select

Submit

Appendix G. Final CLEAR Solution Needed Data Entry Form



Appendix H. Standard Operating Procedures for End-Users to Enter Lessons Learned

The following guidelines provide direction for end-users to submit a lesson learned to the North Carolina Department of Transportation (NCDOT) CLEAR (Communicate Lessons, Exchange Advice, Record) database. A meaningful lesson learned promotes or reinforces positive outcomes and reduces or eliminates the potential for mishaps and failures in future projects. Only items with an asterisk are required, but providing more complete information will provide a more robust database. Thank you for your support of this important program.

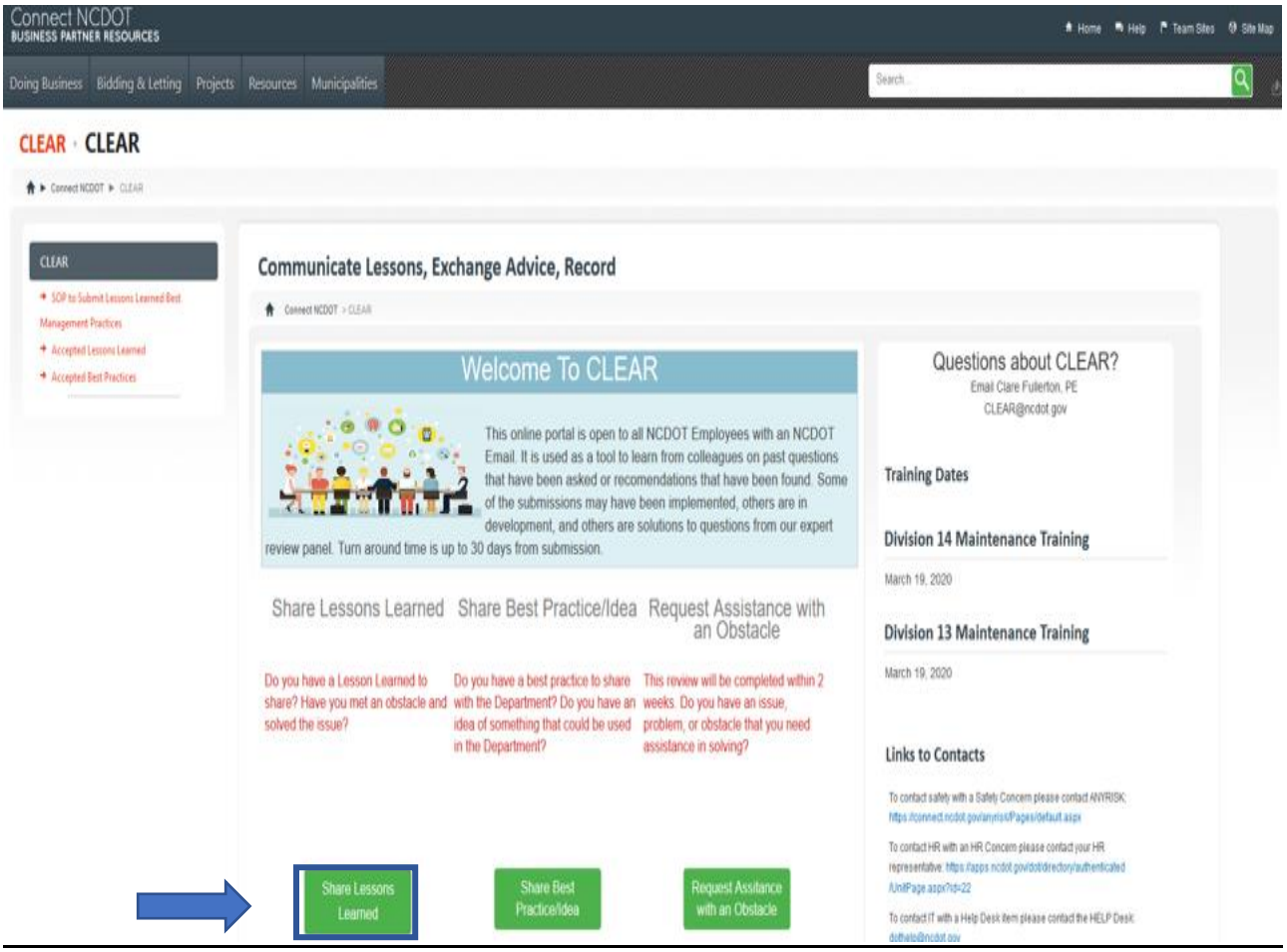
The following steps will help guide you through the submission process.

Step 1: **Log in.** Click on the following link, which will bring you to the log-in screen.

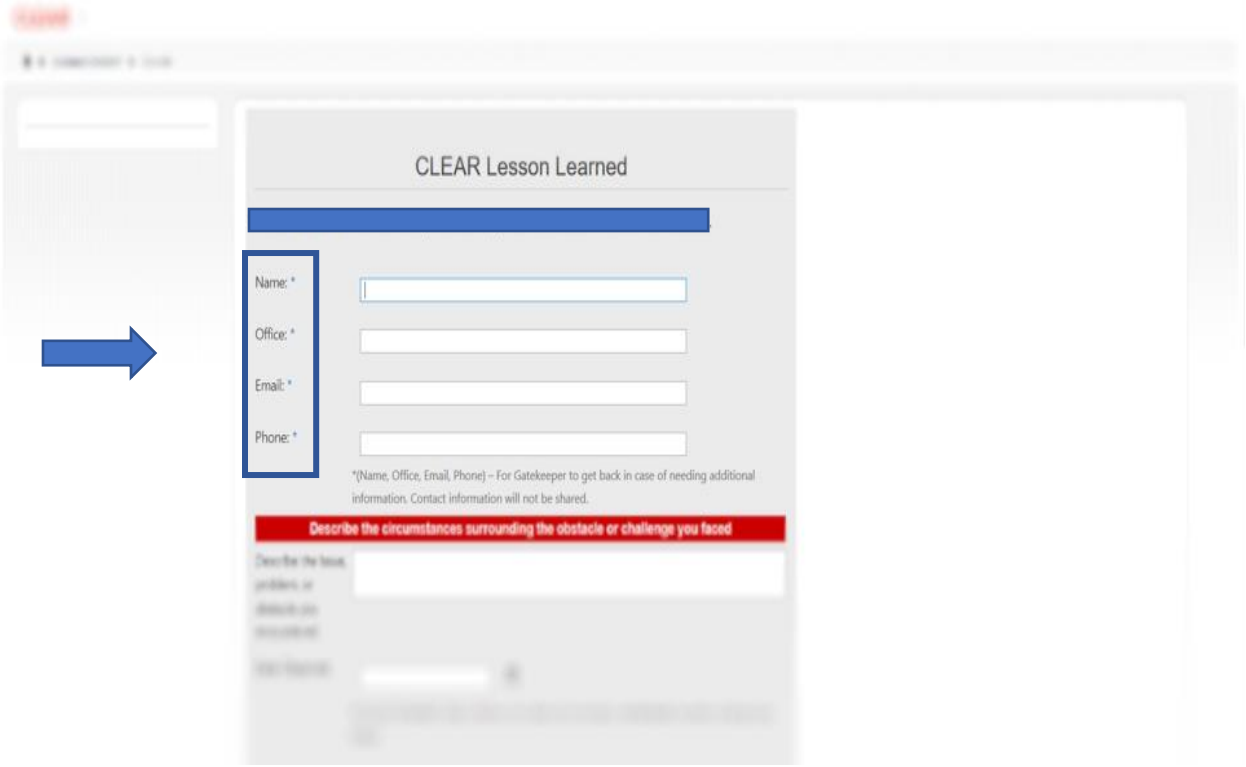
https://connect.ncdot.gov/site/lessons-learned/Pages/default.aspx

Log in with required credentials (you may bypass this part of the log-in process if you are already logged into the NCDOT network) and click on 'Share Lessons Learned' to start entering information.

Once a submission has been initiated, it cannot be saved to retrieve later. The submission must be submitted at the end of the submission process.

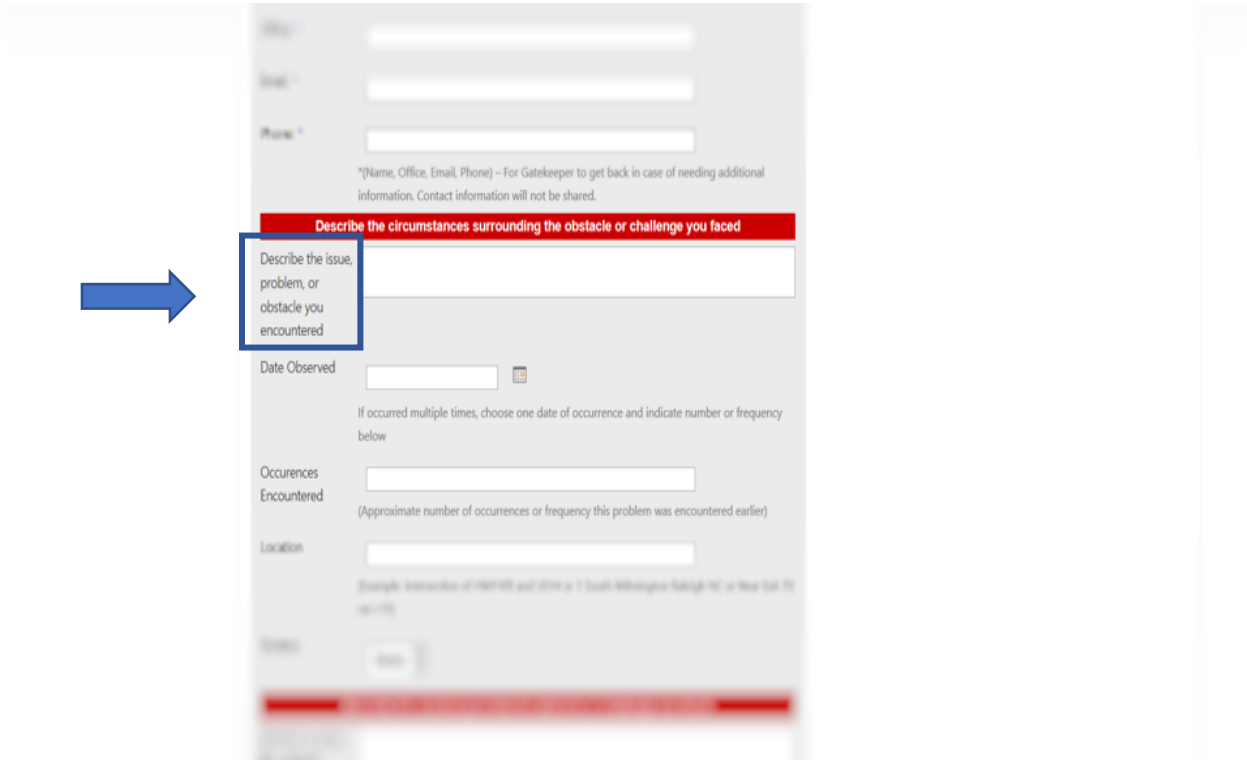


Step 2: **Complete basic respondent information.** The first part of the Lessons Learned form requires basic respondent information, such as your name, office, email address, and office phone number. This information is solely for the purpose of the gatekeeper to contact you in case additional information or clarification is necessary.

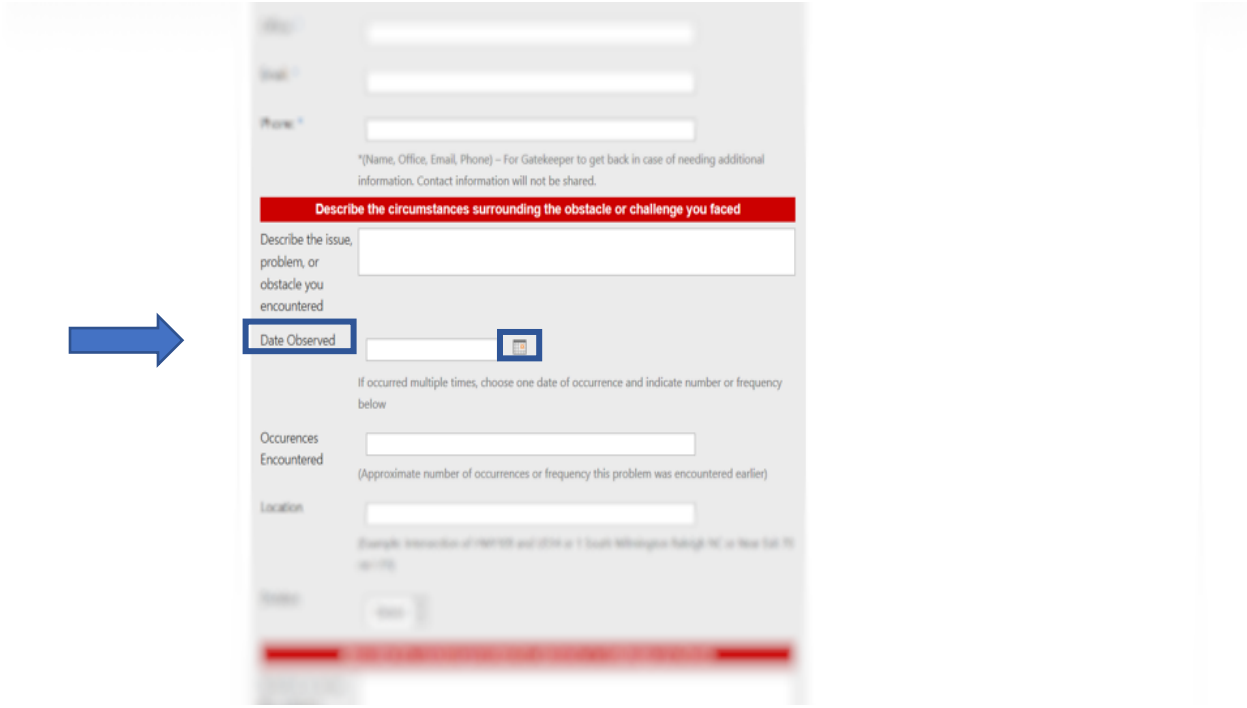


Step 3: Describe the circumstances surrounding the obstacle or challenge you faced. This step captures information about the obstacle or challenge you faced on a project.

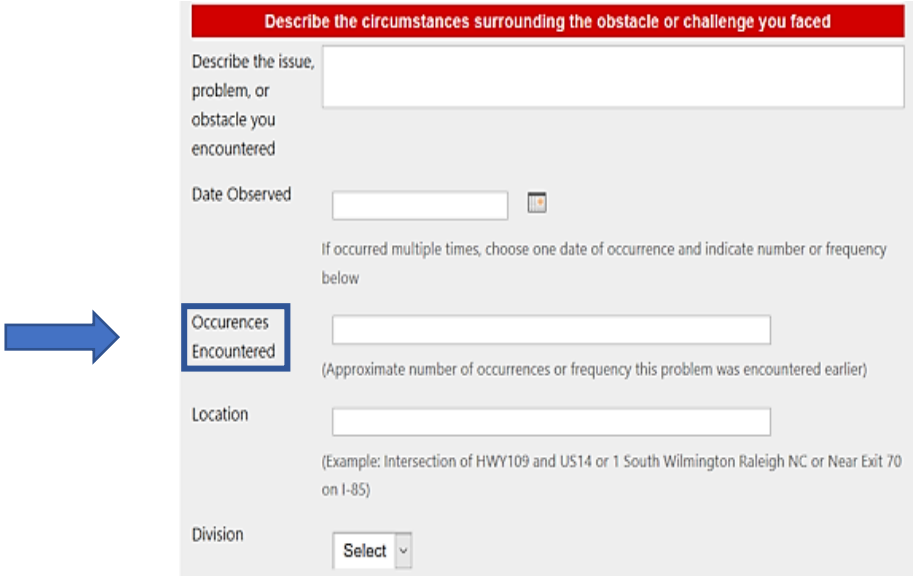
Step 3 a: Describe the issue, problem, or obstacle you encountered. Enter a description of the issue and a summary of the lesson learned that provides an overview of the issue.



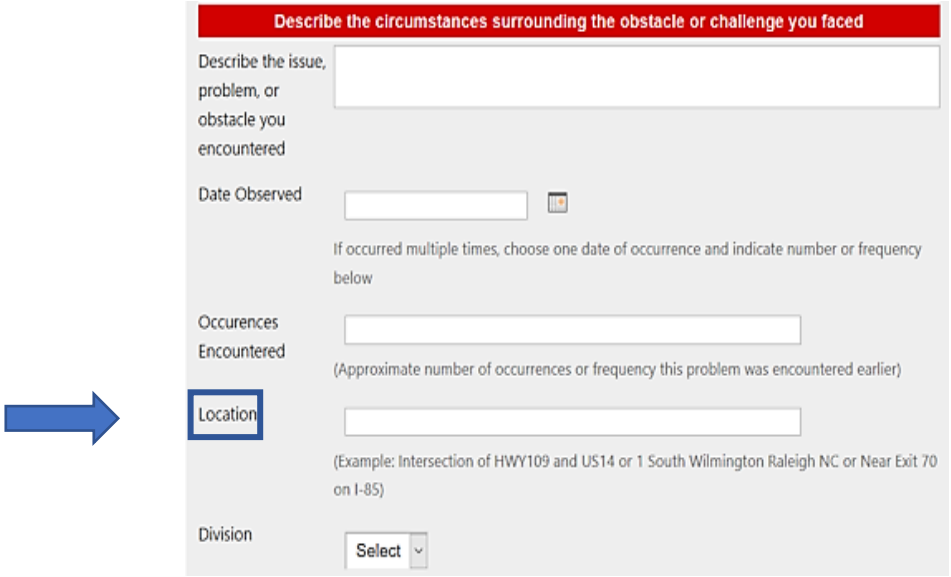
Step 3 b: **Select date observed.** To enter the date that you observed the issue, click on the calendar button and select the approximate date that you observed this issue. If the issue frequently occurs, then enter the most recent date observed and provide details about that particular observation.



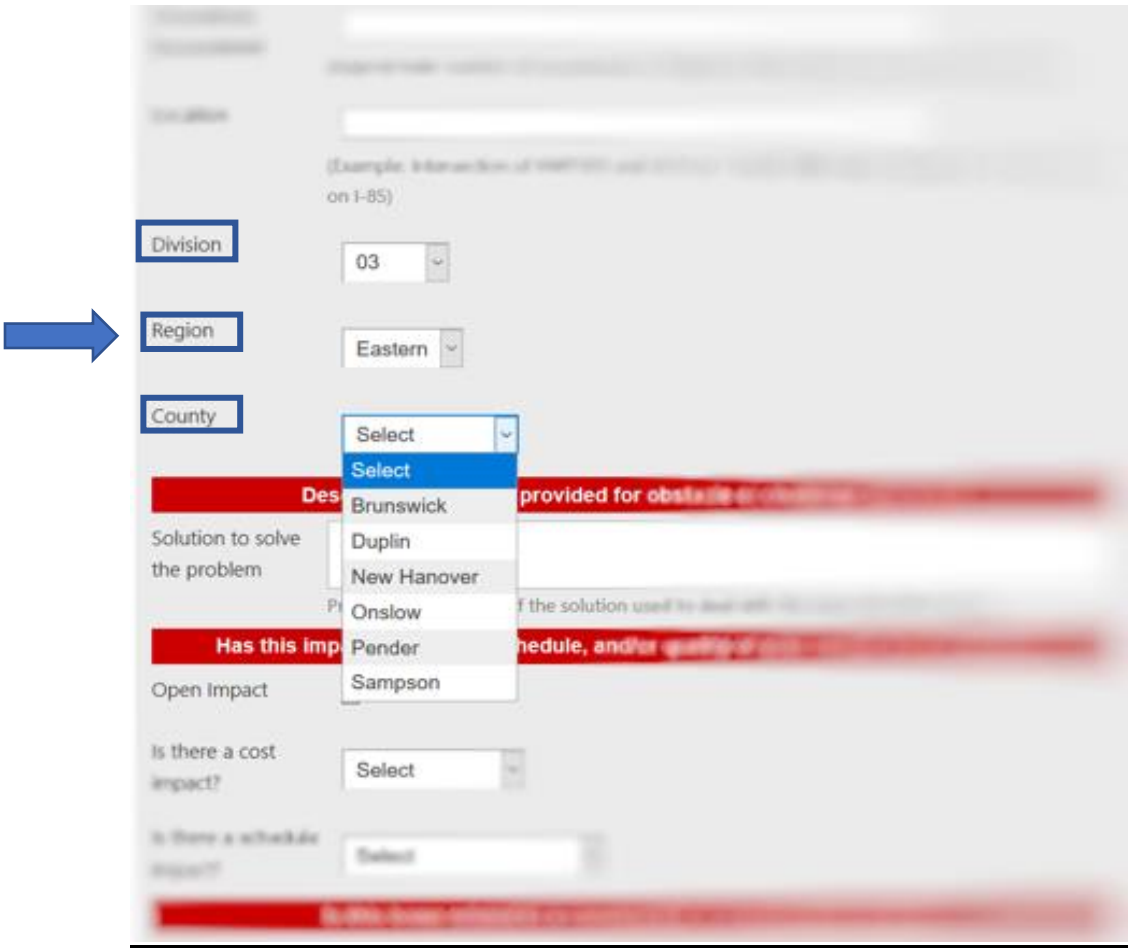
Step 3 c: Indicate issue frequency. Using the drop-down menu, indicate the number of times that you have encountered this issue.



Step 3 d: Identify location of observation. Enter the location where you observed the issue/best practice. If you observed it at multiple locations, enter the most recent occurrence location.

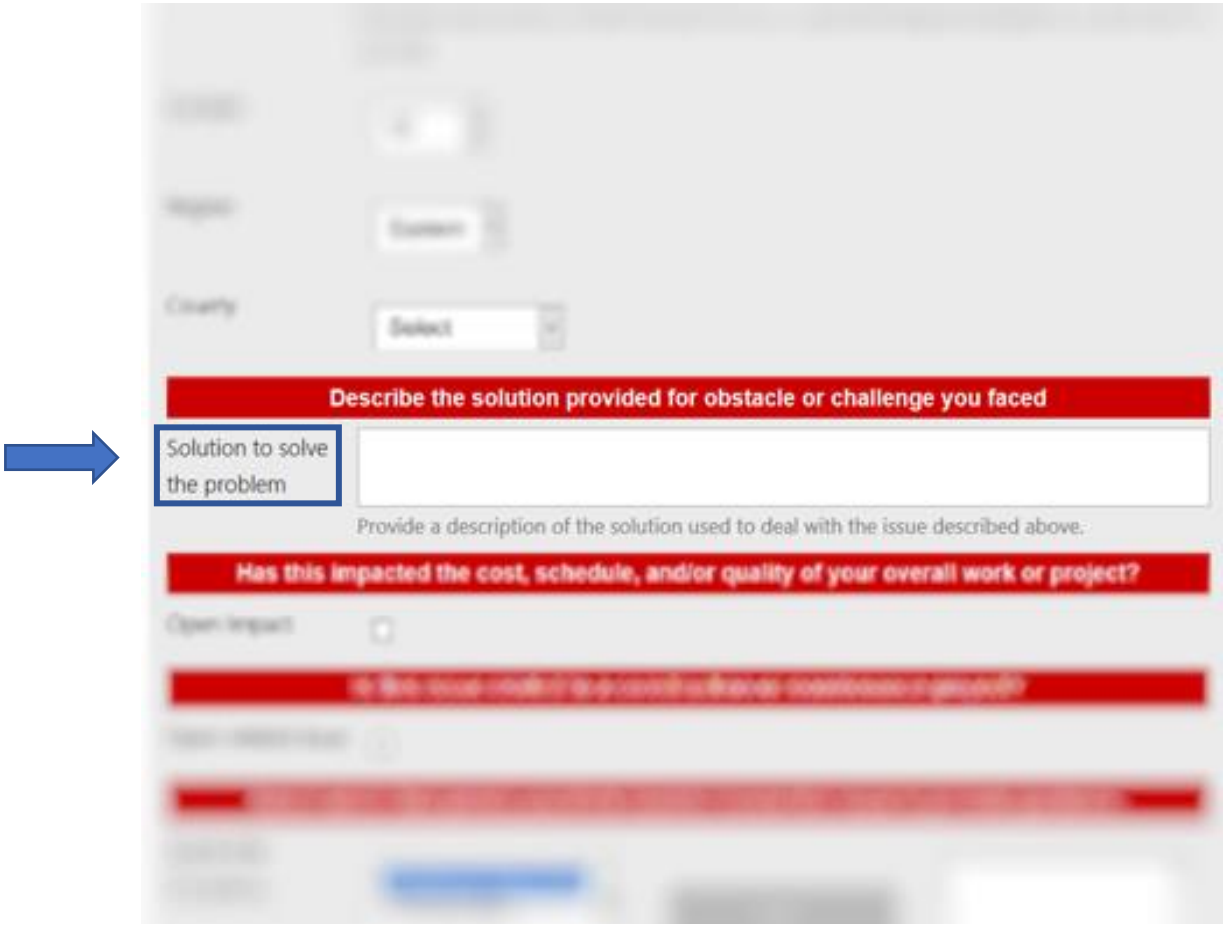


Step 3 e: **Division and County.** Using the drop-down options, select the Division and County related to the issue. Both Region and County will automatically populate based on the Division selected, and thus, Division must always be selected prior to selecting County from the drop-down list.

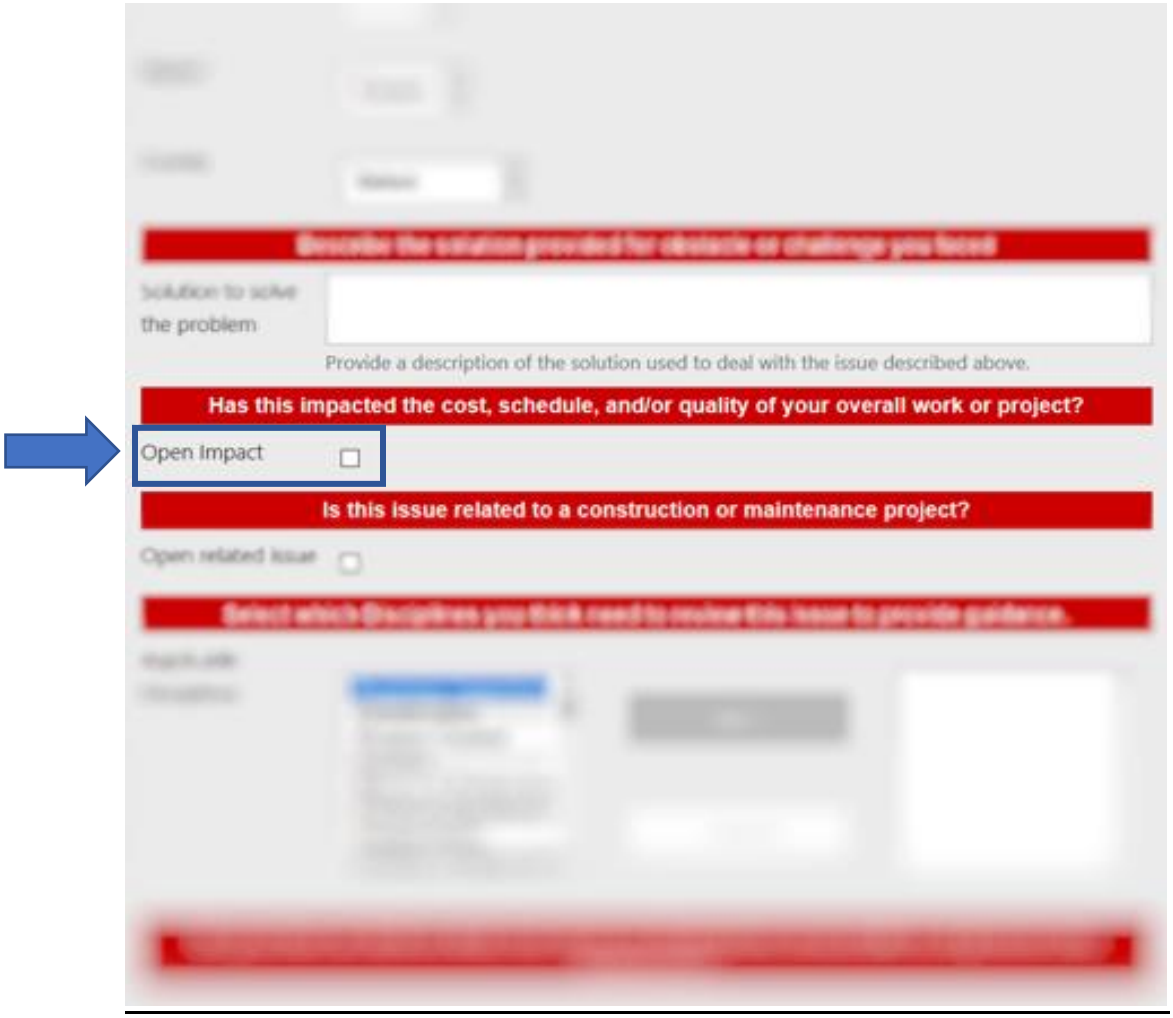


Step 4: **Describe solution(s) to the issue.** Provide details about if and how the issue was resolved in the 'Solution to solve the problem' field. Also, if you have determined the solution to this problem in another DOT or any other relevant source, please provide such examples in the box provided.

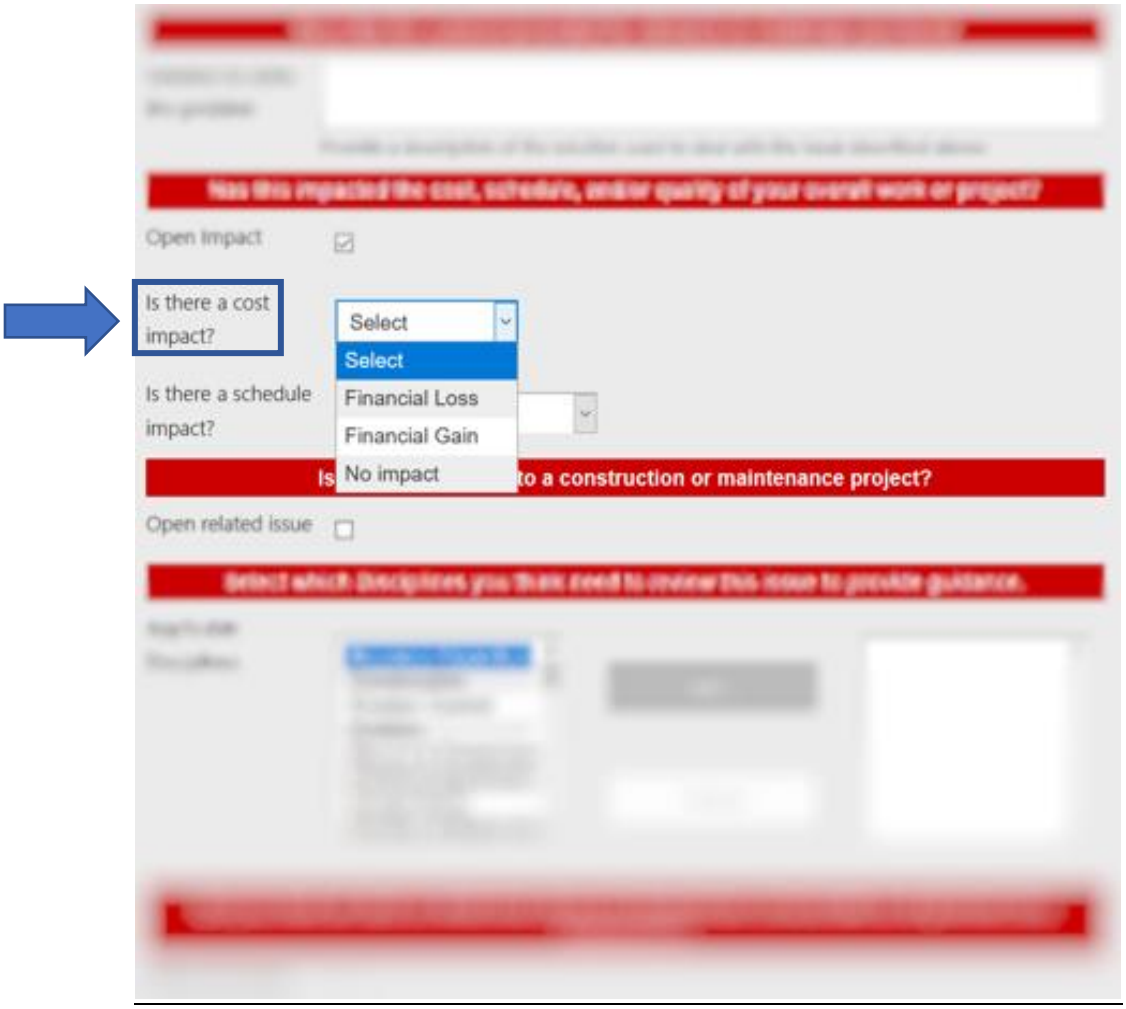
If you are looking for assistance to find a solution and do not have any suggestions at the time of submission, then use the Solution Needed form to solicit a solution to an issue. Similarly, use the Best Practices form to share a best practice/innovative idea that you might have used in a project.



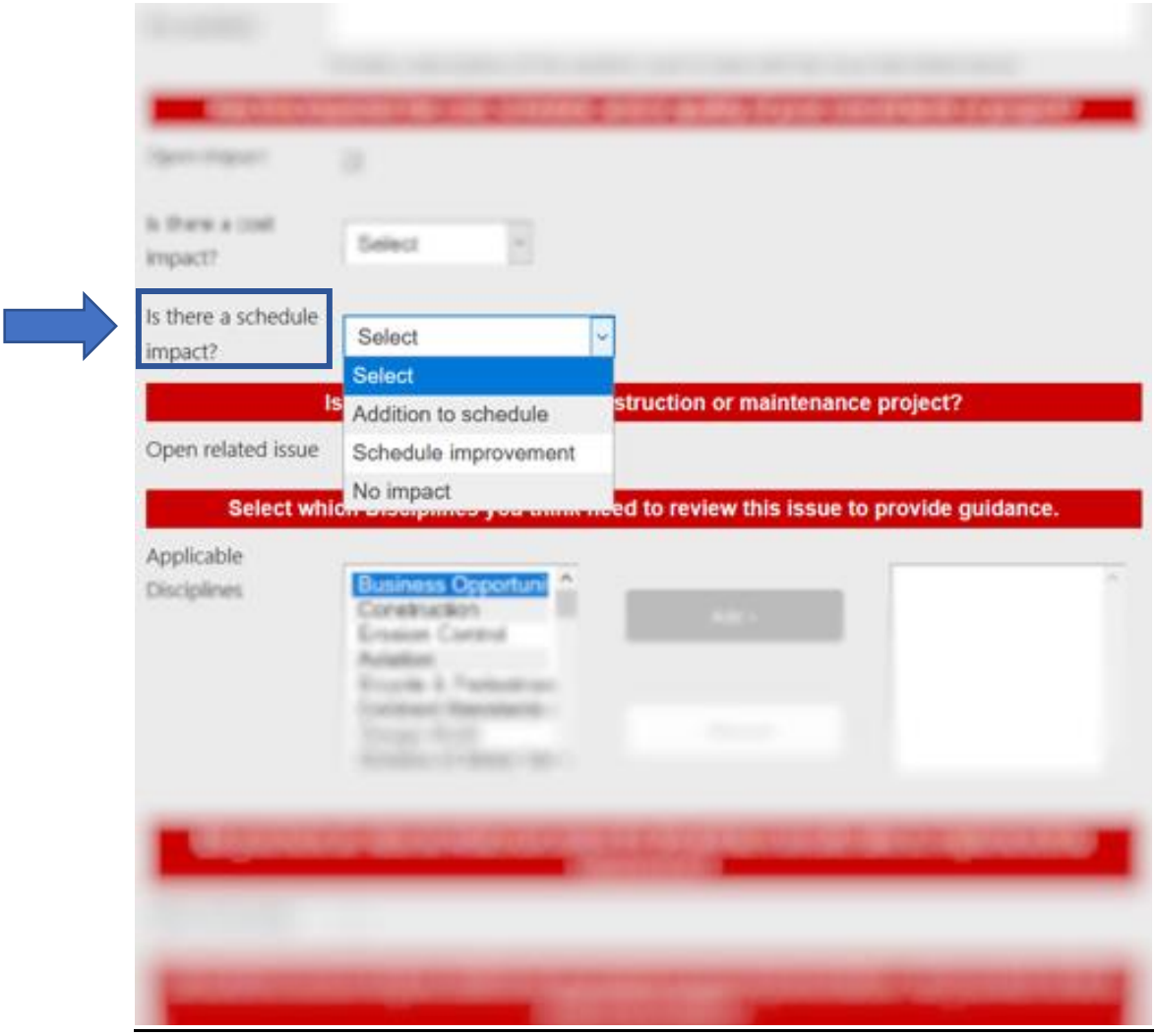
Step 5: **Cost and schedule impacts.** If the lesson learned/issue impacted the cost and/or schedule of the project, then click on the 'Radio' button to enter relevant information. If the lesson learned/issue did not impact cost and schedule, skip to Step 6.



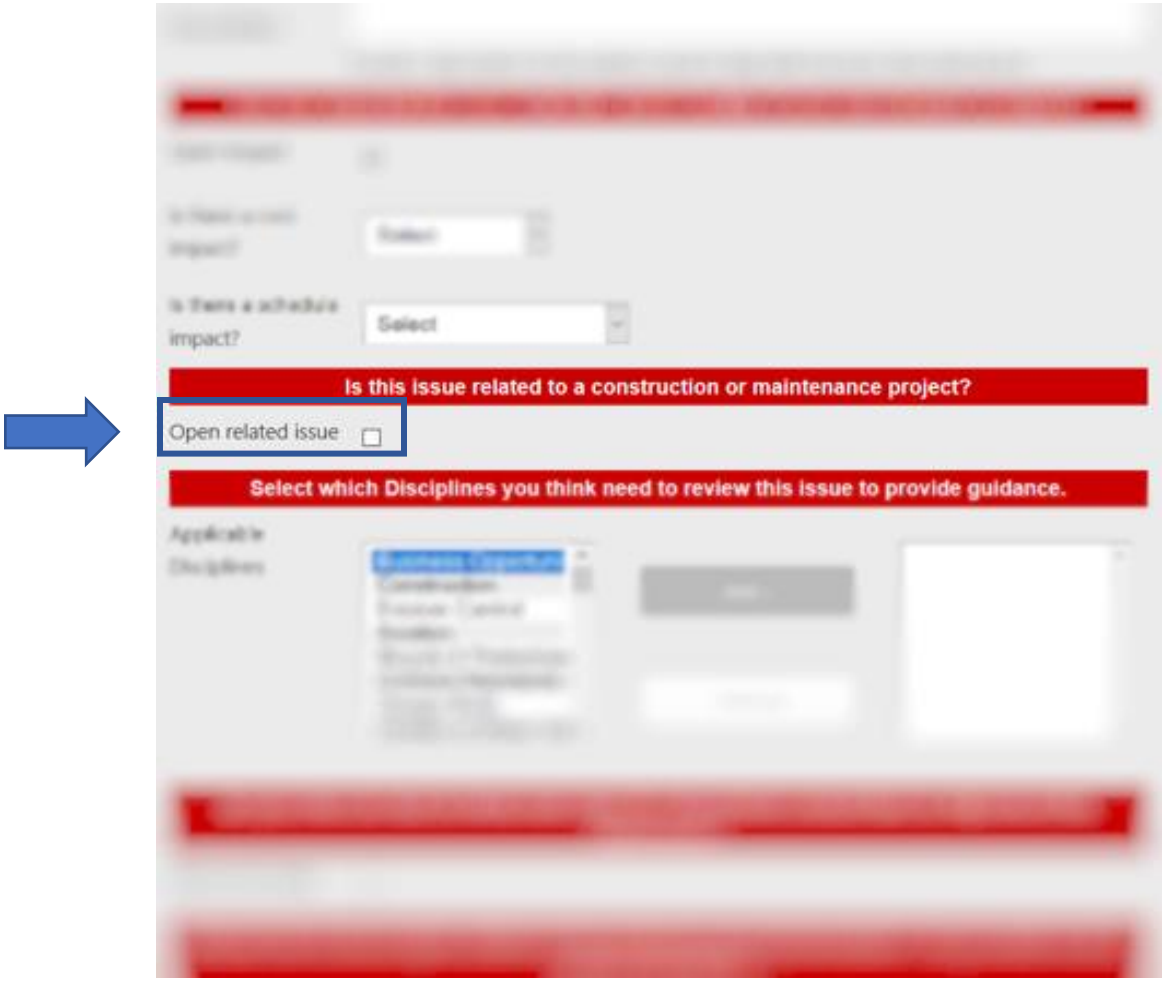
Step 5 a: **Impact on cost.** Select the appropriate cost impact from the drop-down menu.



Step 5 b: **Impact on schedule.** Select the appropriate schedule impact from the drop-down menu.

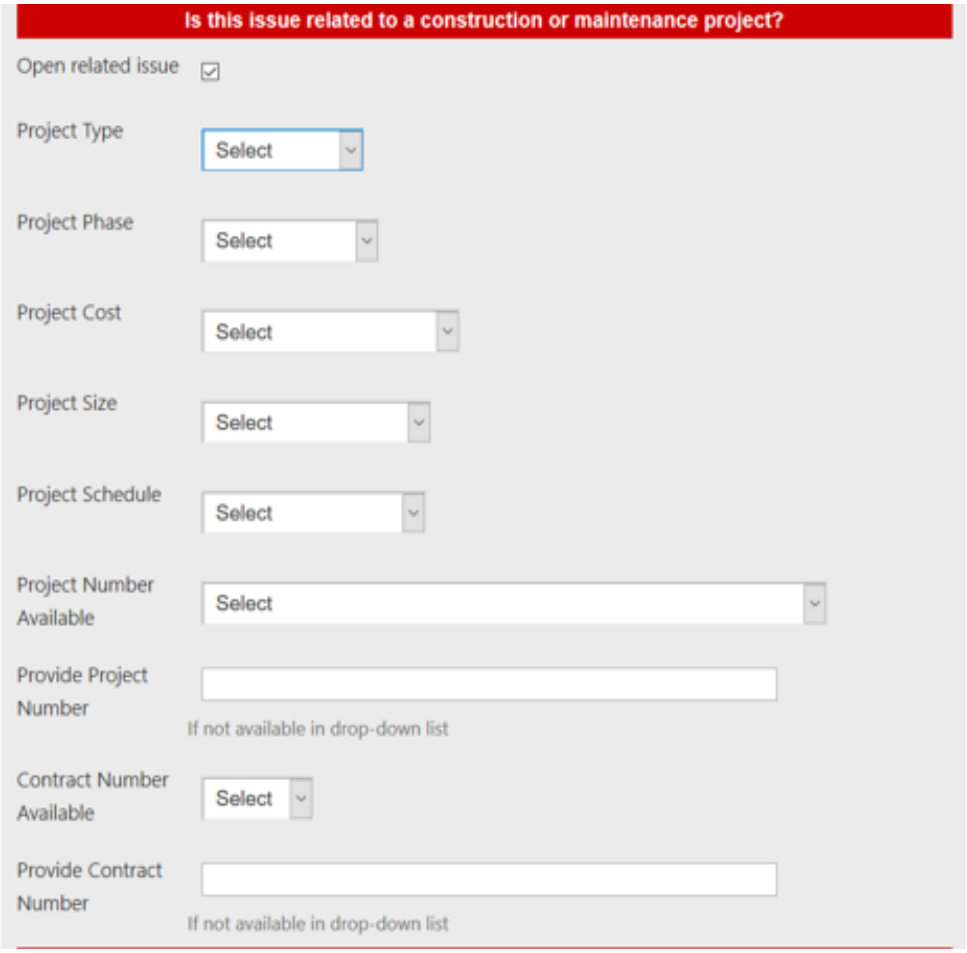


Step 6: **Is this issue related to construction or maintenance?** If yes, click on the 'Radio' button to enter relevant project information. If this issue does not relate to construction or maintenance, skip to Step 7.

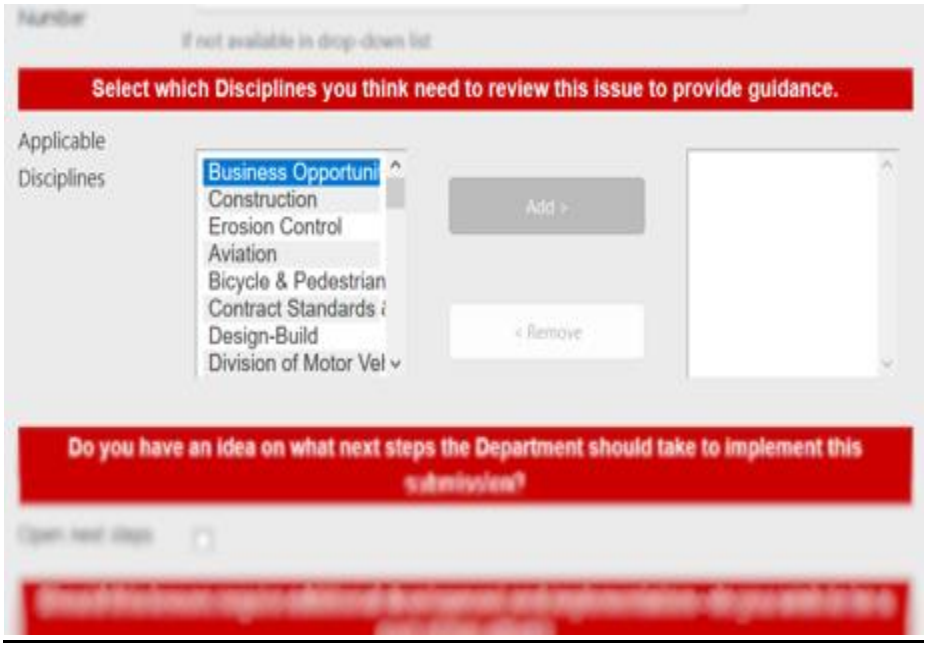


Step 6 a: **Enter project details.** Select the Project Type, Project Phase, Project Cost, Project Size, and Project Schedule from the respective drop-down menus. The Project Number must then be selected from the drop-down menu prior to selecting the Contract Number. These fields are populated from the Highway Construction and Materials System (HiCAMS) database, and the Contract Number is populated based on the Project Number selected.

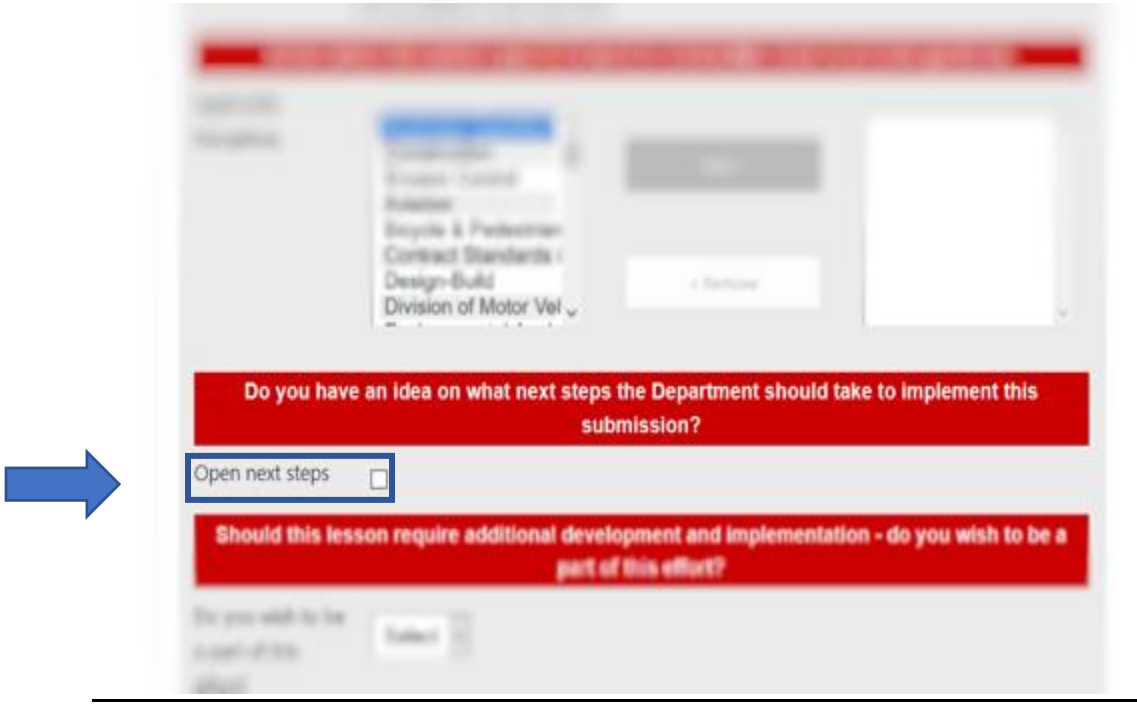
If the Project Number is not available from the drop-down menu, then fill in the fields manually.



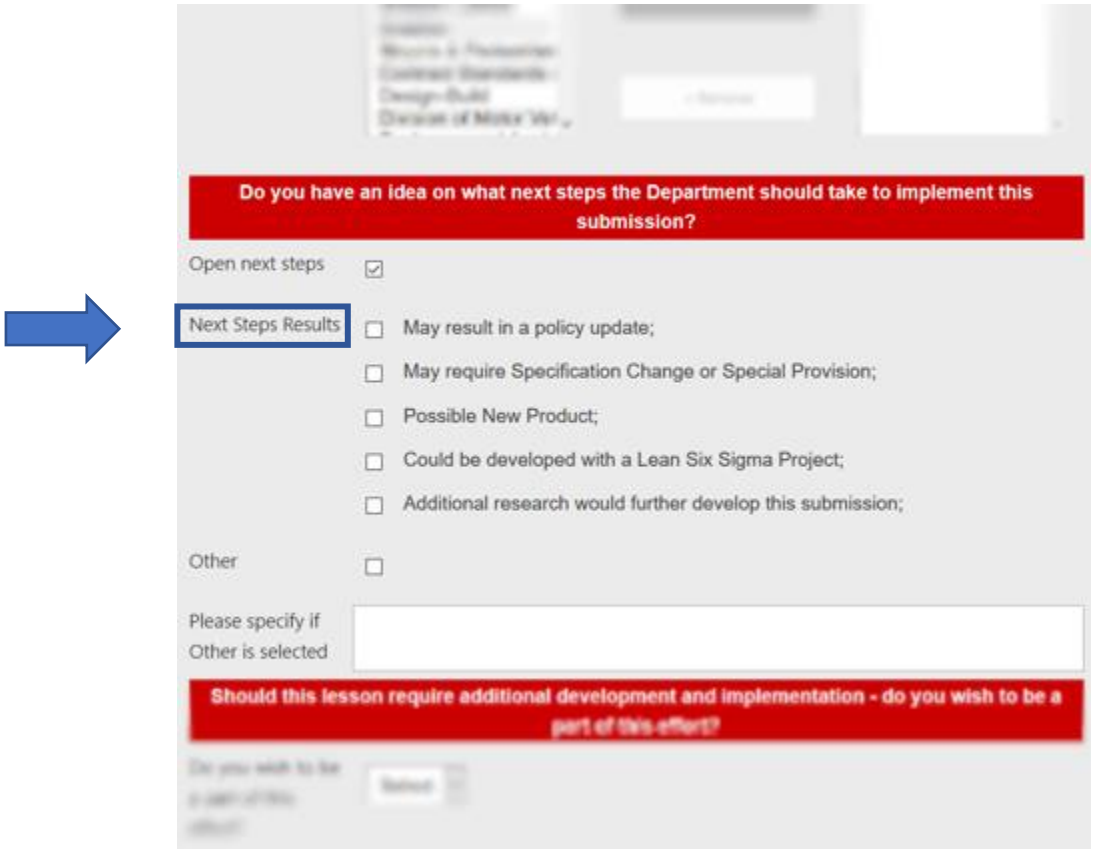
Step 7: Identify applicable disciplines. Select the Applicable Disciplines for this lesson; 38 disciplines are possible within the scope of the CLEAR program. Although the number of applicable disciplines is not limited, please select only the most pertinent or applicable discipline(s). You can scroll down and view all 38 applicable disciplines. For multiple selections, press and hold the Ctrl button on the keyboard to select all the applicable disciplines using a mouse-click. Once you have made all possible selections, click on 'Add' to finalize the selections. If you added an option by mistake or want to remove selection(s), you can select the discipline to be removed from the list and press the 'Remove' button.



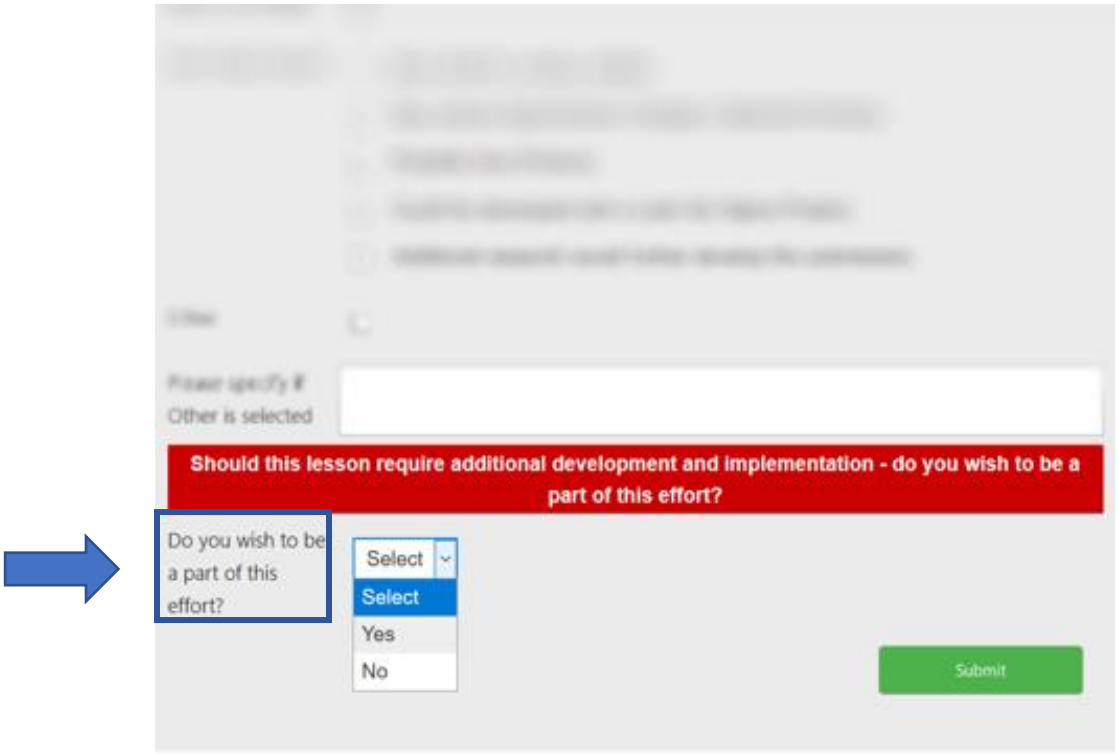
Step 8: Open next steps. If you have a recommendation about how this issue and/or solution could be developed further or integrated into the department, then click on the ‘Radio’ button that reads ‘Open next steps’.



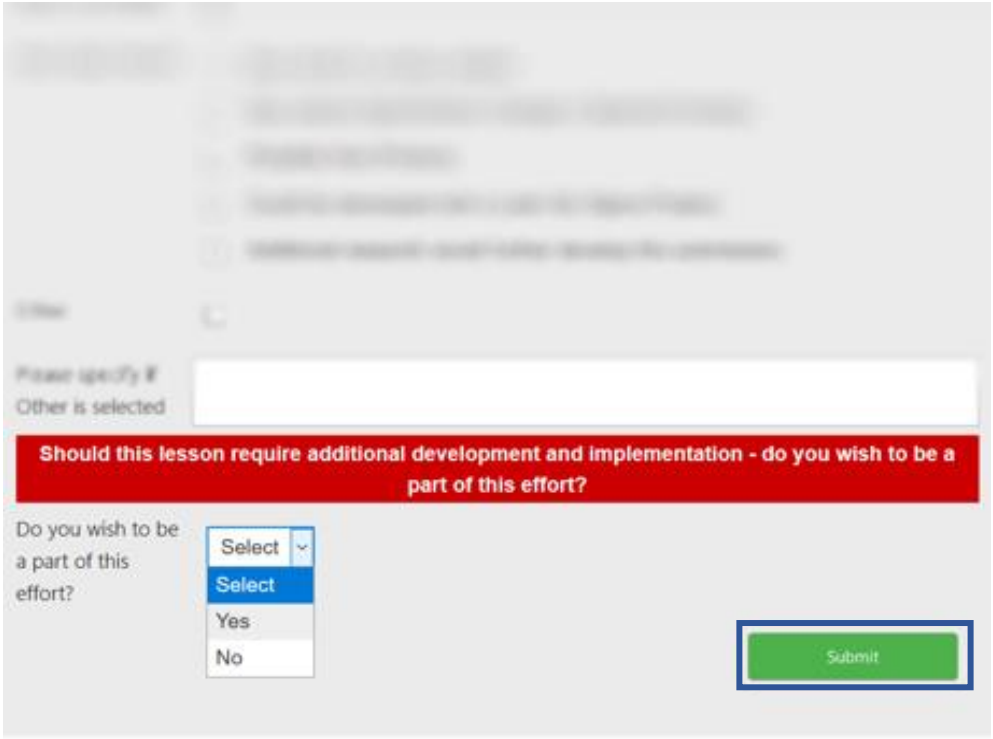
Step 8 a: Next step results. Select the appropriate boxes that you feel match the impact of the lesson learned on the NCDOT.



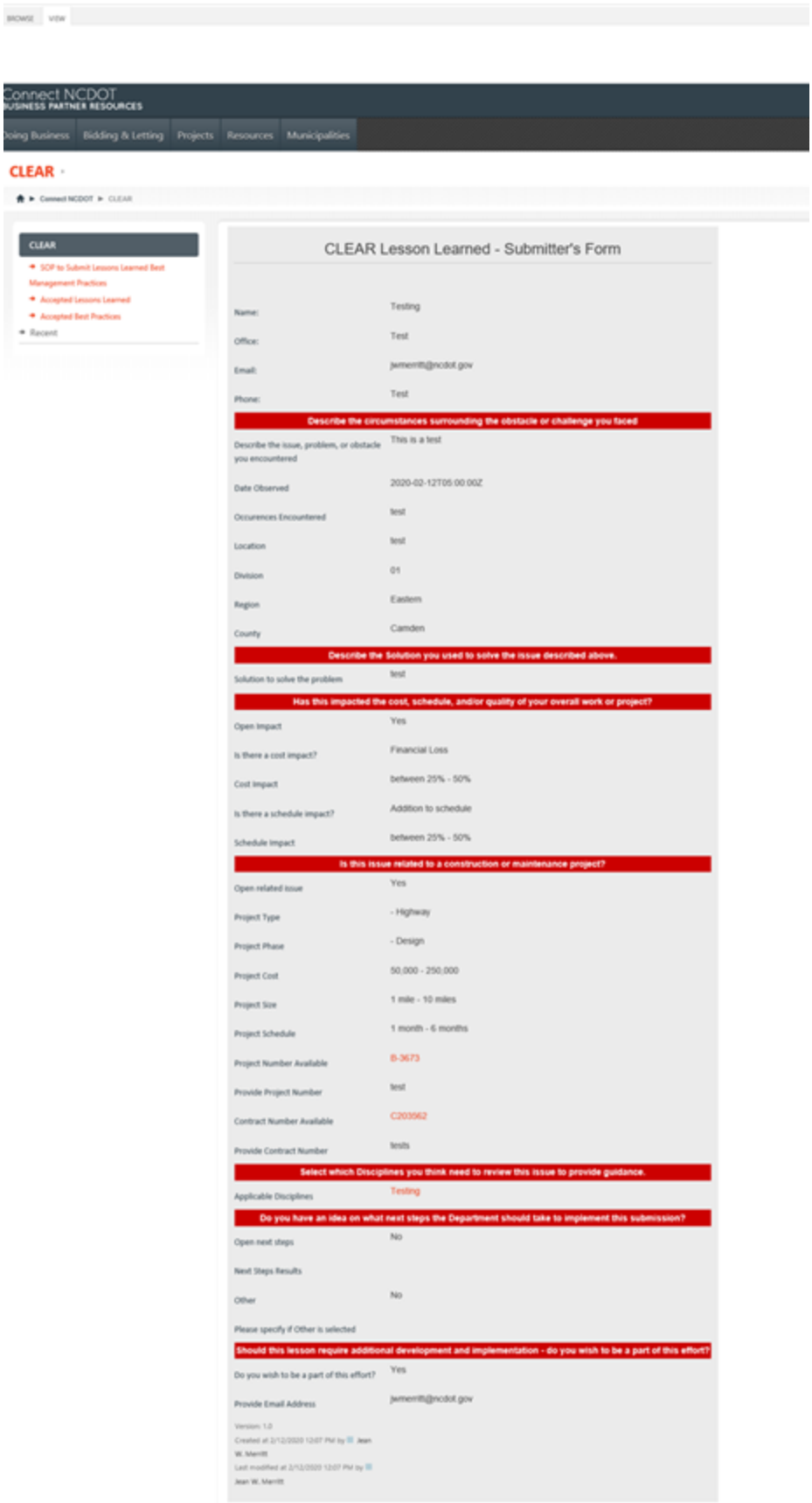
Step 9: Additional development and implementation. If you wish to be part of the development and possible implementation of this lesson learned to benefit the organization as a whole, then select 'Yes' from the drop-down menu.



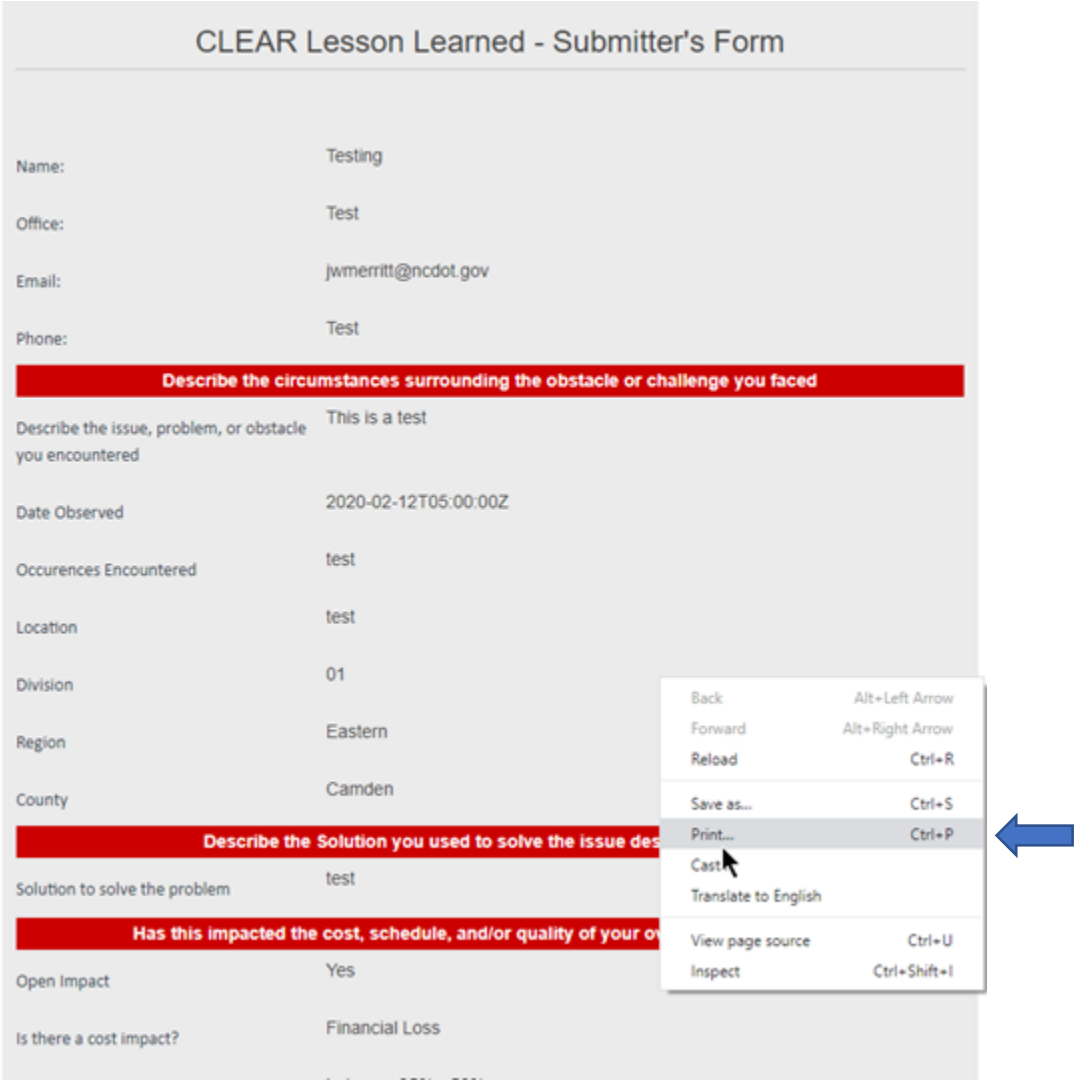
Step 10: Check fields and submit. Upon completing the form, kindly go through all the fields to check for any missing fields. Once you are satisfied that the form is complete, submit the lesson learned. It will be sent to the gatekeeper in the Value Management Office for review. Once you have clicked on the 'Submit' button, no further changes can be made to the form.



NOTE: Once the form has been submitted, a weblink will be emailed to you automatically. This link will let you see your responses and you can bookmark this link or print a copy of your responses for future reference. Please note that no changes can be made to the entries once the form has been submitted. A typical lesson learned entered will look as shown below.


BROWSE
VIEW
Connect NCDOT
BUSINESS PARTNER RESOURCES
Doing Business
Bidding & Letting
Projects
Resources
Municipalities
CLEAR
Connect NCDOT ▶ CLEAR
CLEAR
SOP to Submit Lessons Learned Best Management Practices
Accepted Lessons Learned
Accepted Best Practices
Recent
CLEAR Lesson Learned - Submitter's Form
Name: Testing
Office: Test
Email: jwmerritt@ncdot.gov
Phone: Test
Describe the circumstances surrounding the obstacle or challenge you faced
Describe the issue, problem, or obstacle you encountered: This is a test
Date Observed: 2020-02-12T05:00:00Z
Occurences Encountered: test
Location: test
Division: 01
Region: Eastern
County: Camden
Describe the Solution you used to solve the issue described above.
Solution to solve the problem: test
Has this impacted the cost, schedule, and/or quality of your overall work or project?
Open Impact: Yes
Is there a cost impact?: Financial Loss
Cost Impact: between 25% - 50%
Is there a schedule impact?: Addition to schedule
Schedule Impact: between 25% - 50%
Is this issue related to a construction or maintenance project?
Open related issue: Yes
Project Type: - Highway
Project Phase: - Design
Project Cost: 50,000 - 250,000
Project Size: 1 mile - 10 miles
Project Schedule: 1 month - 6 months
Project Number Available: B-3673
Provide Project Number: test
Contract Number Available: C203562
Provide Contract Number: tests
Select which Disciplines you think need to review this issue to provide guidance.
Applicable Disciplines: Testing
Do you have an idea on what next steps the Department should take to implement this submission?
Open next steps: No
Next Steps Results:
Other: No
Please specify if Other is selected:
Should this lesson require additional development and implementation - do you wish to be a part of this effort?
Do you wish to be a part of this effort?: Yes
Provide Email Address: jwmerritt@ncdot.gov
Version: 1.0
Created at 2/12/2020 12:07 PM by Jean W. Merritt
Last modified at 2/12/2020 12:07 PM by Jean W. Merritt

You can bookmark the online link to your lesson learned submission in your web browser or print a record of your responses by right-clicking anywhere on the form and selecting the 'Print' option; see below.



Thank you for your contribution.

Appendix I. Standard Operating Procedures for End-Users to Enter Best Practices/Ideas

The following guidelines provide direction for end-users to submit a best practice or an innovative idea to the North Carolina Department of Transportation (NCDOT) CLEAR (Communicate Lessons, Exchange Advice, Record) database. A best practice is an effective procedure that has been used in a project to obtain optimal results and can be proposed for widespread adoption throughout the organization. An example of a best practice includes cost/schedule savings by adopting innovative strategies. Only items with an asterisk are required, but providing more complete information will provide a more robust database. Thank you for your support of this important program.

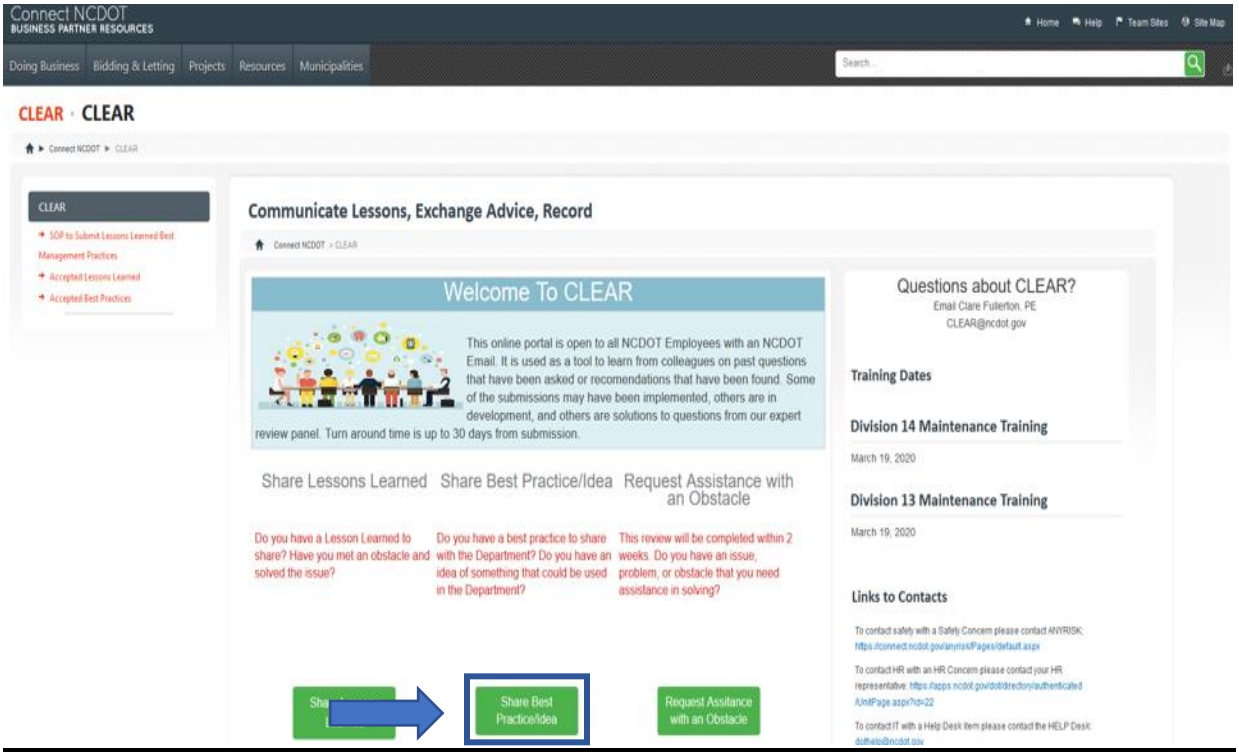
The following steps will help guide you through the submission process.

Step 1: **Log in.** Click on the following link, which will bring you to the log-in screen.

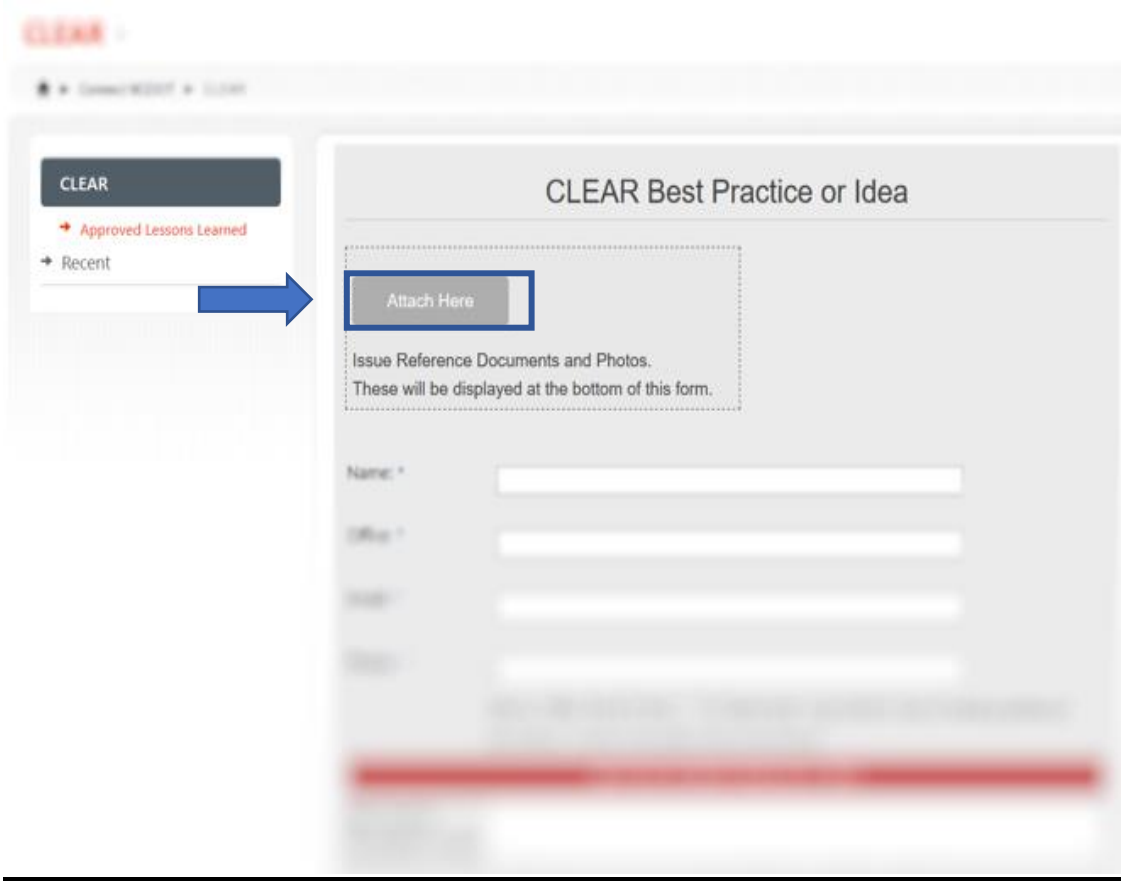
https://connect.ncdot.gov/site/lessons-learned/Pages/default.aspx

Log in with required credentials (you may bypass this part of the log-in process if you are already logged into the NCDOT network) and click on 'Share Best Practices/Idea', as shown in the screenshot below.

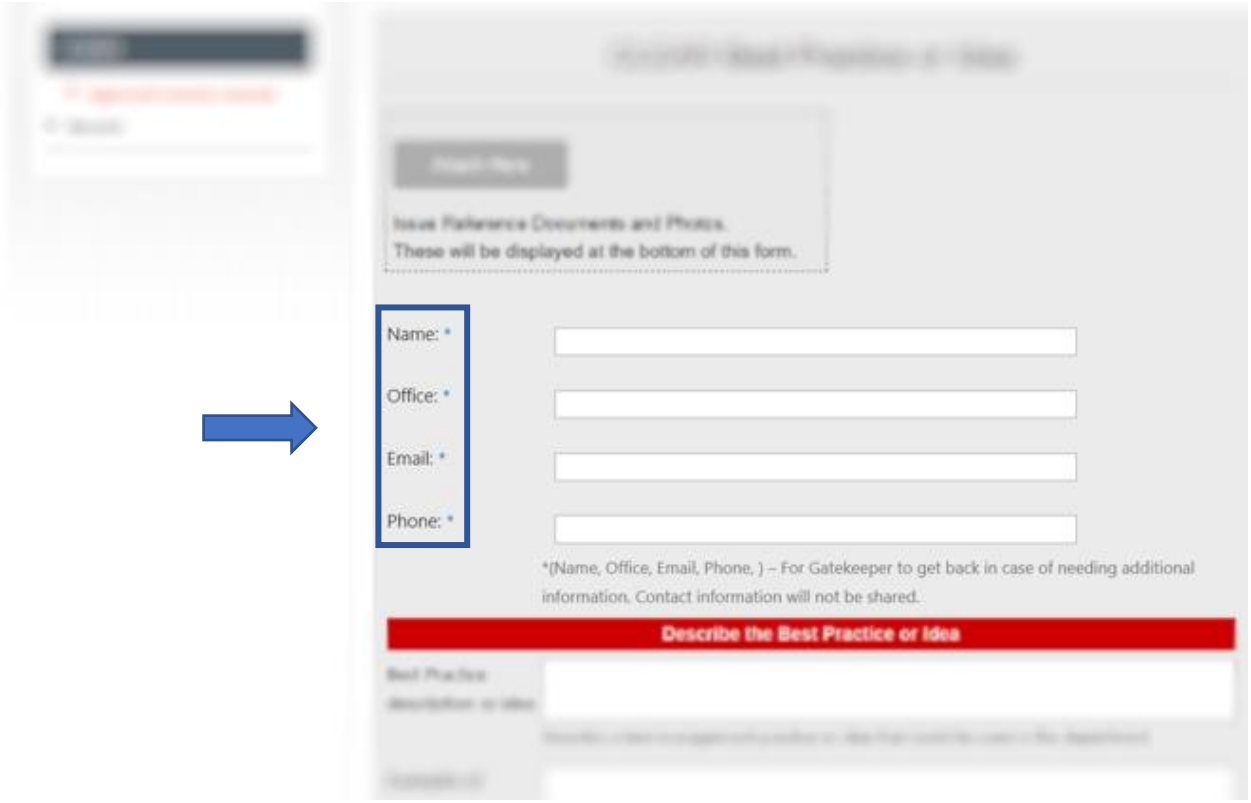
Once a submission has been initiated, it cannot be saved to retrieve later. The submission must be submitted at the end of the submission process.



Step 2: Attach supporting documents. The first part of the Best Practices or Idea form allows you to include pertinent reference documents, such as images, emails, PDFs, standard drawings, contract language, or other files, to make the best practice/idea clear and easy to understand. The attached files will be visible to you before submission to ensure that the appropriate files are attached.

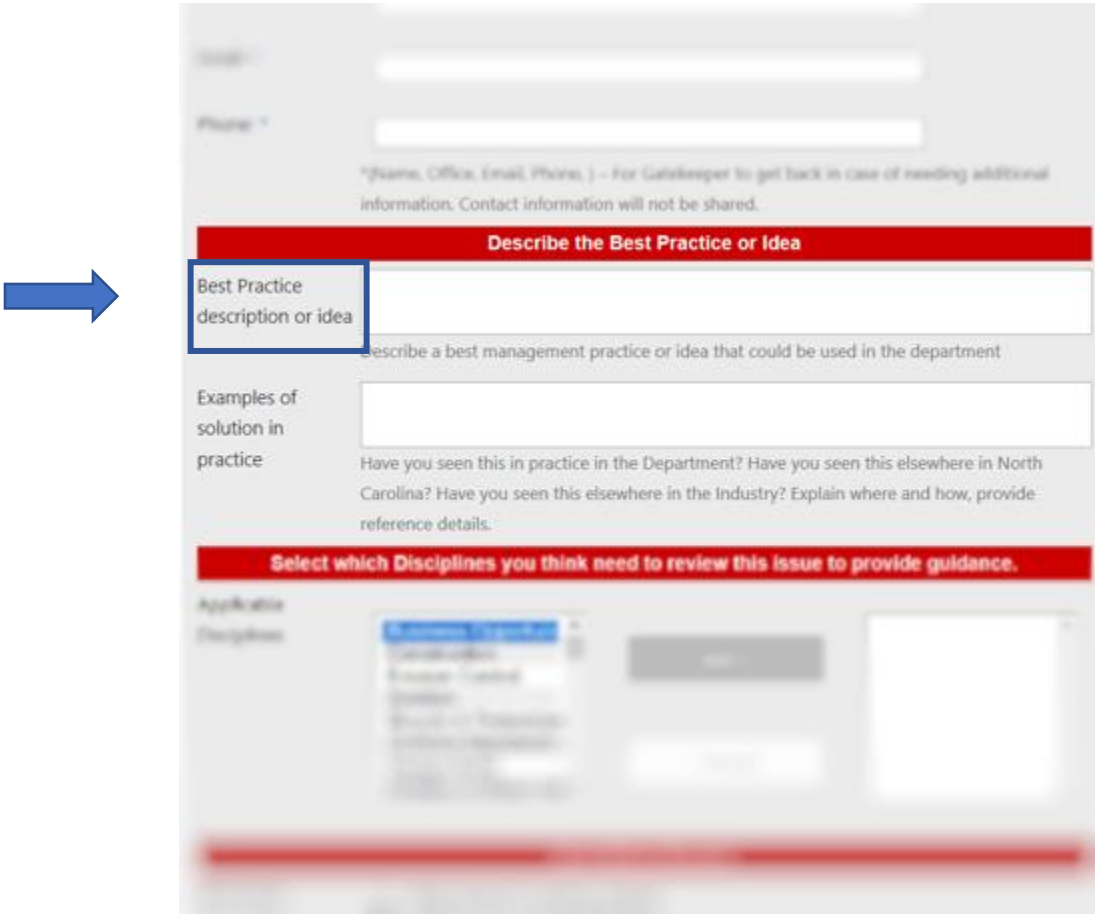


Step 3: **Complete basic respondent information.** The next part of the Best Practice or Idea form requires basic respondent information, such as your name, office, email address, and office phone number. This information is solely for the purpose of the gatekeeper to contact you in case additional information or clarification is necessary.

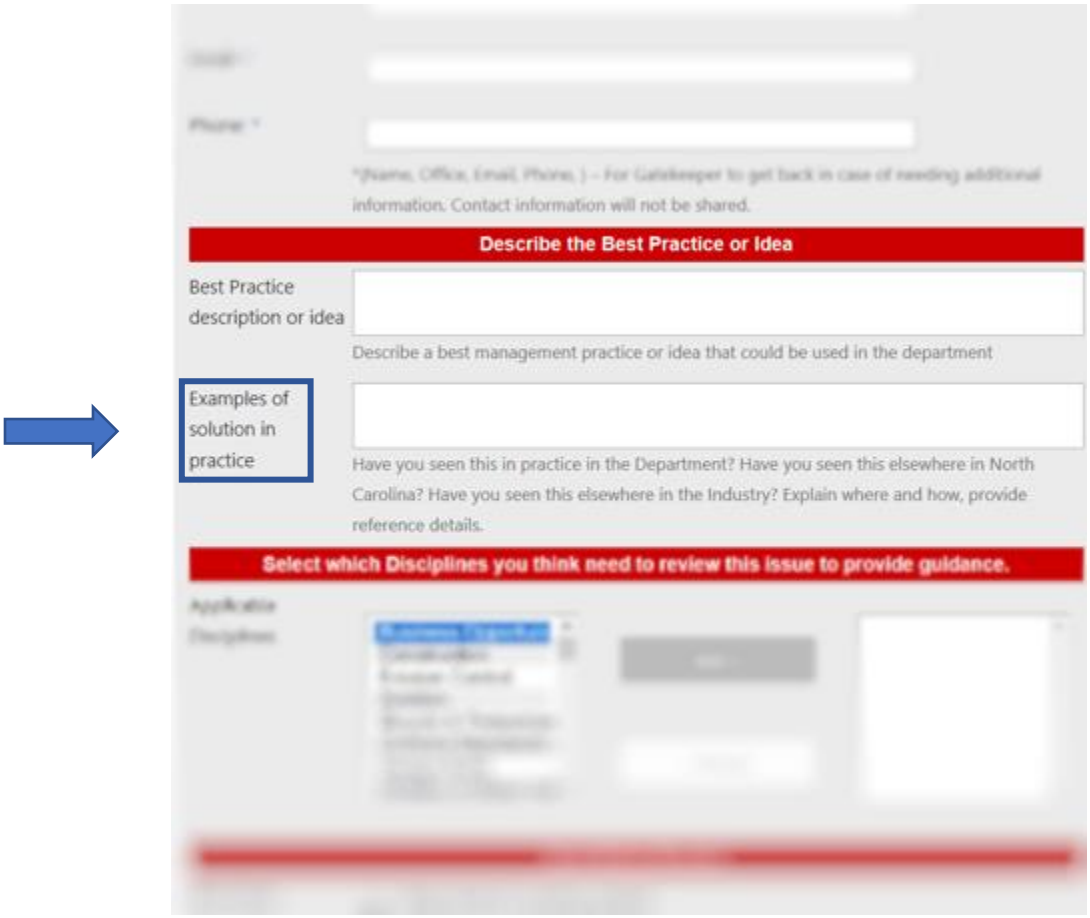


Step 4: Describe the best practice or idea. This step captures information about the best practice or idea that has been implemented for a project or may be implemented in future.

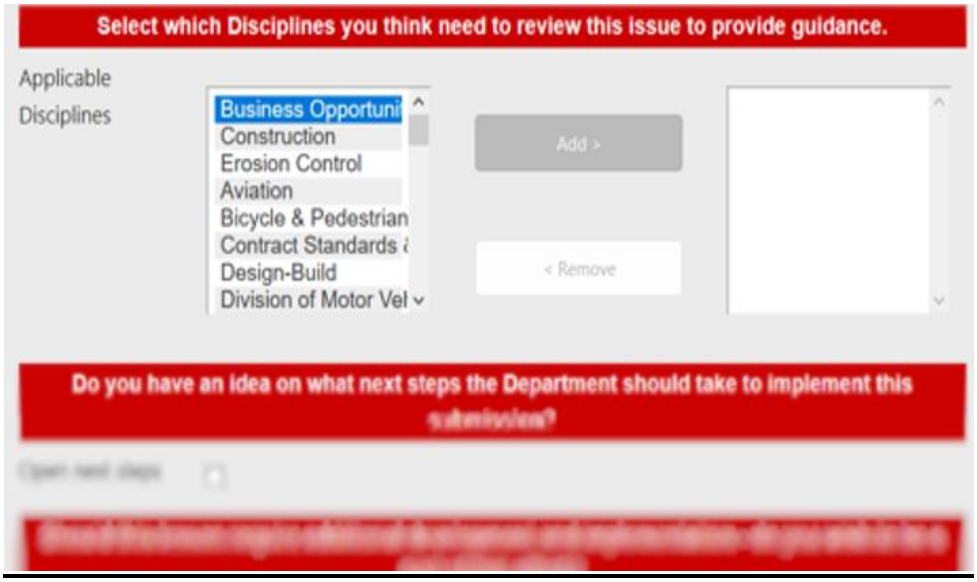
Step 4 a: Describe the best practice or idea. Provide information about a best practice or idea that can be implemented throughout the organization to improve the effectiveness of workflow processes.



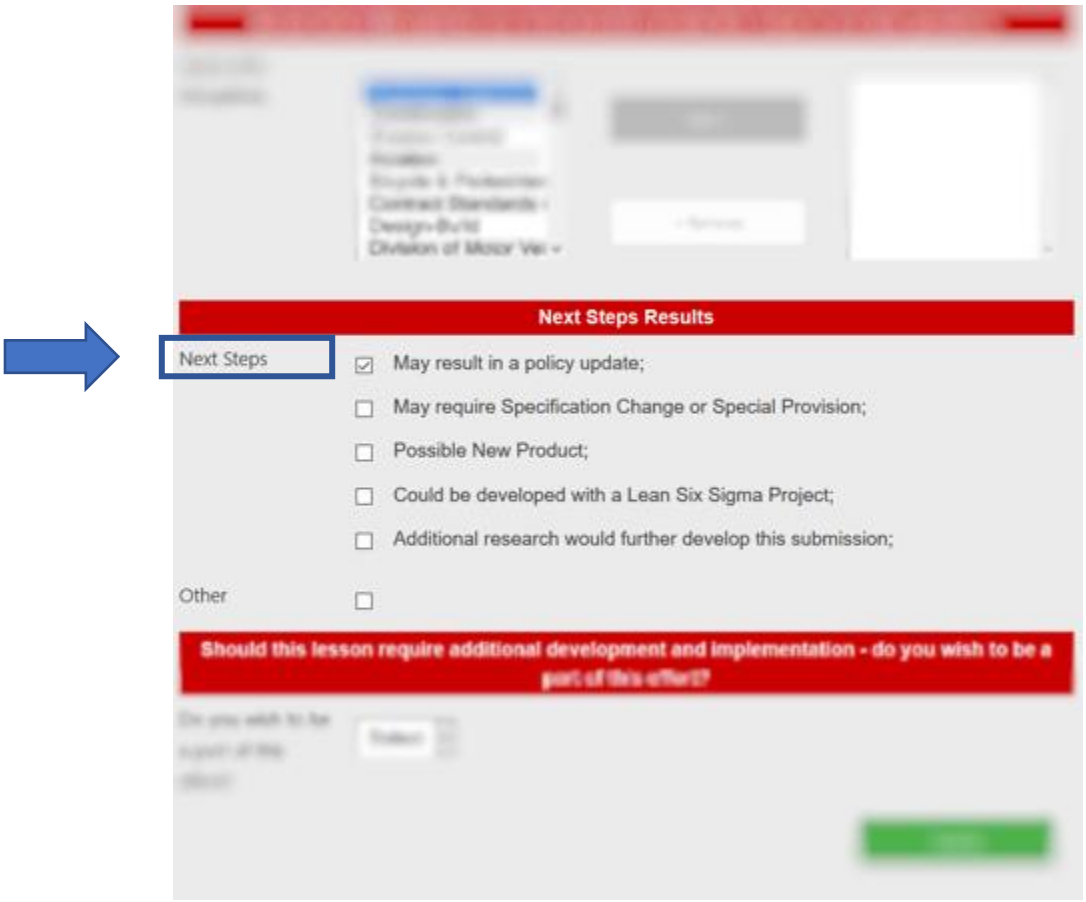
Step 4 b: **Describe examples of solution in practice.** If this best practice/idea has been implemented in your department or elsewhere in North Carolina or another DOT, provide details about its implementation and its possible benefits for the NCDOT. Consider including relevant images/documents as attachments (refer to Step 1) to provide clarity regarding the feasibility of implementation throughout the organization.



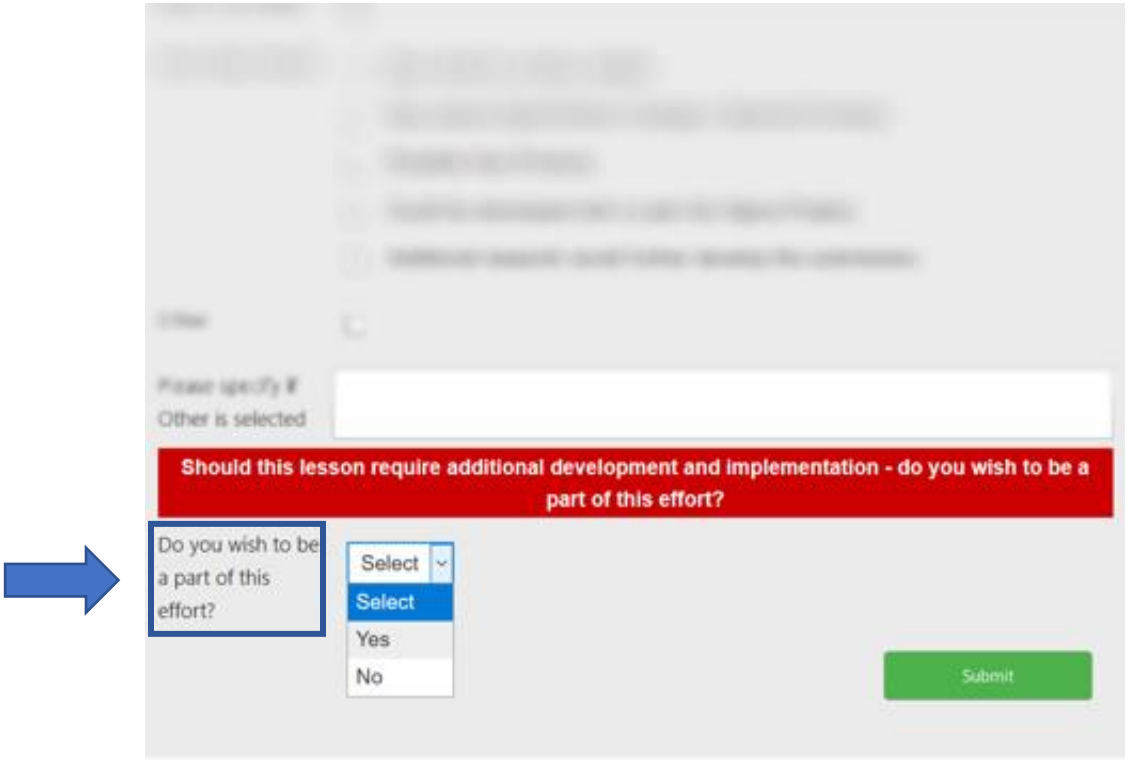
Step 5: Identify applicable disciplines. Select the Applicable Disciplines for this lesson; 38 disciplines are possible within the scope of the CLEAR program. Although the number of applicable disciplines is not limited, please select only the most pertinent or applicable discipline(s). You can scroll down and view all 38 applicable disciplines. For multiple selections, press and hold the Ctrl button on the keyboard to select all the applicable disciplines using a mouse-click. Once you have made all possible selections, click on 'Add' to finalize the selections. If you added an option by mistake or want to remove selection(s), you can select the discipline to be removed from the list and press the 'Remove' button.



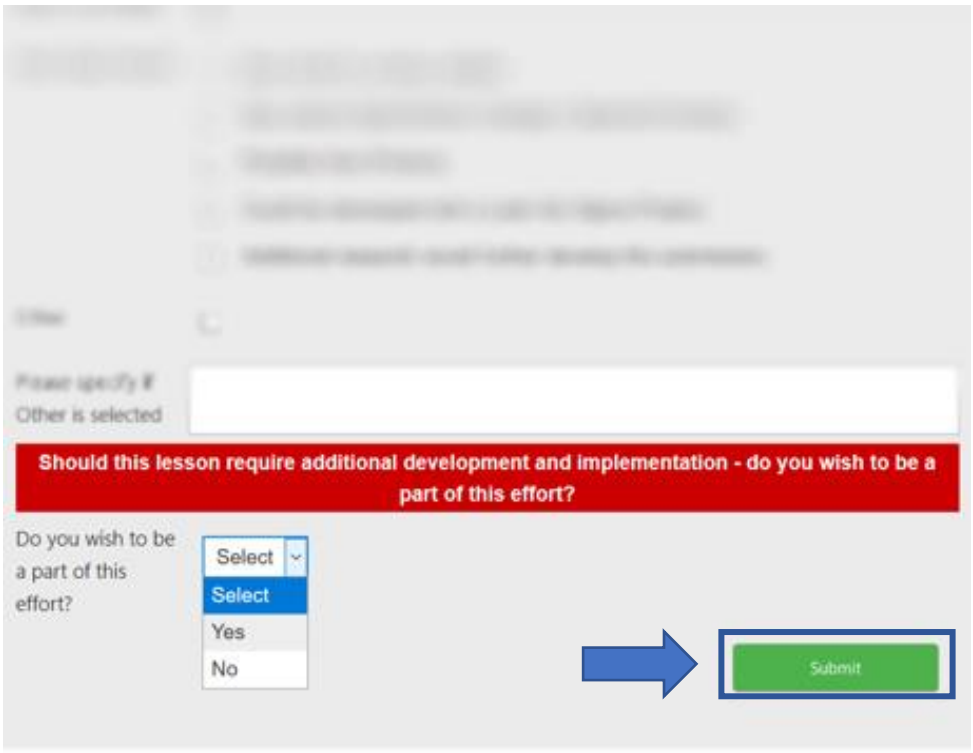
Step 6: Next step results. Select the appropriate boxes that you feel match the impact of the best practice or idea on the organization as a whole.



Step 7: Additional development and implementation. If you wish to be a part of developing and possibly implementing this best practice or idea to benefit the organization as a whole, then select 'Yes' from the drop-down menu.



Step 8: Check fields and submit. Upon completing the form, kindly go through all the fields to check for any missing fields. Once you are satisfied that the form is complete, then click on 'Submit'. Your submission will be sent to the gatekeeper in the Value Management Office for review. Once the 'Submit' button is clicked, no further changes can be made to the form.



Thank you for your contribution.

Appendix J. Standard Operating Procedures for End-Users for Solution Needed

The following guidelines provide direction about how to request information using the North Carolina Department of Transportation (NCDOT) CLEAR (Communicate Lessons, Exchange Advice, Record) database for solutions that are needed for issues or challenges faced. Soliciting information about ways to solve problems will allow the user to obtain relevant ideas from other users who have overcome similar challenges. Only items with an asterisk are required, but providing more complete information will provide a more robust database. Thank you for your support of this important program.

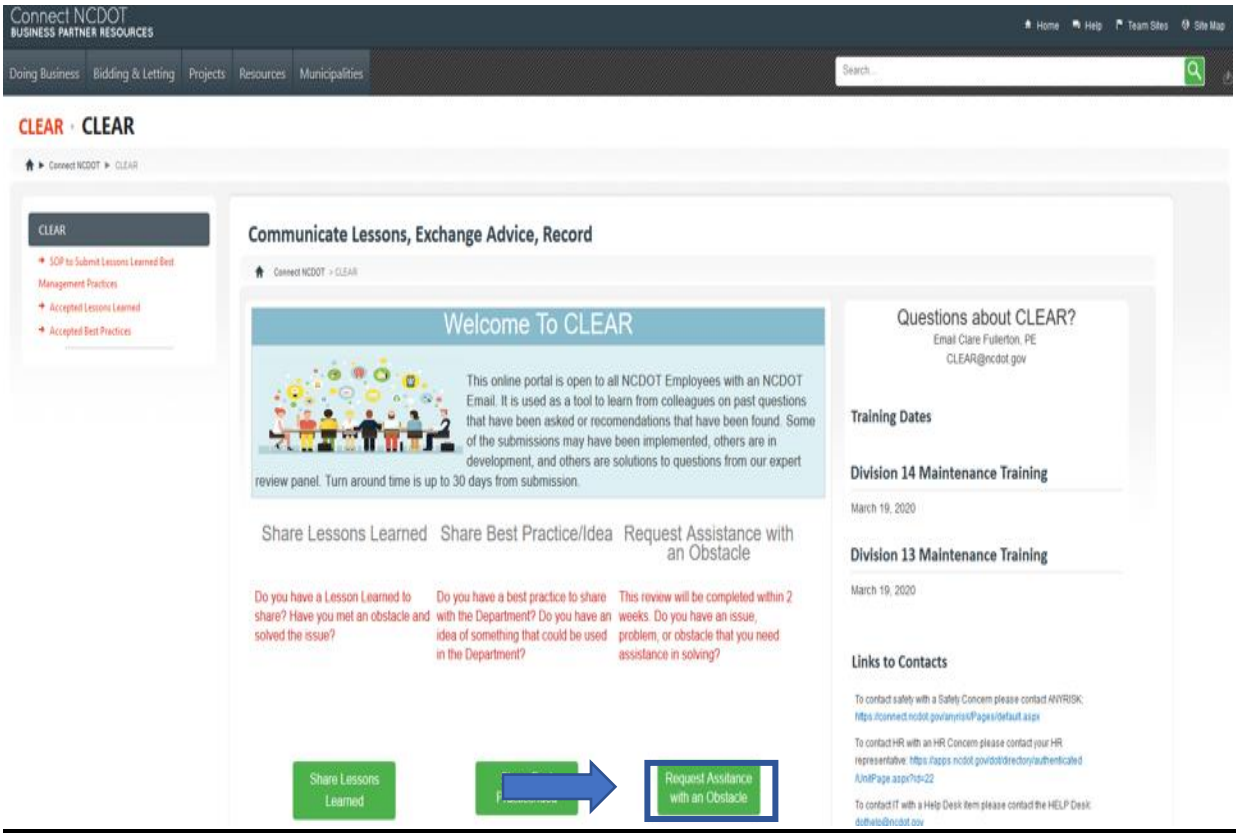
The following steps will help guide you through the submission process.

Step 1: **Log in.** Click on the following link, which will bring you to the log-in screen.

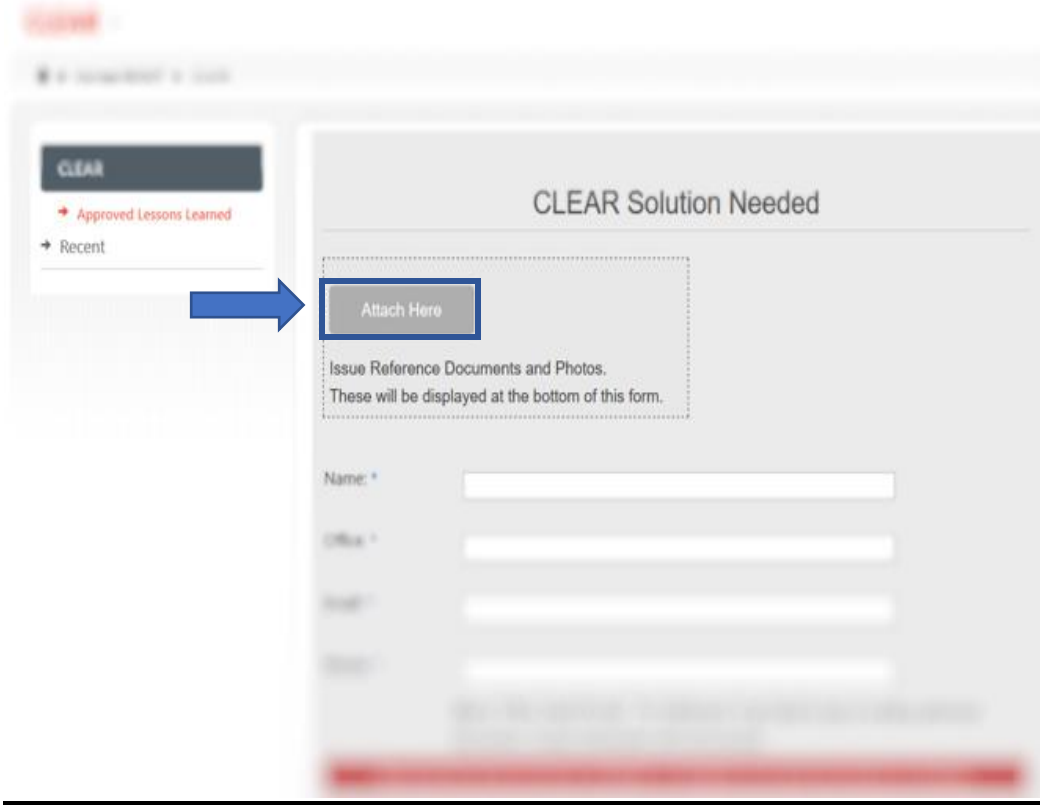
https://connect.ncdot.gov/site/lessons-learned/Pages/default.aspx

Log in with required credentials (you may bypass this part of the log-in process if you are already logged into the NCDOT network) and click on 'Request Assistance with an Obstacle', as shown in the figure below.

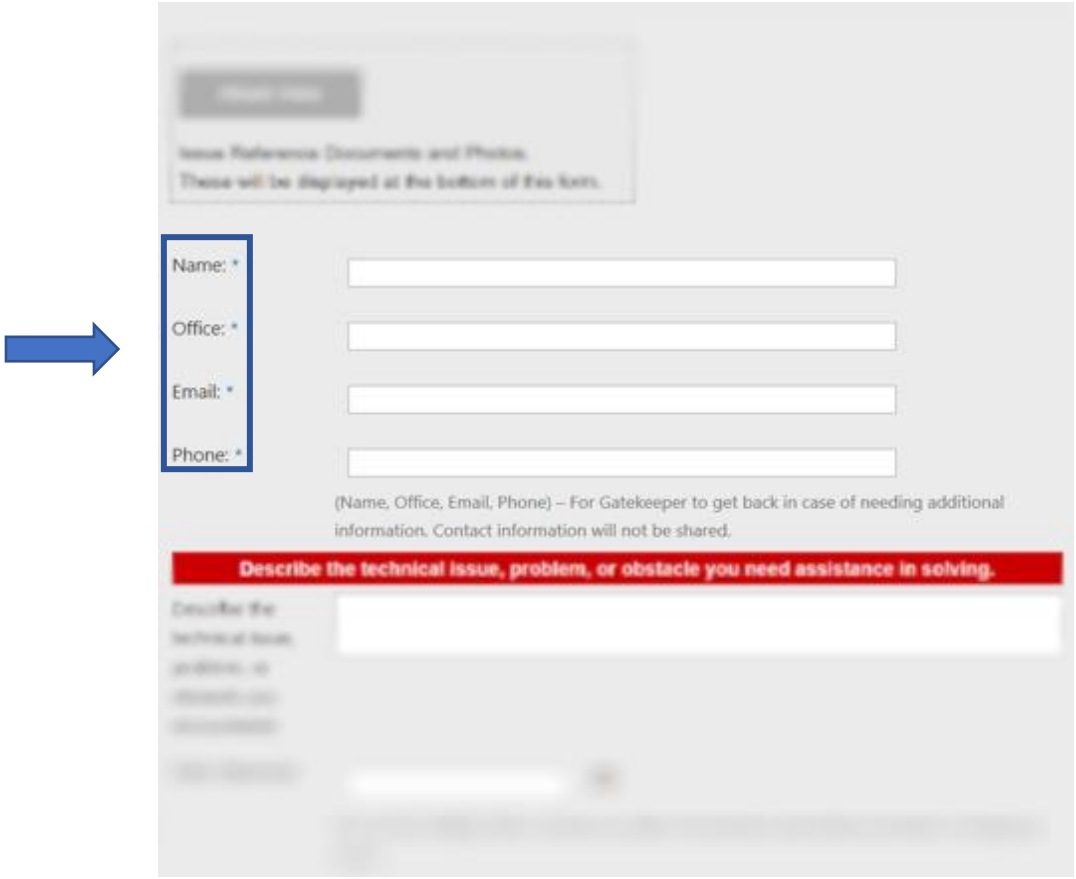
Once a submission has been initiated, it cannot be saved to retrieve later. The submission must be submitted at the end of the submission process.



Step 2: Attach supporting documents. The first part of the Solution Needed form allows you to include pertinent reference documents, such as images, emails, PDFs, standard drawings, contract language, or other files, that relate to a search for the intended solution. The attached files will be visible to you before submission to ensure appropriate files are attached.

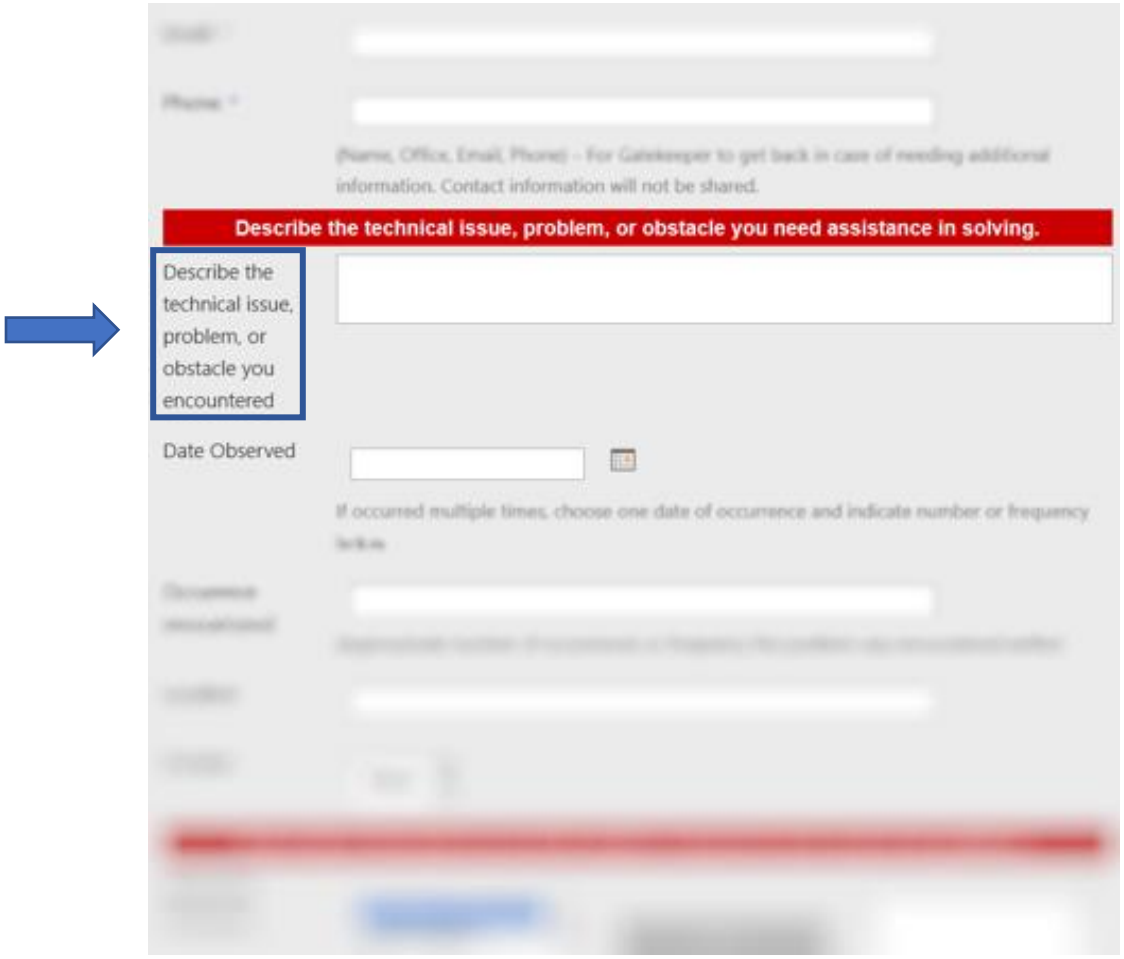


Step 3: **Complete basic respondent information.** The next part of the Solution Needed form requires basic respondent information, such as your name, office, email address, and office phone number. This information is solely for the purpose of the gatekeeper to contact you in case additional information or clarification is necessary.

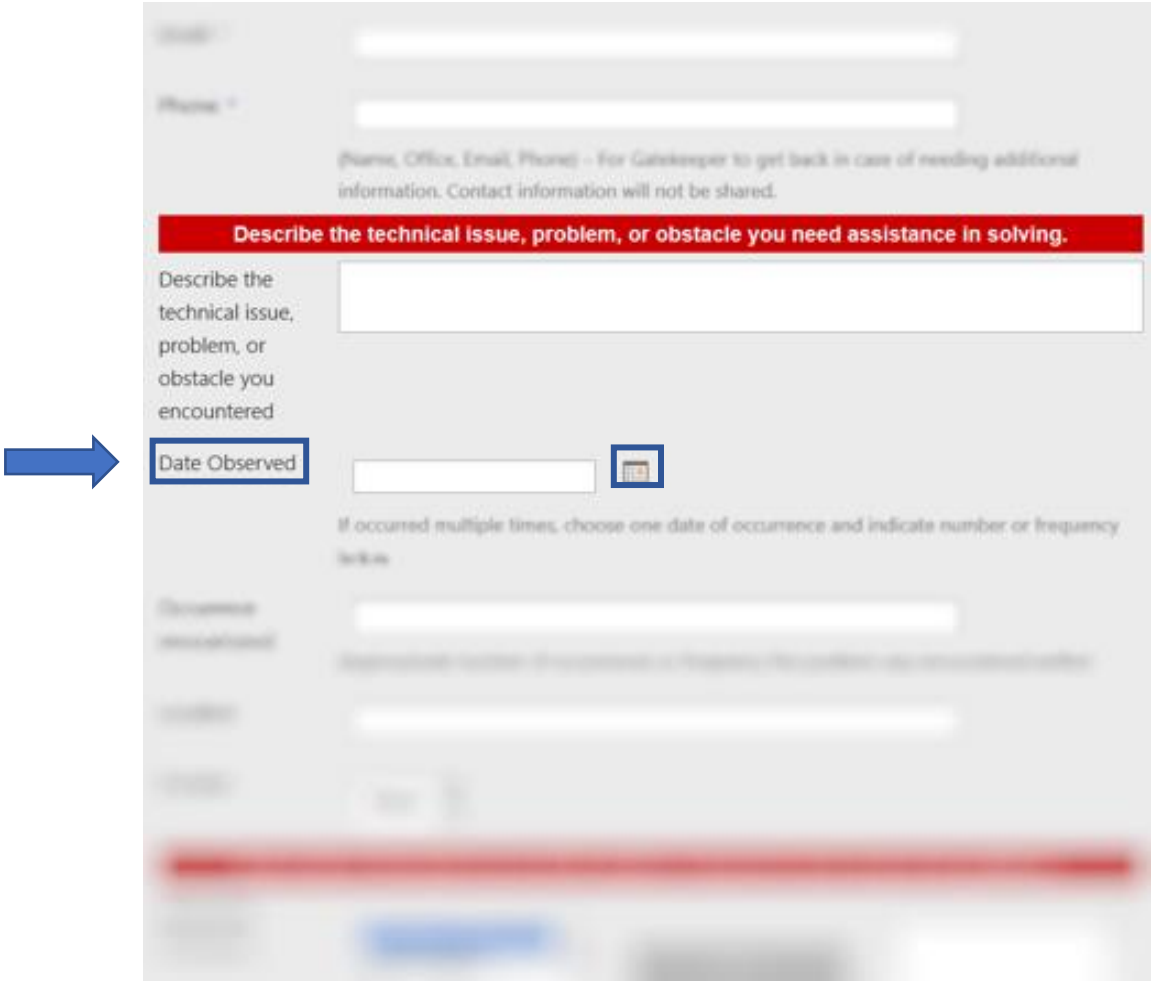


Step 4: Describe the technical issue, problem, or obstacle for which a solution is needed. This step captures information about the technical issue or challenge that needs a solution.

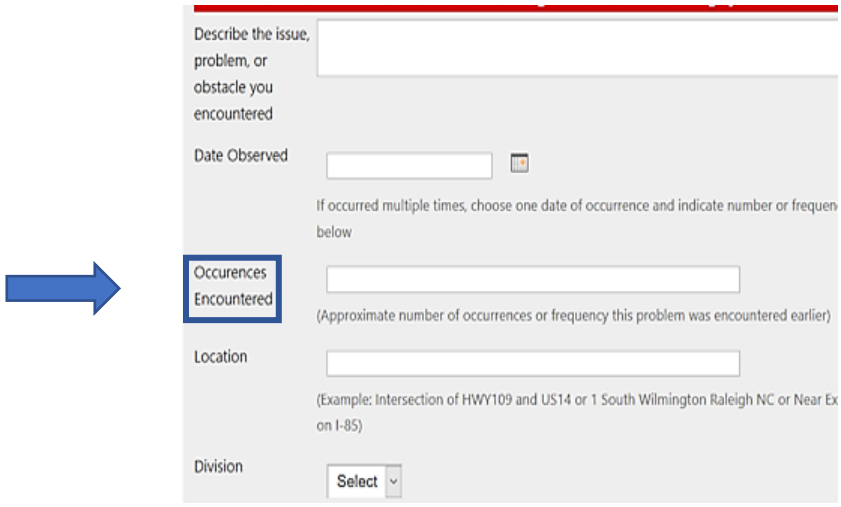
Step 4 a: Describe the issue, problem, or obstacle you encountered. Enter the problem description as a summary of the challenge that needs resolving.



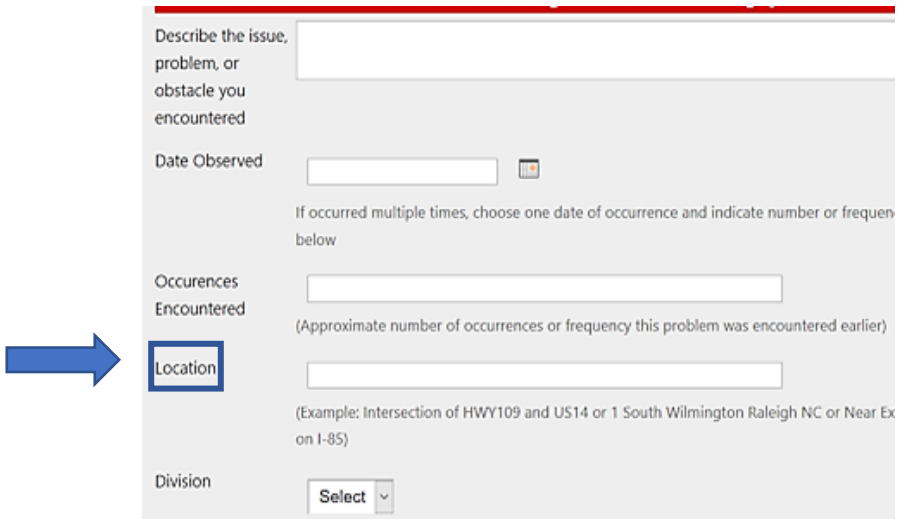
Step 4 b: **Select date observed.** For the date observed, click on the calendar button and select the approximate date that the issue that requires a solution was observed. If the issue frequently occurs, then enter the most recent date observed and provide details regarding that particular observation.



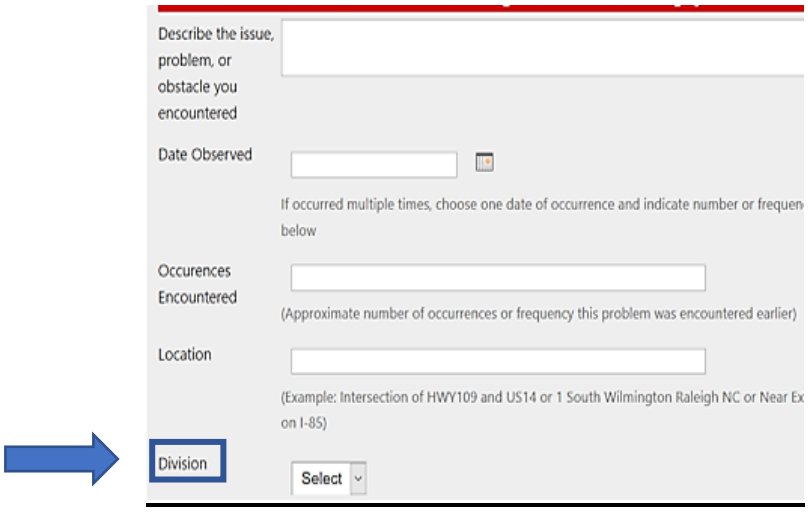
Step 4 c: Indicate issue frequency. Using the drop-down menu, indicate the number of times that you have encountered this issue.



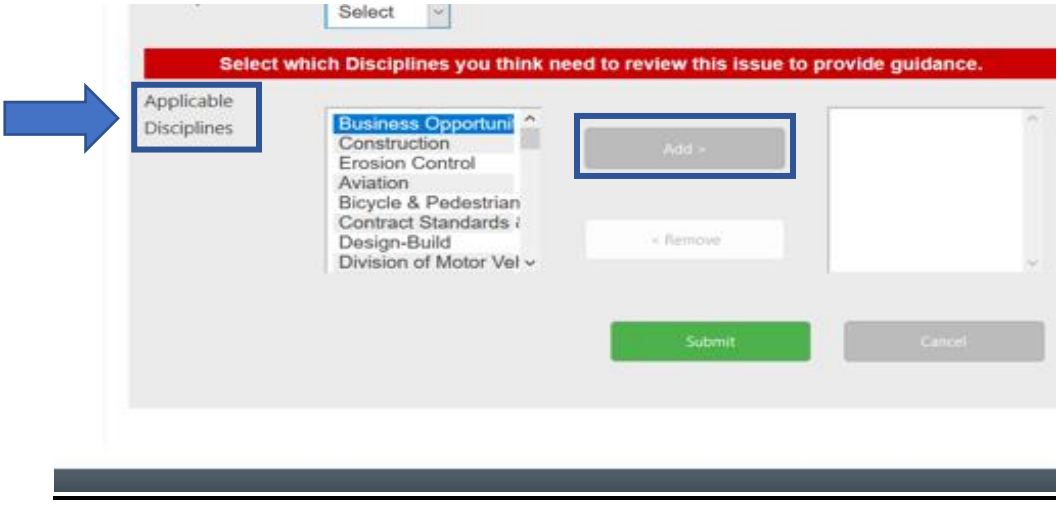
Step 4 d: Identify location of observation. Enter the location where you observed the issue. If it was observed in multiple locations, enter the most recent occurrence location.



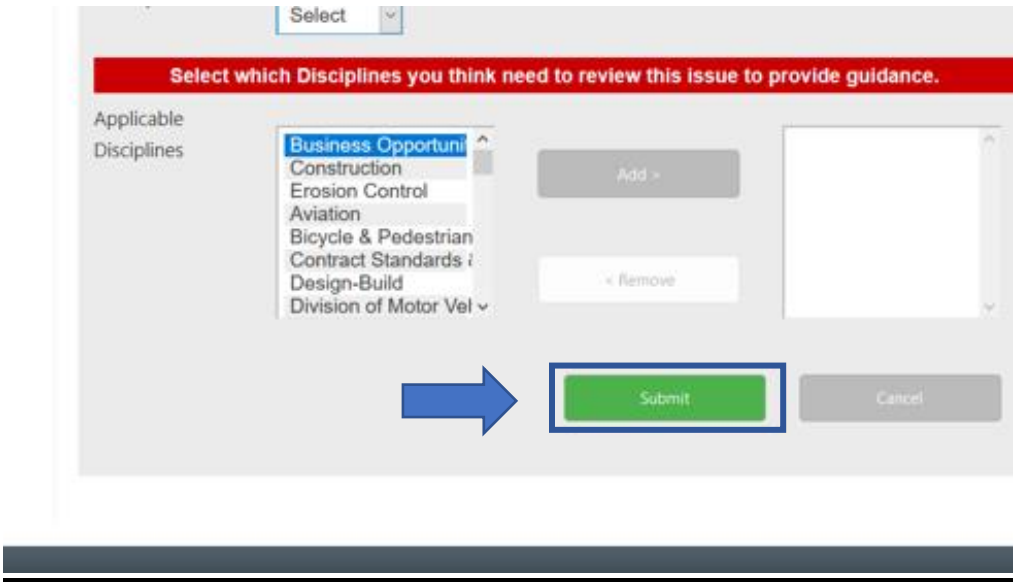
Step 4 e: **Division and County.** Using the drop-down options, select the Division and County that are related to the issue that needs a solution. Region will automatically populate based on the Division selected. County will also populate based on the Division selected, and thus, the Division must always be selected prior to selecting County and/or Region.



Step 5: Identify applicable disciplines. Select the Applicable Disciplines for this lesson; 38 disciplines are possible within the scope of the CLEAR program. Although the number of applicable disciplines is not limited, please select only the most pertinent or applicable discipline(s). You can scroll down and view all 38 applicable disciplines. For multiple selections, press and hold the Ctrl button on the keyboard to select all the applicable disciplines using a mouse-click. Once you have made all possible selections, click on 'Add' to finalize the selections. If you added an option by mistake or want to remove selection(s), you can select the discipline to be removed from the list and press the 'Remove' button.



Step 6: Check fields and submit. Upon completing the form, kindly go through all the fields to check for any missing fields. Once you are satisfied that the form is complete, click on 'Submit'. The submission will be sent to the gatekeeper in the Value Management Office for review. Once the 'Submit' button is clicked, no further changes can be made to the form. Clicking on 'Cancel' will erase all the information that has been entered and should be used only if you do not intend to submit Solution Needed information.



Thank you for your contribution.

Appendix K. Standard Operating Procedures for End-Users to Search for Lessons Learned

Instructions for Searching Lessons Learned and Creating a Personal View

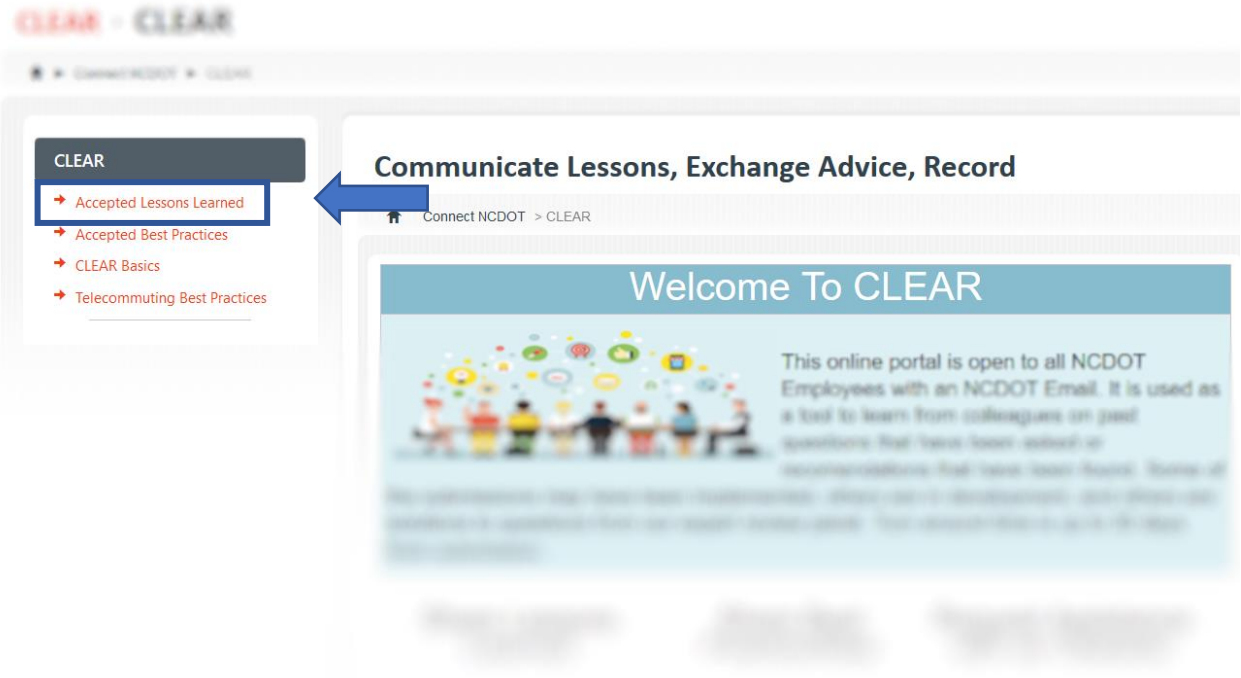
The following guidelines provide direction for users to search for lessons learned in the North Carolina Department of Transportation (NCDOT) CLEAR (Communicate Lessons, Exchange Advice, Record) database. Searching for lessons learned reduces the need to sift through numerous approved lessons learned and promptly displays the most relevant results based on the search criteria provided. Searching for lessons learned will help users to explore the existing knowledge base and apply appropriate knowledge to their projects as needed. These standard operating procedures (SOPs) also provide steps to create a 'personal view'. By creating a personal view, users can customize the level of detail that they want the lessons learned to be displayed. Thank you for your support of this important program.

The following steps will help guide you through the search process.

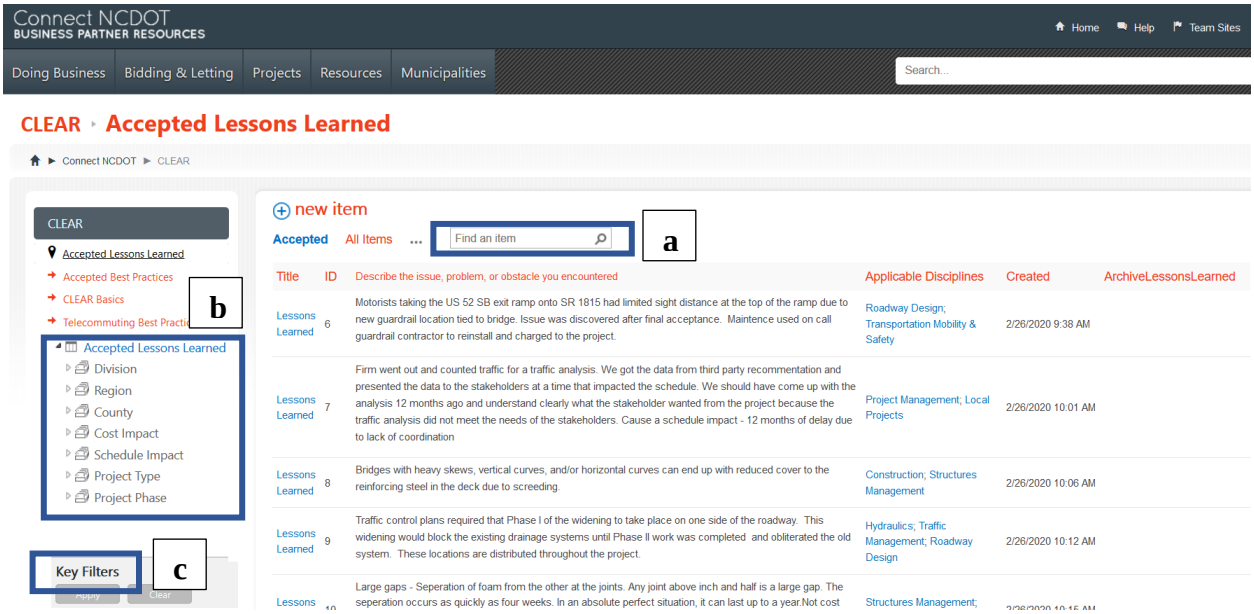
Step 1: **Log in**. Click on the following link, which will bring you to the log-in screen.

https://connect.ncdot.gov/site/lessons-learned/Pages/default.aspx

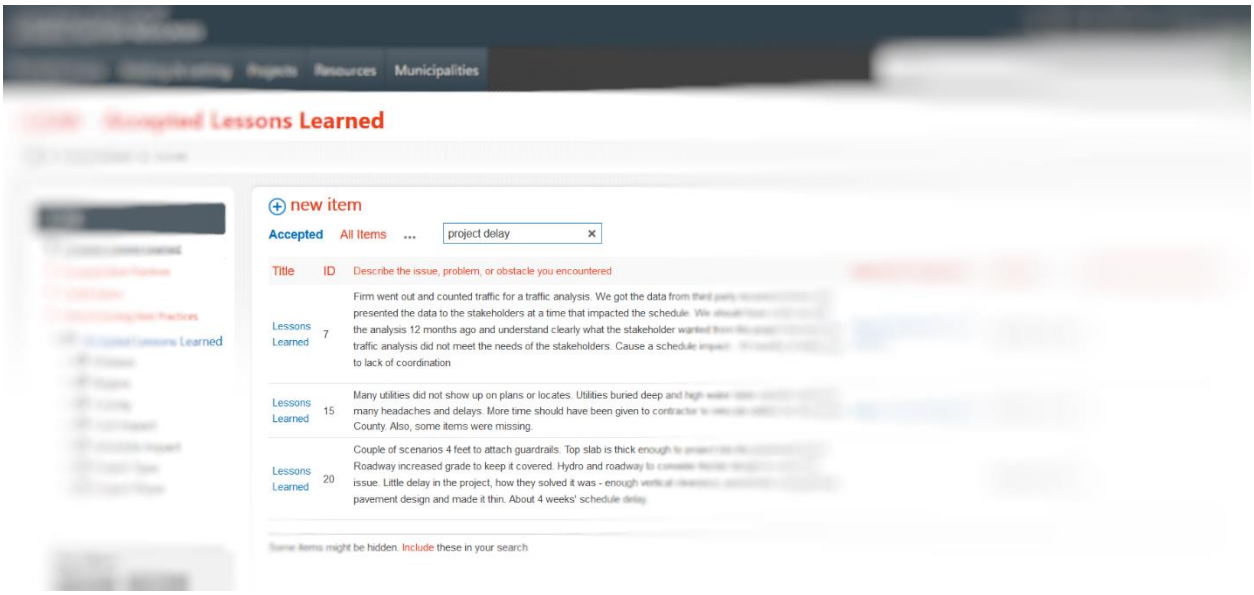
Log in with required credentials (you may bypass this part of the log-in process if you are already logged into the NCDOT network) and click on 'Accepted Lessons Learned' to start entering information.



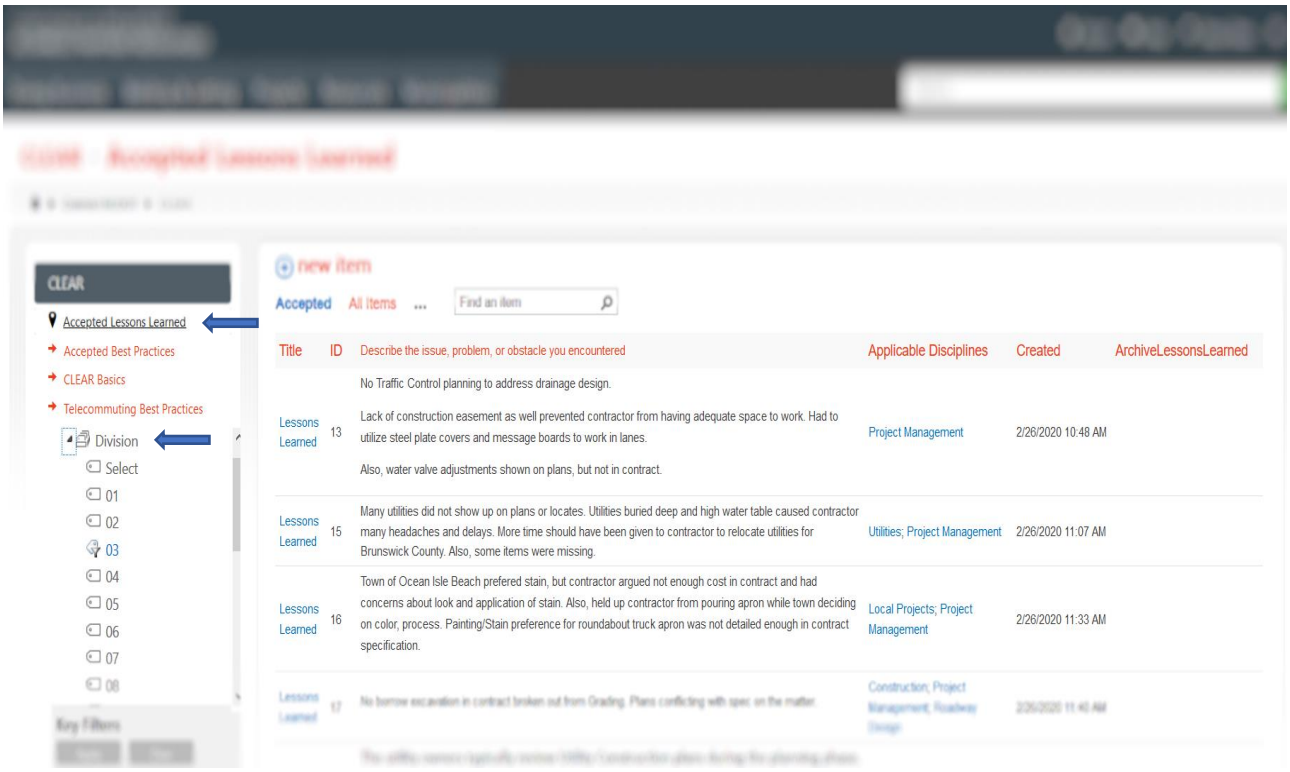
Step 2: **Search for relevant lessons learned.** On this webpage, you have three options (keywords, a single criterion, or multiple filters) to use the search functionality, as shown below. Note that only one search option can be used at a time.



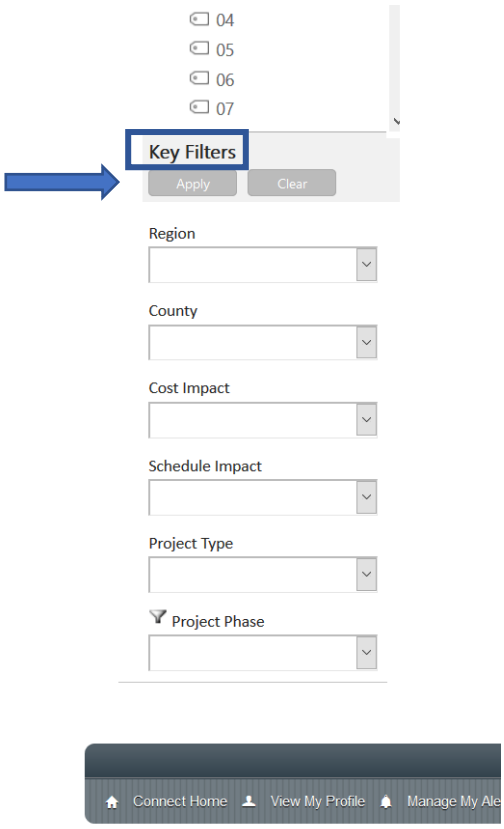
Step 2 a: Search using keywords. The first option is to use relevant keywords to search for lessons learned. Multiple keywords can be entered to narrow the search. For example, if you want to search for lessons learned that contain the keyword ‘project delay’, the search results will display only the lessons learned that contain that keyword, as shown in the screenshot below.



Step 2 b: Search using a single criterion. The second option is to search for lessons learned based on a single criterion in terms of the following fields: Division, Region, County, Cost Impact, Schedule Impact, Project Type, or Project Phase. This option is suitable if you want to look at all the lessons learned that pertain to any one of these fields. For instance, the screenshot below shows all the accepted lessons learned in Division 3.

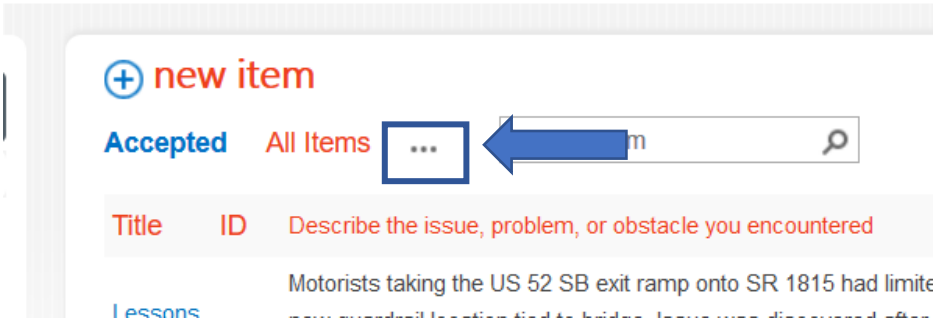


Step 2 c: **Search based on key filters.** The third option is to search for lessons learned using several drop-down options for multiple criteria to narrow the search results. Once the search drop-downs are finalized, click on the 'Apply' button to search. To reset the drop-down options and restart the drop-down selection options, click on the 'Reset' button.

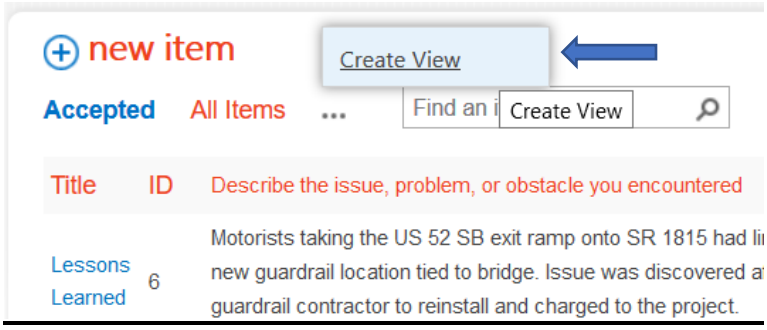


Step 3: **Create a personal view.**

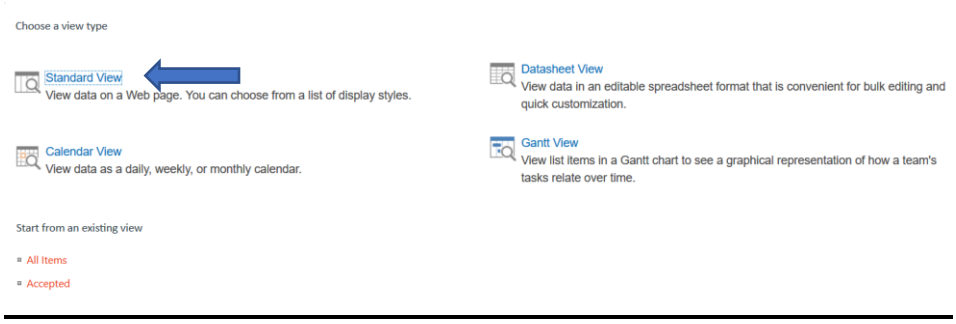
Step 3 a: **Click on the ellipses located at the top of the list.**



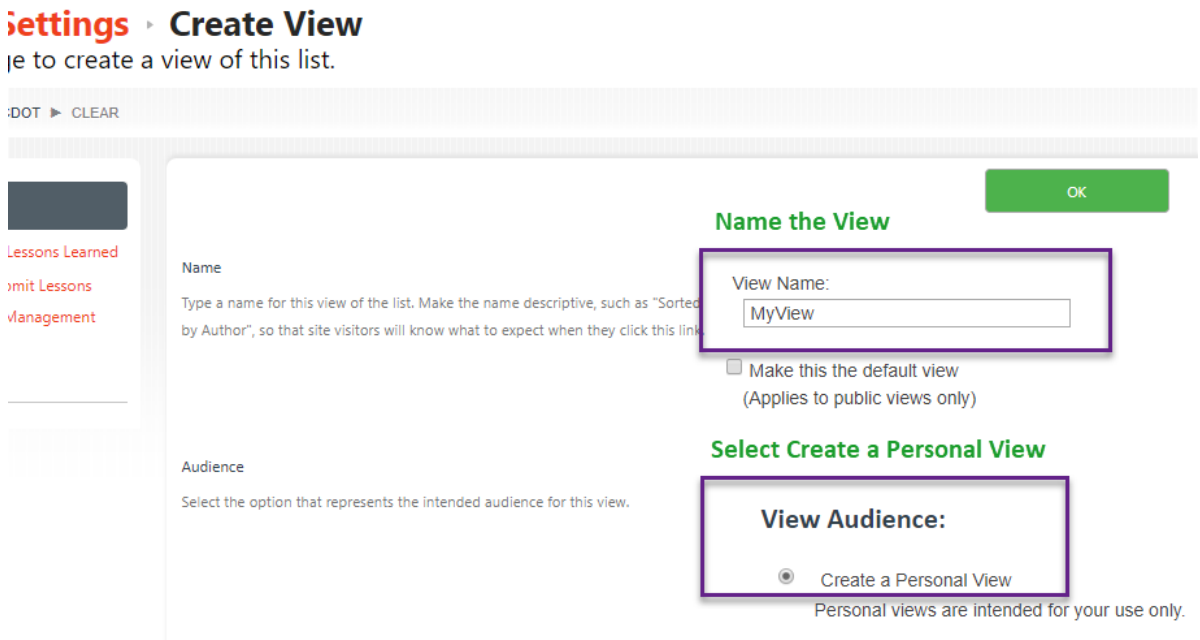
Step 3 b: Select 'Create View'.



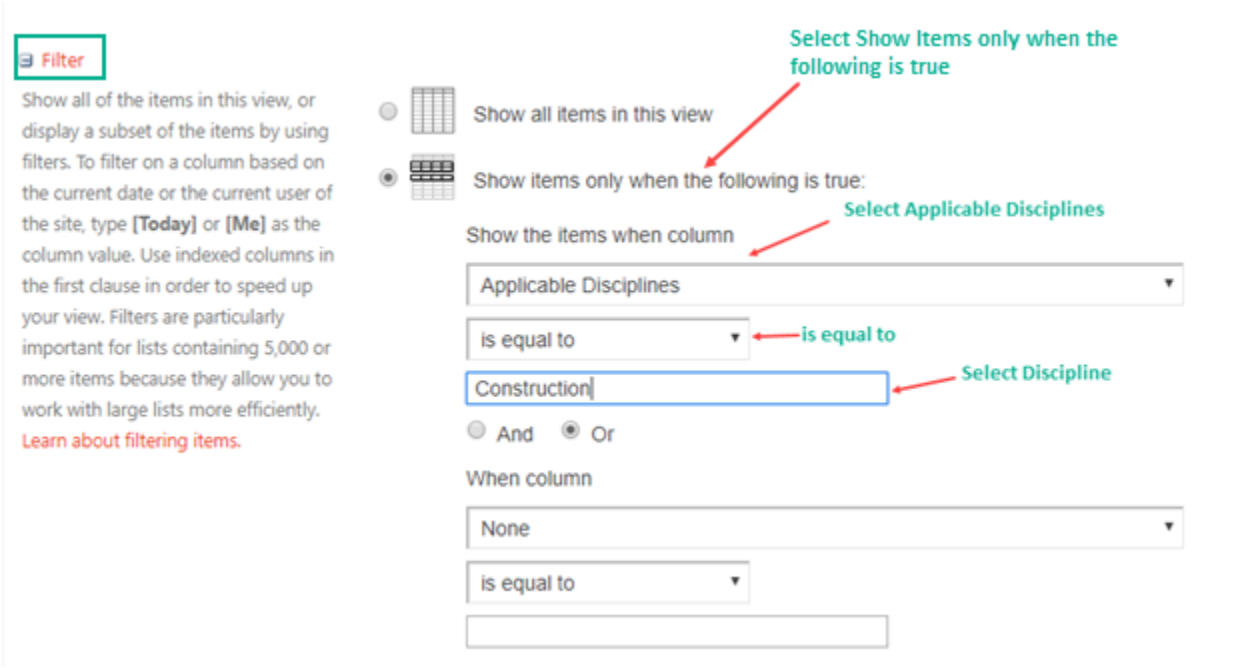
Step 3 c: In the Settings 'View Type' page, select 'Standard View'.



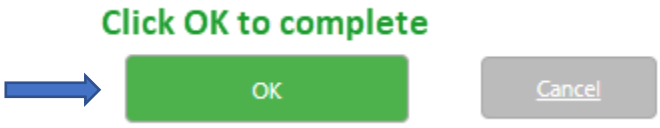
Step 3 d: In the 'Create View' page, name your view in the 'View Name' text box and under 'View Audience', select 'Create a Personal View'.



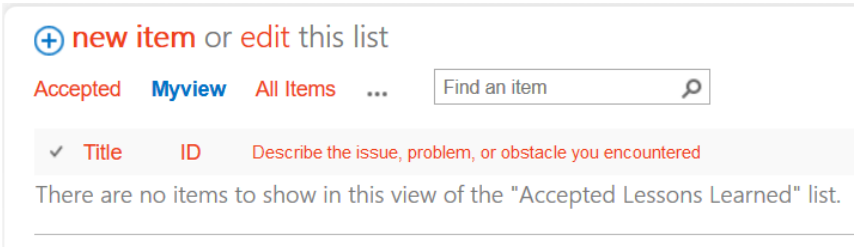
Step 3 e: Customize the personal view. You can make specific selections to customize the appearance of your personal view. For instance, if you want to create a personal view to browse lessons learned that have Construction as the Applicable Discipline, then select 'Filter', which is near the bottom of the page. Select 'Show items only when the following is true' and then select 'Applicable Disciplines' in the drop-down menu. In the next drop-down menu, select 'is equal to'. In the next text box, enter 'Construction' in the list, as shown in the image below. Note that the fields are not case-sensitive. You can add multiple filter criteria using the 'And'/'Or' option to narrow or expand the search results, respectively.



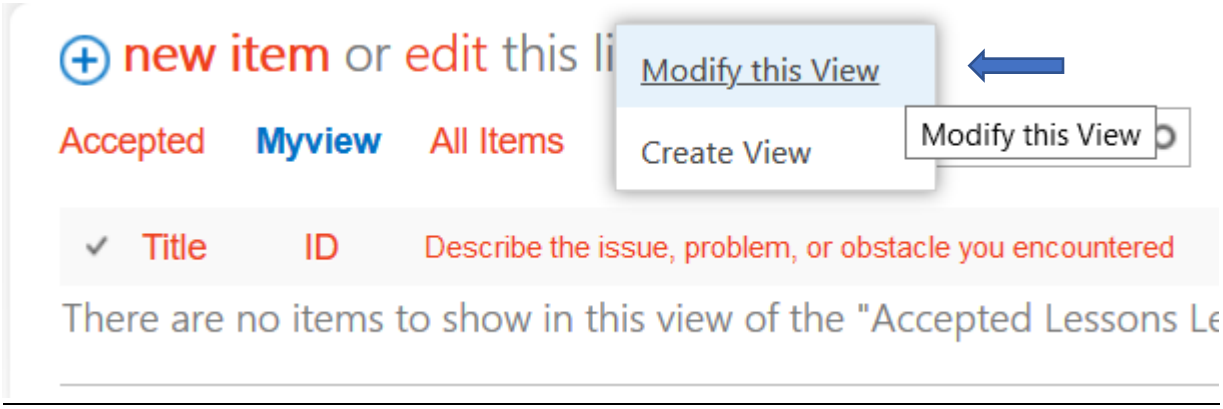
Step 3 f: Once all the necessary selections have been made, click 'OK' to complete.



Step 3 g: Find personal view. To find your personal view, open the list. Your personal view will be located at the top of the page or in the drop-down menu.



Step 3 h: Modify personal view. Click on the ellipses to modify your personal view.



Thank you for using the CLEAR database.

Appendix L. Frequently Asked Questions (FAQs) Related to CLEAR

Why should I enter information into the CLEAR database?

The CLEAR (Communicate Lessons, Exchange Advice, Record) database is intended to serve as a data repository for knowledge about projects that has been gained by North Carolina Department of Transportation (NCDOT) personnel. To serve its purpose effectively, you are encouraged to submit any relevant lesson learned/best practice using the appropriate form in CLEAR to help NCDOT personnel work on future projects more effectively.

What qualifies as a lesson learned?

Lessons learned are experiences that should be taken into consideration for future projects, process improvement, and/or guideline improvement. After a challenge (e.g., a risk or problem) or opportunity has been observed, the lesson learned is the knowledge or insight gained from that experience that then can be shared with others to promote/reinforce positive outcomes and reduce/eliminate the potential for future mishaps and failures.

What qualifies as a best practice/idea?

A best practice/idea is an innovative solution that has been practiced or is proposed.

What qualifies as a solution needed?

If you are looking for ways to improve a certain workflow process or solve a particular problem or issue, you can submit a 'Solution Needed' form to obtain helpful responses and potential solutions from other units or divisions.

What happens to my submission once I've submitted it?

Once submitted, your submission goes to the gatekeeper (the Value Management Office) for initial review. The gatekeeper will ensure the completeness of the information you have shared and, if necessary, will ask you to provide additional information or clarification before sending the file to the Expert Review Panel (ERP). The ERP will review the submission, provide comments or responses, and decide on its contribution to the CLEAR database.

Can my consultant use the CLEAR database to submit and search lessons learned/best practices/solutions?

The CLEAR database can be accessed by anyone with valid official NCDOT credentials. Currently, external consultants do not have access to files internal to the NCDOT and hence cannot access and use the CLEAR database directly. However, if you are an NCDOT employee and have access to the database, you can submit lessons learned that are associated with your work in consultation with the external consultant.

How can I share information in the CLEAR database with my consultant?

Due to the nature of the database, external consultants do not have direct access to CLEAR. However, you can enter lessons learned on their behalf by entering printed reports and uploading email correspondence, etc.

Can I edit my submission once it is submitted?

No. Once you click 'Submit', the submission cannot be retrieved and modified.

What if I get an email that is 'Request for Information'?

This email would indicate that the gatekeeper requires additional information from you in order to vet the submission.

What information do I need for a submission?

The information you enter will vary depending on the form(s) that you choose to use (i.e., Lessons Learned, Best Practice or Idea, or Solution Needed).

Why would my submission be rejected?

A submission may be rejected for several reasons, including: (1) the submitted form is incomplete and/or (2) the ERP does not consider the submission acceptable for CLEAR.

How many submissions can I have?

You are encouraged to input as many useful lessons learned/best practices as possible. The number of submissions is unlimited.

What if I want to be part of the review process?

At the end of the submission form, you will be asked if you would like to be a part of the development and implementation of your idea and you will be able to indicate if you would like to be involved in this process.

Who is an Innovation Coordinator?

Innovation Coordinators are personnel who are highly motivated in championing CLEAR, thereby promoting the culture of innovation within their unit or office.

Can I save my submission and finish editing at a later time?

No. The submission cannot be saved to work on later. Once the 'Submit' button is clicked, the form is submitted.

What does 'accepted' mean?

An accepted lesson learned/best practice is a submission that has been fully vetted and reviewed by the ERP and has been made available for sharing. You can find approved submissions in the accepted lessons learned list or accepted best practices list.

Who reviews my submission?

Each submitted lesson learned goes through two rounds of screening. The gatekeeper will perform the initial screening to ensure completeness of the entered data. The ERP will make the final decision regarding acceptance/rejection of the submission.

How long does it take for my submission to be reviewed?

The ERP will have a 30-day window to report its decision to the gatekeeper.

Who do I contact if I want an update?

Please contact Clare Fullerton at the NCDOT Value Management Office: clear@ncdot.gov or (919) 707-6683.

How do I log in to the CLEAR SharePoint site?

You can log in with your official credentials using the following link: https://connect.ncdot.gov/site/lessons-learned/Pages/default.aspx. If you already are logged in to the Connect NCDOT portal, you may bypass the requirement of entering your credentials.

How do I search for accepted submissions?

The approved submissions can be searched based on various conditions, such as Division, keywords, etc. The link to search for submissions is provided on the CLEAR webpage in the Connect NCDOT portal.

Is my name and contact information published?

No. This information is used only by the gatekeeper in case additional information or clarification is needed from you. Your information is made available only to the gatekeeper and ERP. Also, your contact information will not be shared once the submission is approved.

How do I know what next steps to suggest?

If you think that the information you entered can be developed further into an innovative idea, such as the organization-wide application of a novel material or application of Lean Six Sigma to improve project processes, then such information constitutes a strong basis for suggesting next steps.

If I select 'Suggest a Next Step', will someone contact me regarding Lean Six Sigma, a research project idea, etc.?

Based on the usefulness of the next step suggested and its applicable benefits to the NCDOT, you might be contacted by the Value Management Office or a member of the ERP to discuss your suggestion further.

How do I decide which Applicable Discipline(s) to select?

Based on the information entered, select the discipline that is the most relevant or applicable to your lesson learned or best practice. Even if a discipline is not directly applicable for the submission, select one that may be even indirectly applicable.

Which form do I select to enter information?

Currently, you can choose among three forms to enter information into the CLEAR database: (1) the Lessons Learned form to enter useful information about successes and failures in a project (2) the Best Practices form to share an innovative idea or best practice that can yield significant organizational benefits to the NCDOT, and (3) the Solution Needed form to solicit solutions to a problem faced in a project.

How can I learn more about entering information into one of the forms?

Standard operating procedures (SOPs) have been developed for each of the three forms. On the website landing page, look for ‘CLEAR SOPs’. Under the title for each form, step-by-step guidance about entering information is provided. Also, video training material is available under ‘CLEAR Videos’ to show users how to enter information.

How long will a submission stay in the database?

If the submission becomes superseded by, e.g., a specification or policy, it will be archived so that such records can be maintained.

Appendix M. What Happens to a Lesson Learned? Specific Case of Utilities

This appendix presents an example of a lessons learned experience to show how the North Carolina Department of Transportation (NCDOT) CLEAR (Communicate Lessons, Exchange Advice, Record) database can be used to improve the NCDOT knowledge base and address a specific problem that pertains to utilities claims.

How did we identify this issue?

During the lessons learned data gathering phase for the CLEAR database, the North Carolina State University (NCSU) research team realized significant project concerns that relate to, for example, utilities not being moved within the agreed-upon timeframe. Unknown utilities often were discovered during construction, and other unexpected utilities conflicts led to claims and supplementary agreements that ultimately increased project costs and schedules.

What are some next steps to investigate an issue?

The NCDOT Value Management Office determined that next steps were needed to investigate this ongoing issue and requested further research to understand the actual cost and schedule impacts and to identify the root cause(s). The NCSU research team performed careful analysis of utilities claims data for 1996 through 2018. The NCSU team also carried out a literature review to understand how other state DOTs mitigate potential utilities issues on their projects. The team also solicited feedback from current NCDOT personnel about ways that utilities-related issues are handled on a day-day basis. The data analysis revealed the following observations:

- Approximately 90% of projects with utilities claims had one or two utilities-related claims.
- Each division had at least 30 utility-related claims during the study period.
- Smaller projects (up to $5 million) were more affected by utilities claims than larger projects; roughly three out of four smaller projects were affected by utilities claims.
- Claims that pertain to utilities conflicts accounted for about 57% of all utilities-related schedule delays.
- For the projects affected by utilities claims, project costs increased by about 2.4%, with schedule delays increased by 70 days on average.

Based on the literature review and discussions with NCDOT personnel, the NCSU research team identified the following key mitigation strategies:

- Communicate early and frequently with utilities providers in order to have a shared sense of responsibility (with the NCDOT) in relocating utilities.
- Hold constructability reviews with utilities owners to minimize plan changes.
- Explore the possibility of imposing liquidated damages on utilities companies to ensure that they do not default on agreed-upon dates for utilities relocation.
- Perform comprehensive subsurface investigations for all projects to avoid encountering buried utilities.

What can be done to implement this experience into lessons learned or to bring about positive change in the NCDOT?

The NCSU research team provided its analysis results to the NCDOT utilities group for further action. This sharing of knowledge may lead to revising contract language that pertains to utilities providers and specifications in order to detect underlying utilities by ensuring that proper subsurface investigations are performed on all projects, thus turning the lessons learned into lessons remembered. These changes will allow the NCDOT to be more efficient and effective in their workflow processes and mitigate utilities-related claims in future projects. For this particular example of utilities-related claims, the recommendation was for the NCDOT to consider establishing a Strategic Implementation Team to review the data and best practices from other states and pilot new initiatives to work on this ongoing issue of utilities-related claims.

Appendix N. CLEAR Training Feedback Form:

Feedback from Division Personnel

Consent Agreement

Your participation in providing feedback is voluntary and you can choose not to participate or to stop participating at any time. You consent that you are willing to participate in this survey by providing feedback. Your input will provide valuable perspectives about the North Carolina Department of Transportation (NCDOT) CLEAR (Communicate Lessons, Exchange Advice, Record) program and will allow the North Carolina State University research team to improve it accordingly.

Division:
County:
Number of years working at the NCDOT:

Currently, users can use three forms to share/solicit relevant information. Rank the forms based on your preference and the one(s) that you think you would use the most.

CLEAR Input/Sharing Options	Rank (1 = highest, 3 = lowest)
Share lesson(s) learned	
Share best practice/idea that has been implemented	
Solicit information to resolve a challenge/issue/problem faced on a project	

Please select your response to each of the following statements.

Response	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
The presentation of the CLEAR program and its objectives are clear to me.					
I feel the CLEAR program will help the NCDOT become more efficient in its project delivery.					
I found the forms easy to complete.					
I will share information about the CLEAR program with my colleagues and encourage them to learn more by accessing CLEAR.					
I know who to contact if I have any questions about using the CLEAR program.					

If you have anything else you would like the CLEAR team to know about your perspectives and ideas regarding this program, please add it here.

Appendix O. Lessons Learned Information Gathered from NCDOT Personnel Regarding Utilities

The table that comprises this appendix lists a few issues and suggested solutions provided by the survey respondents in the form of lessons learned within the North Carolina Department of Transportation (NCDOT) CLEAR (Communicate Lessons, Exchange Advice, Record) database that were related to utilities. Some of the responses have been paraphrased to better fit the table format. Any respondent identifier information has been removed as required by the North Carolina State University Institutional Review Board for privacy reasons.

Division	County	Issue Description	Issue Details	Solution to the Issue
3	Brunswick	On this project utilities were deep and stacked; they were “located but not picked up”.	Utility items left out of contract.	Add supplemental field surveying when there are several utilities.
3	Brunswick	Several utilities conflicts identified on project.	Utilities not located on plans, causing delays to the contractor.	Contractor worked around utility issues by utilizing different drainage designs, traffic control phasing, and processes.
14	Buncombe	Existing 15" drainage pipe was not in the location as noted on the plans.	Contractor waited for a redesign, which overran on pipe quantities.	Hold field meeting ahead of the project bid and let process.
3	Onslow	Sporadic interactions between contractor and DOT, and between DOT and municipalities.	Utility owners are late in relocating utilities, causing schedule delays.	Need to obtain early buy-in from all stakeholders; get contractor involved.
14	Jackson	Several utilities are generally involved on a widening project whose relocation can inadvertently	Cost and schedule impacts: Added a few months to project schedule. Cost impacts are almost double.	Meet with utility owners and municipalities early on and try to minimize impacts due to utilities.

		affect nearby businesses.		
5	Durham	NCDOT Prime Contractor had crews scheduled to begin on date of availability, but utilities had not been relocated.	Impacts increased project cost and delayed the schedule.	Issue was solved with subsurface utility engineering (SUE) investigation and additional utilities coordination during construction. Should be resolved during preconstruction.
5	Durham	Coordination issues with utility companies; getting utility owners to move utilities is a challenge.	Less than 1% impact on cost and schedule.	Possible solutions include compensating the utilities to get relocation work done on time and conducting division-level meetings with utilities, which improves communication and minimizes surprises.

Appendix P. Gatekeeper Data Dashboard Standard Operating Procedure

The research team prepared several sets of Standard Operating Procedures (SOPs) for the gatekeeper dashboard namely Website Analytics, Lessons learned/Best practices visualizations, and Innovation Culture Index (ICI) survey data visualizations. These SOPs are described below.

Website Analytics

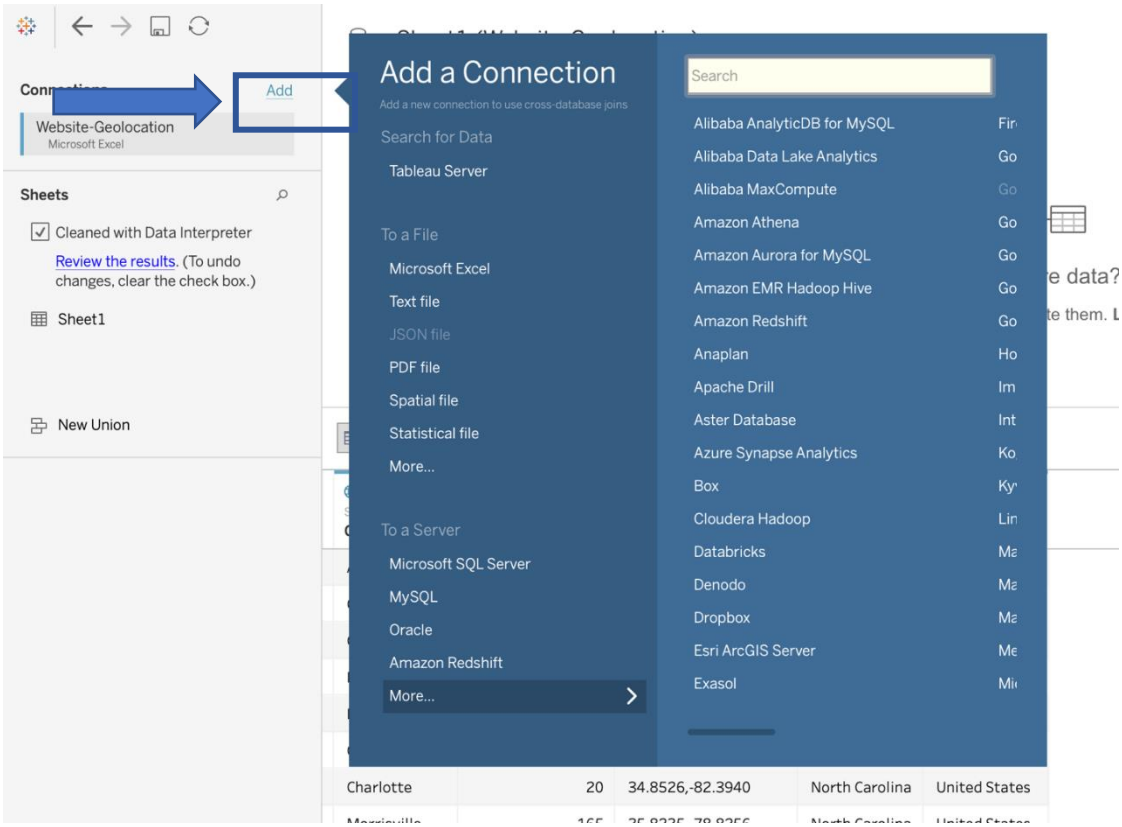
The following guidelines provide direction and instructions for the set-up, administration, and operation of the North Carolina Department of Transportation (NCDOT) CLEAR (Communicate Lessons, Exchange Advice, Record) website data dashboard. Thank you for your support of this important program.

Step 1: **Start by obtaining valid files and saving them in a common folder.**

The workbook for the visualization of the website data is a Tableau file (Clear Website Data Visualization.twbx). It utilizes two data sources: (1) CLEAR Website Data - February 2021-Processed.xlsx for facilitating the data metrics aspect of the dashboard and (2) Website-Geolocation.xlsx for facilitating the geolocation aspect of the dashboard. Both of these files can be edited and renamed to include the latest data to be sent to the dashboard.

Step 2: **Specify the data sources for the dashboard within the Tableau workbook.**

Within the Tableau workbook, open the 'Data Source' tab. Use the 'Add' option to specify the two data sources individually for the website dashboard. Once the data sources have been added, they can be updated by clicking the arrow next to their name within the 'Data' tab and using the 'Edit' option. You may find it useful to always toggle the 'Cleaned with Data Interpreter' option along with the data source. Use this option to add both Excel files to the website visualization dashboard.



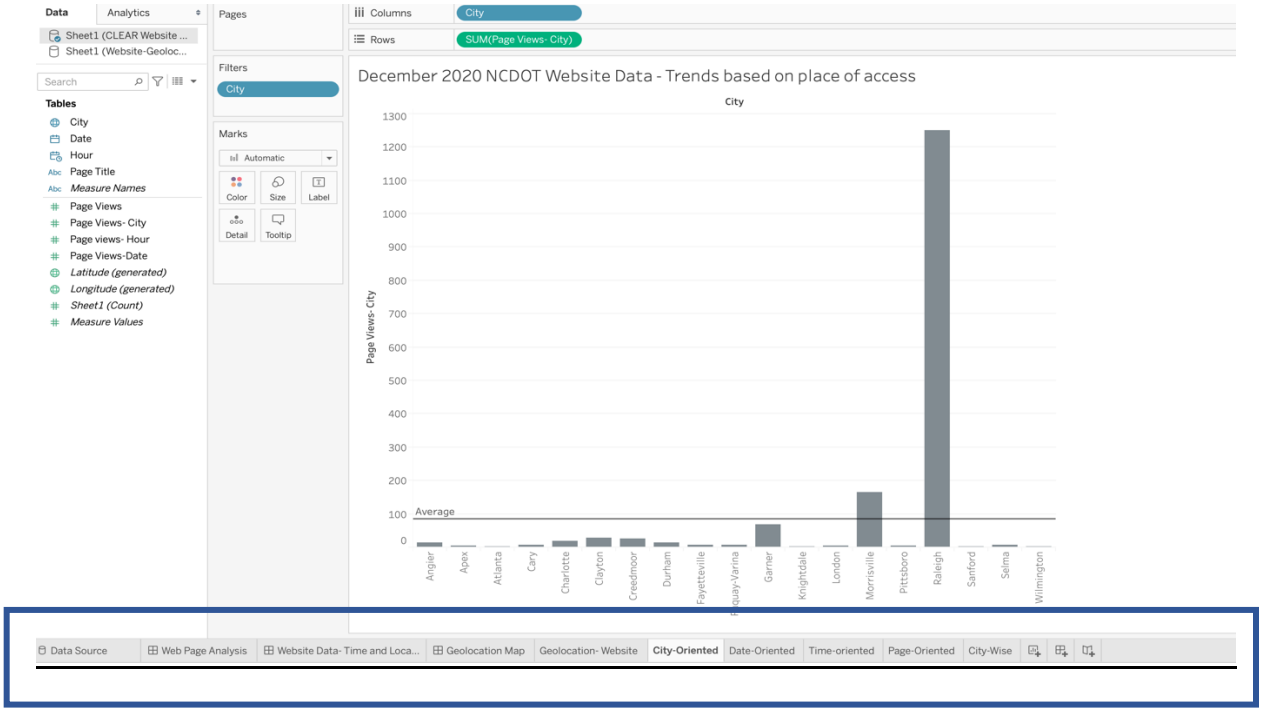
Once you have specified the data sources, you may want to look at the sample data values column exhibited by Tableau within the same 'Data' tab to check that all attributes and their corresponding values are being input correctly within Tableau.

Sort fields | Data source order

Sheet1 City	Sheet1 Page Views- City	Sheet1 Latitude Longitude	Sheet1 State	Sheet1 Country
Apex	4	35.7327,-78.8503	North Carolina	United States
Clayton	29	35.6507,-78.4564	North Carolina	United States
Creedmoor	26	36.1224,-78.6861	North Carolina	United States
Durham	14	35.9940,-78.8986	North Carolina	United States
Fuquay-Varina	6	35.5843,-78.8000	North Carolina	United States
Garner	68	35.7113,-78.6142	North Carolina	United States

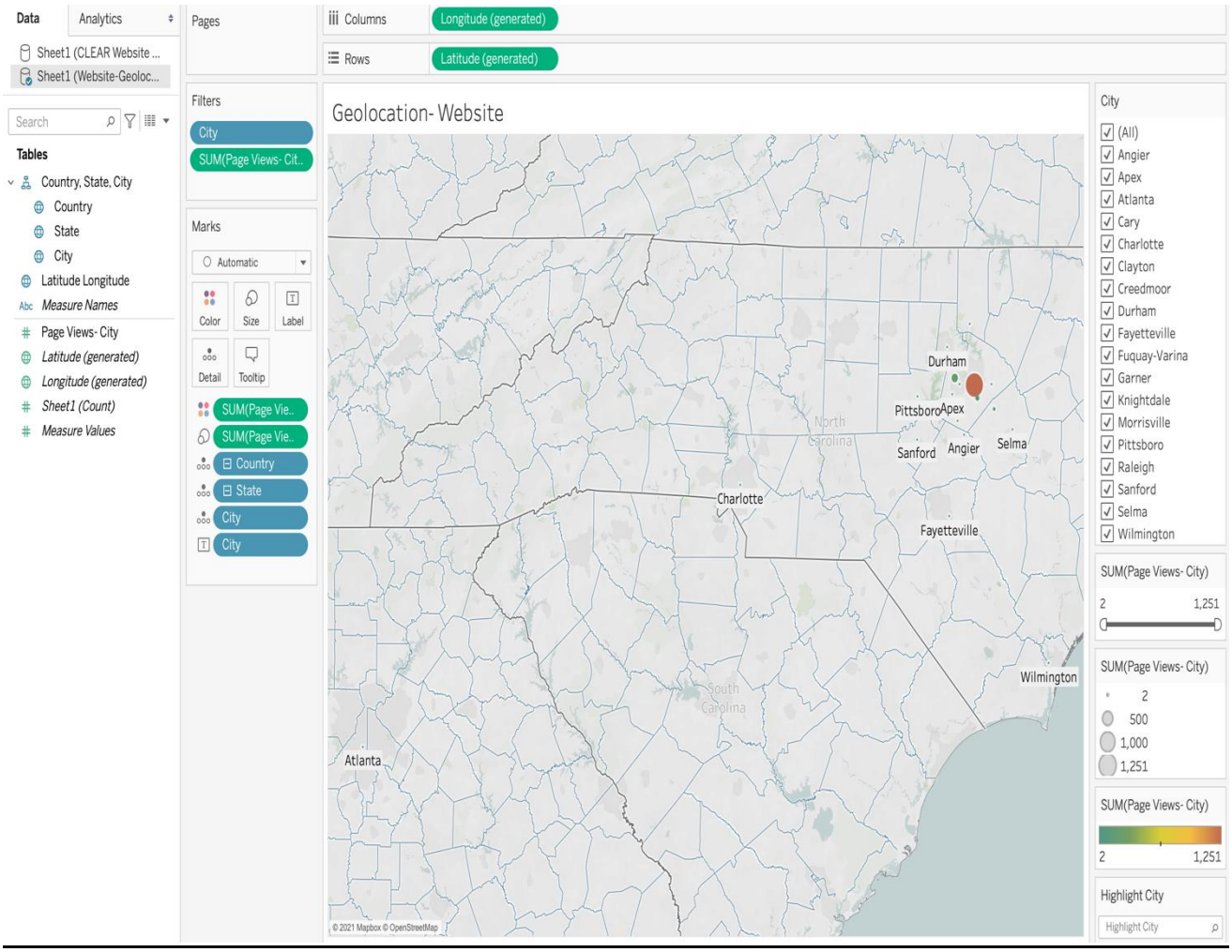
Step 3: **Navigate amongst the various visualization options within Tableau.**

To navigate among the various visualizations and dashboard views, use the 'Navigation' tab at the bottom of the Tableau window to view and edit individual visualizations and the dashboards that they feed.



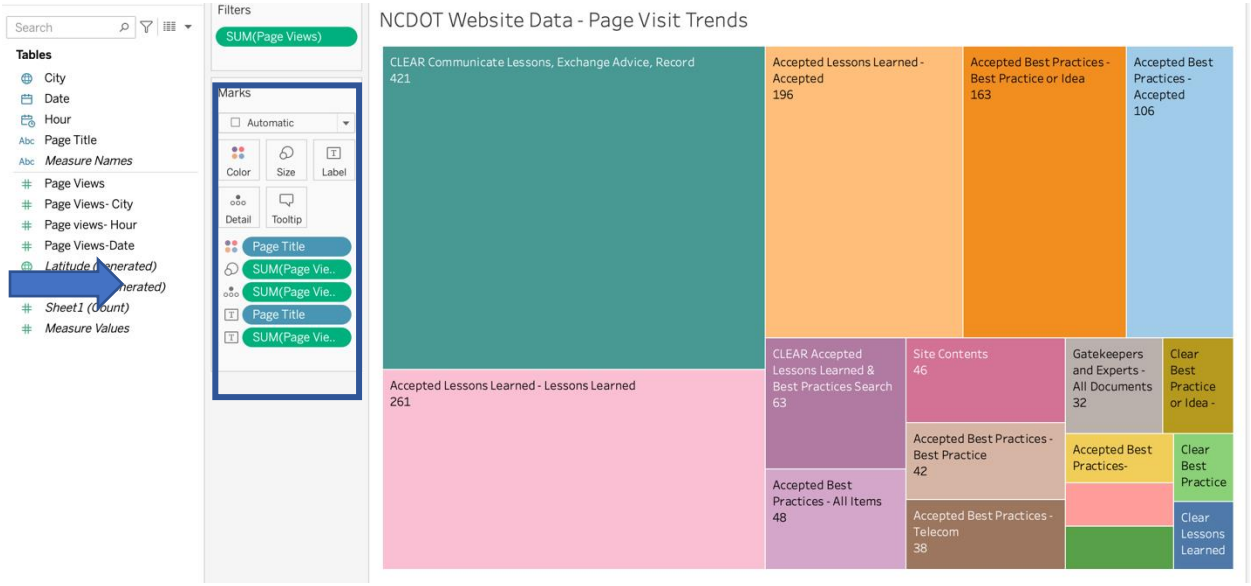
Step 4: **Edit the Geolocation visualization within the dashboard.**

As soon as you add the Website-Geolocation.xlsx file within the dashboard's data sources, you will see the automatically generated latitude and longitude attributes for the cities within the dashboard. These two values are used as the columns and rows, respectively, for the visualization and can be dragged to the visualization from the Tables menu. City and SUM(Page Views) are useful filters that can help you regulate the cities shown on the map visualization. Additional attributes are specified in the Marks menu to control the level of detail exhibited within the map.


Data
Analytics
Sheet1 (CLEAR Website ...
Sheet1 (Website-Geoloc...
Search
Tables
Country, State, City
Country
State
City
Latitude Longitude
Measure Names
Page Views- City
Latitude (generated)
Longitude (generated)
Sheet1 (Count)
Measure Values
Pages
Filters
City
SUM(Page Views- Cit..
Marks
Automatic
Color
Size
Label
Detail
Tooltip
SUM(Page Vie..
SUM(Page Vie..
Country
State
City
City
Columns
Longitude (generated)
Rows
Latitude (generated)
Geolocation- Website
Durham
Pittsboro
Apex
Sanford
Angier
Selma
Charlotte
Fayetteville
Wilmington
Atlanta
North Carolina
South Carolina
© 2021 Mapbox © OpenStreetMap
City
(All)
Angier
Apex
Atlanta
Cary
Charlotte
Clayton
Creedmoor
Durham
Fayetteville
Fuquay-Varina
Garner
Knightdale
Morrisville
Pittsboro
Raleigh
Sanford
Selma
Wilmington
SUM(Page Views- City)
2
1,251
SUM(Page Views- City)
2
500
1,000
1,251
SUM(Page Views- City)
2
1,251
Highlight City
Highlight City

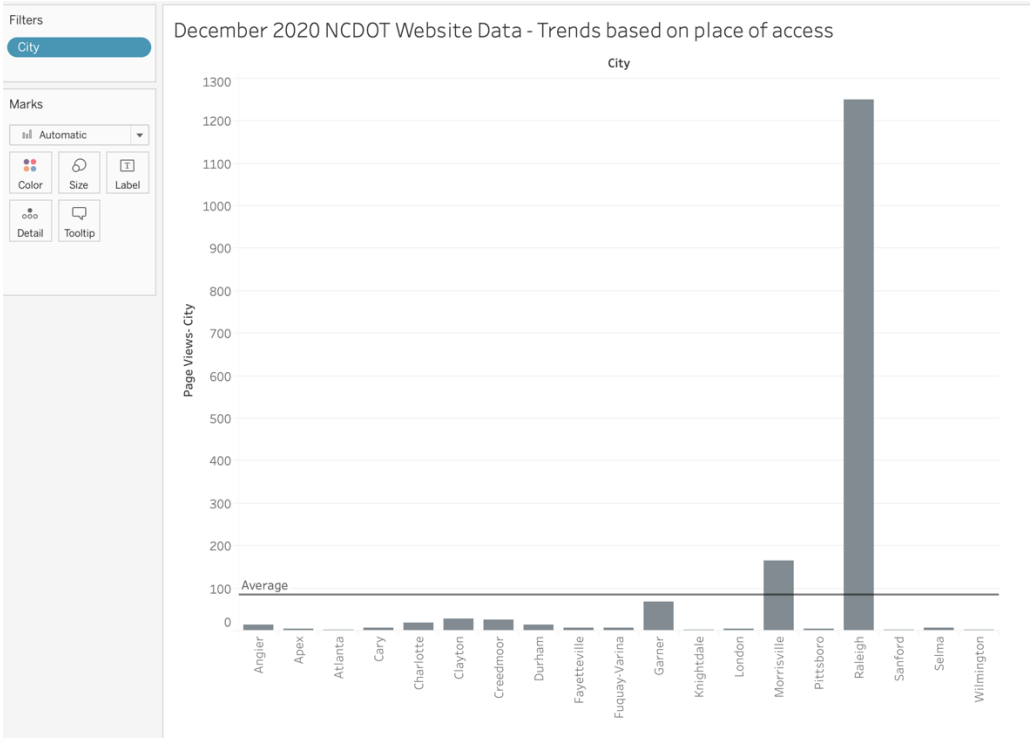
Step 5: **Edit the Page-View oriented visualization within the dashboard.**

For the Page-View oriented visualization, you do not need to specify any rows and columns values explicitly. Rather, the Marks menu allows various attributes, such as Page Title, to be added to help the visualization. The SUM(Page Views) is a filter for the visualization.

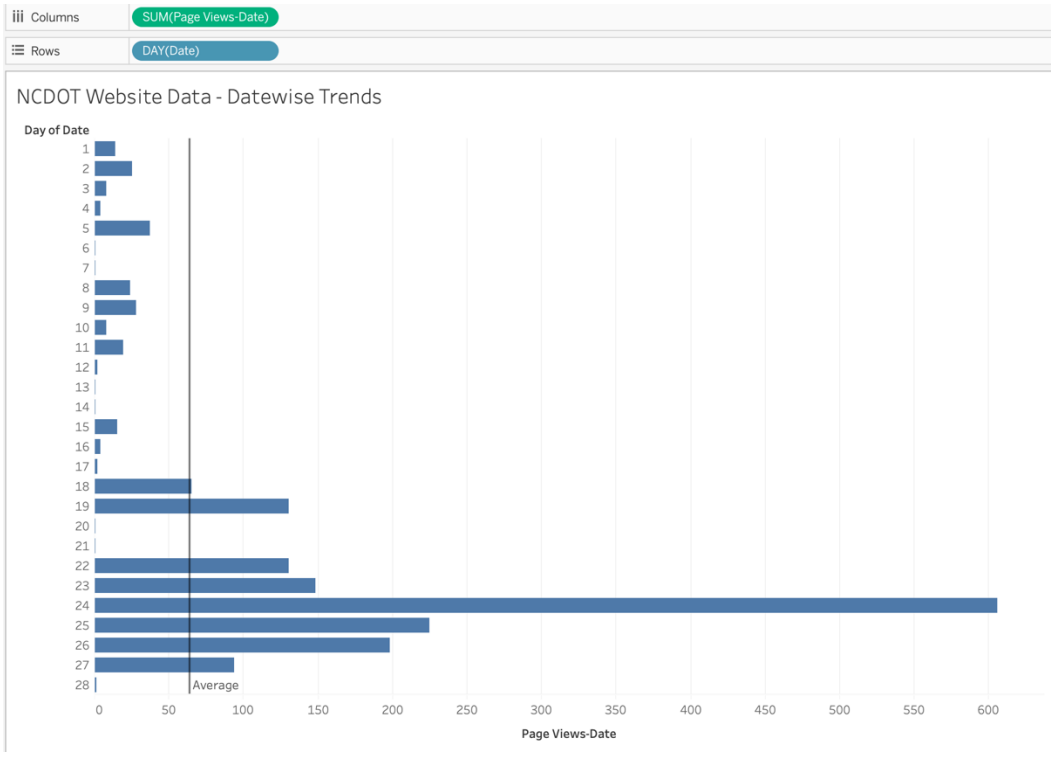


Step 6: **Edit the city-oriented, time-oriented, and date-oriented visualizations within the dashboard.**

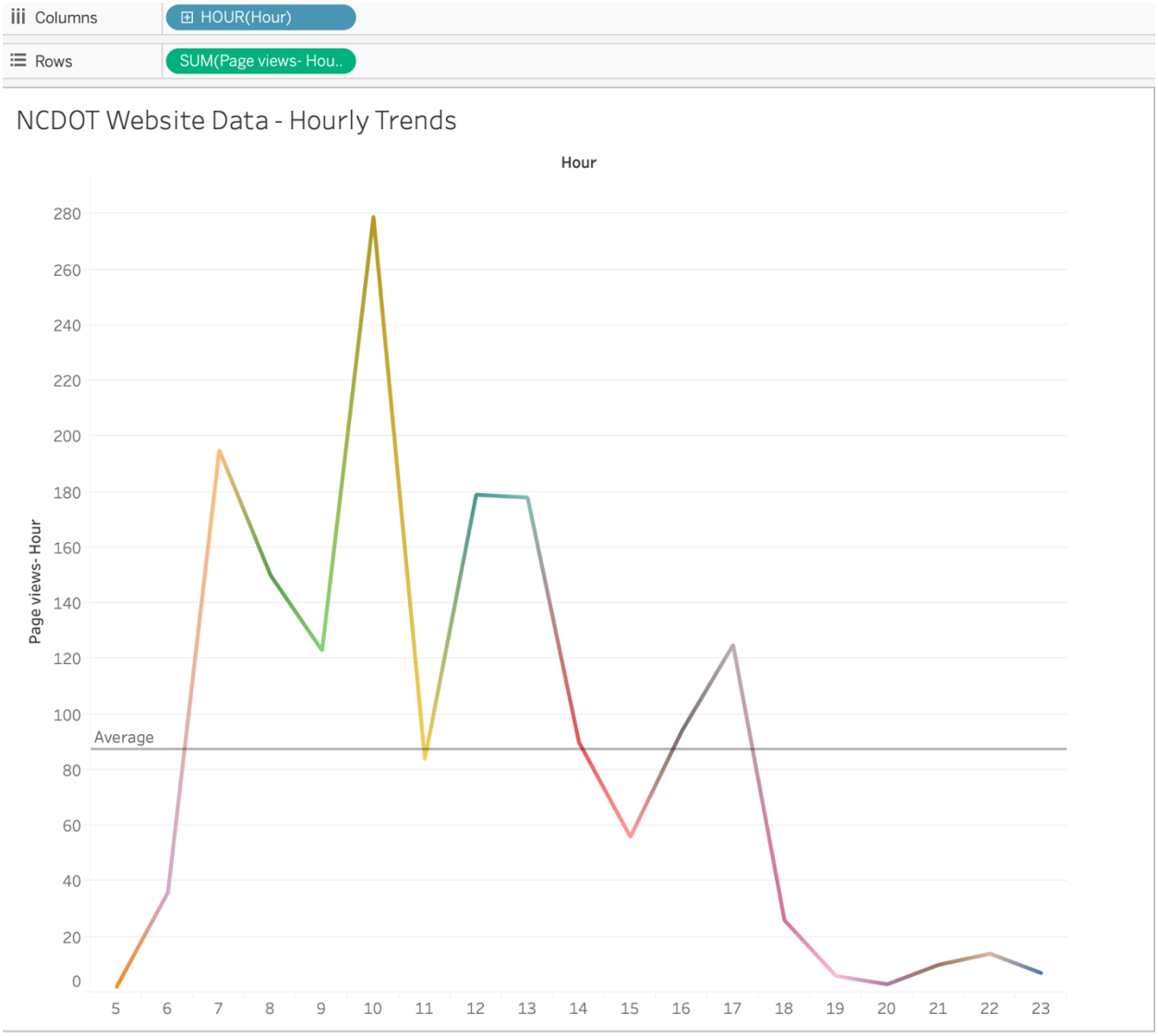
For the City-oriented visualization, specify City and the Sum (Page Views - City) attributes as columns and rows. The City attribute also is a filter to regulate the data points included within the visualization.



For the Date-oriented visualization, specify Day (Date) and the Sum (Page Views - City) attributes as columns and rows, respectively.



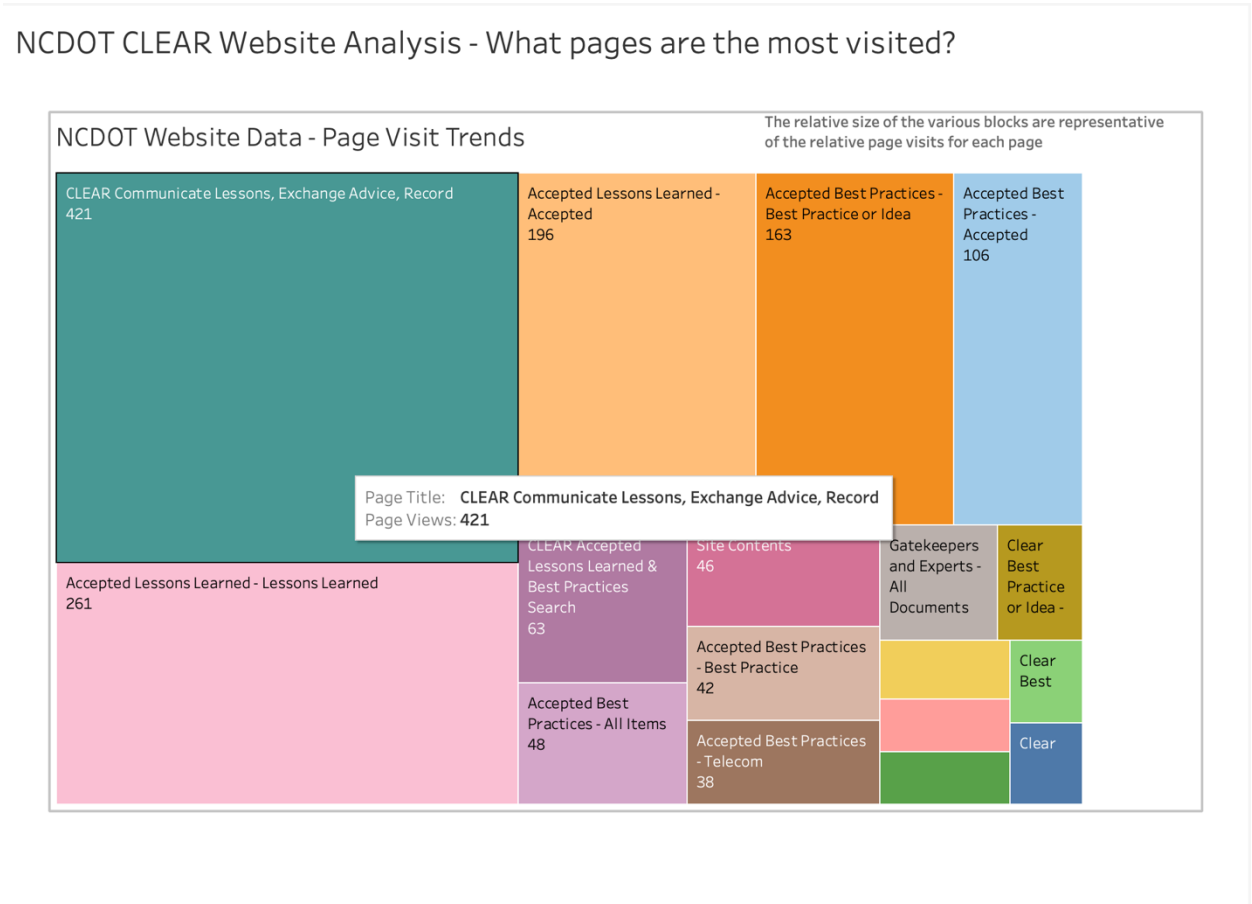
For the Time-oriented visualization, specify Hour (Hour) and Sum (Page Views - City) attributes as columns and rows, respectively. The Hour attribute is a filter to regulate the data points included within the visualization.



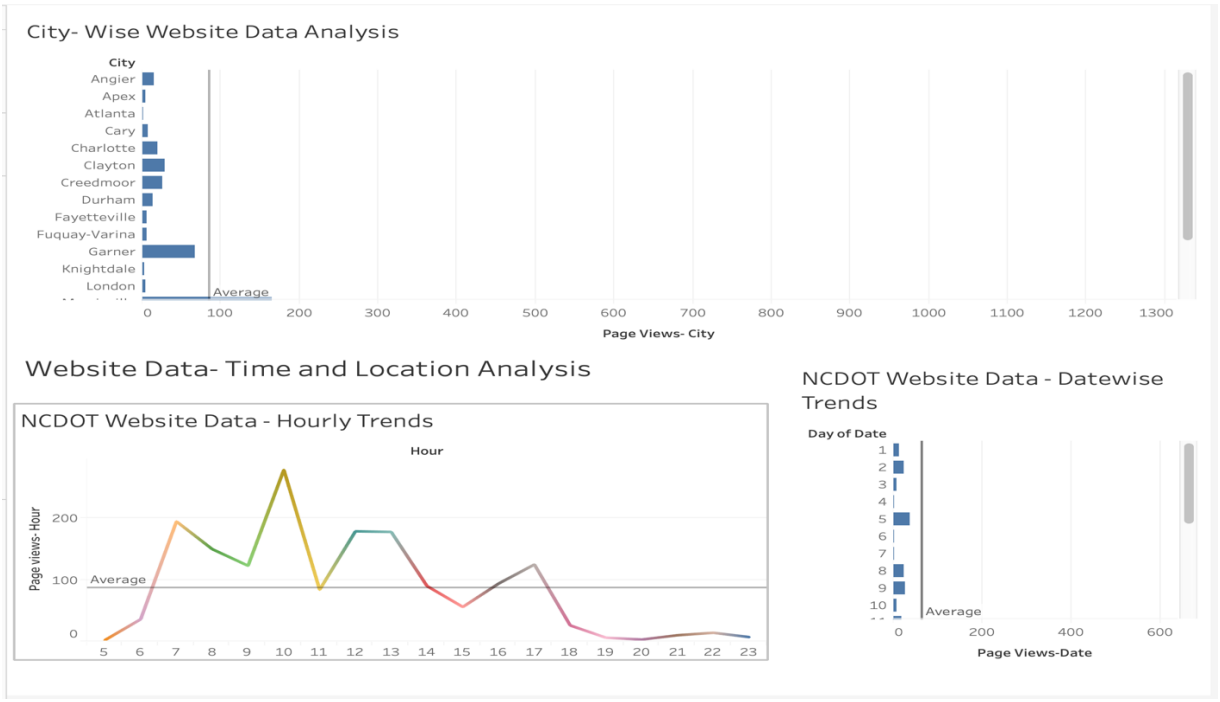
Step 7: **Access the dashboards being generated through the visualizations.**

The visualizations are utilized in three separate dashboards within the Tableau file. These dashboards can be navigated via the Navigation column at the bottom of the Tableau screen.

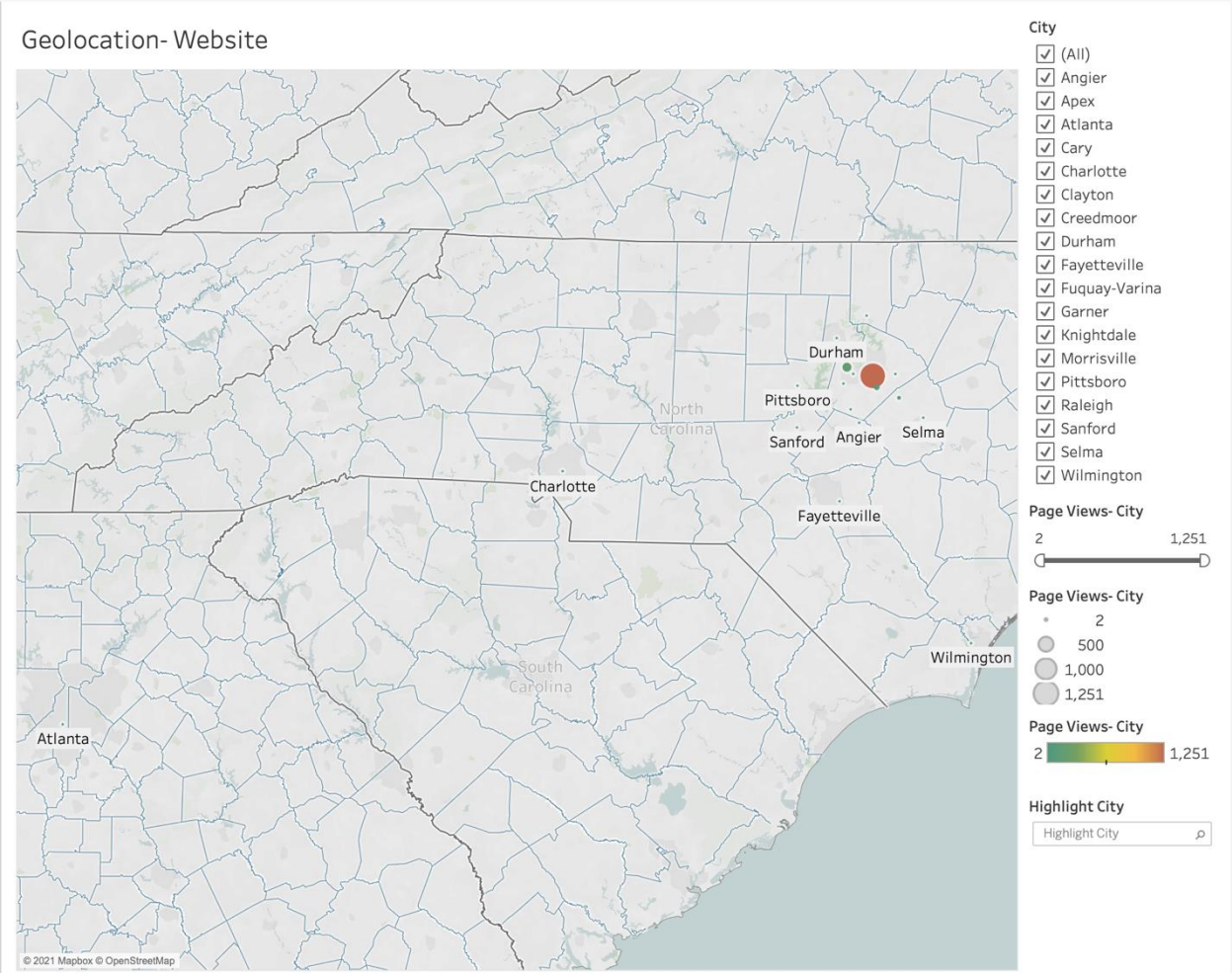
The first dashboard, Website Analysis – Page Visit Trends, is used for displaying the web-page access trends. You can view further information by putting the mouse cursor on the elements within the dashboard to activate the ‘Tooltip’ option within the Tableau dashboard.



The second dashboard, Website Data - Time and Location, is used to display the city, time, and date web-page access trends.



The third dashboard, Geolocation Map, is used to display the map-based visualization of the website data based on place-of-access. The filtering and Tooltip capacity of Tableau can be utilized within this dashboard.


Geolocation- Website
Durham
Pittsboro
North Carolina
Sanford
Angier
Selma
Charlotte
Fayetteville
South Carolina
Wilmington
Atlanta
© 2021 Mapbox © OpenStreetMap
City
(All)
Angier
Apex
Atlanta
Cary
Charlotte
Clayton
Creedmoor
Durham
Fayetteville
Fuquay-Varina
Garner
Knightdale
Morrisville
Pittsboro
Raleigh
Sanford
Selma
Wilmington
Page Views- City
2
1,251
Page Views- City
2
500
1,000
1,251
Page Views- City
2
1,251
Highlight City
Highlight City

Lessons Learned/Best Practices Visualizations

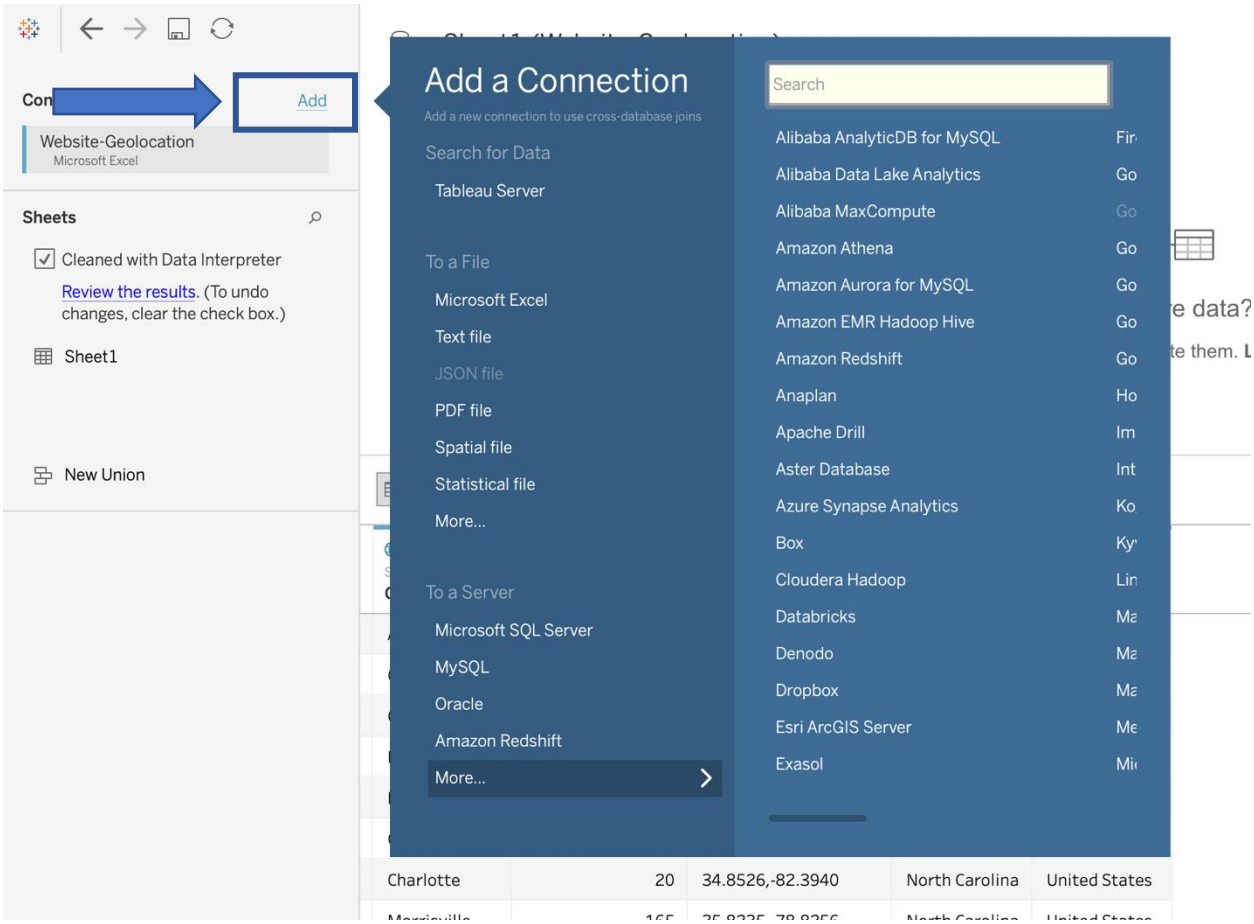
The following guidelines provide direction and instructions for the set-up, administration, and operation of the CLEAR Lessons Learned Data dashboard. Thank you for your support of this important program.

Step 1: **Obtain the valid files and save them in a common folder.**

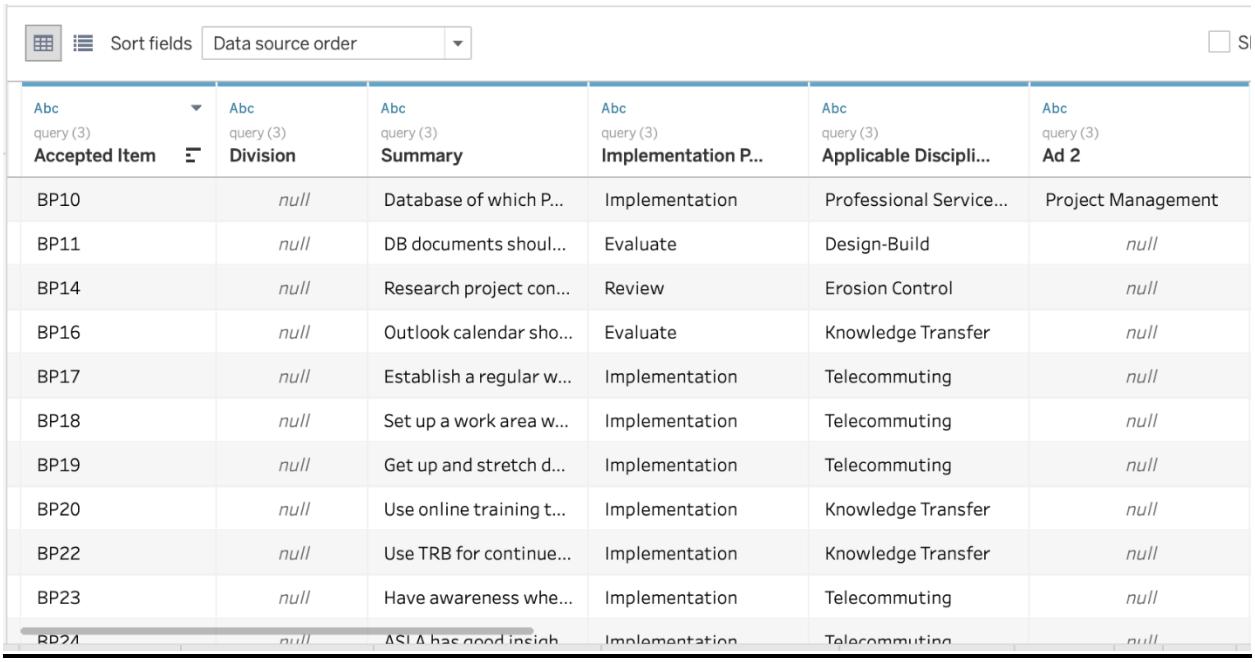
The workbook for the visualization of the website data is a Tableau file (LL BP Dashboard Visualization.twbx). It utilizes three data sources: (1) NCDOT Division Boundaries. json , (2) SB LLs BPs March 29 2021.xlsx, and (3) LL_Geo_Division.xlsx.. All three files can be edited and renamed to include the latest data to be sent to the dashboard.

Step 2: **Specify the data sources for the dashboard within the Tableau workbook.**

Within the Tableau workbook, open the Data Source tab. Use the ‘Add’ Option to specify the three data sources individually for the Lessons Learned Dashboard. Once the data sources have been added, they can be updated by clicking the arrow next to their name within the Data tab and using the ‘Edit’ option. You may find it useful to always toggle the ‘Cleaned with Data Interpreter’ option along with the data source. Use this option to add all three Excel files to the website visualization dashboard.



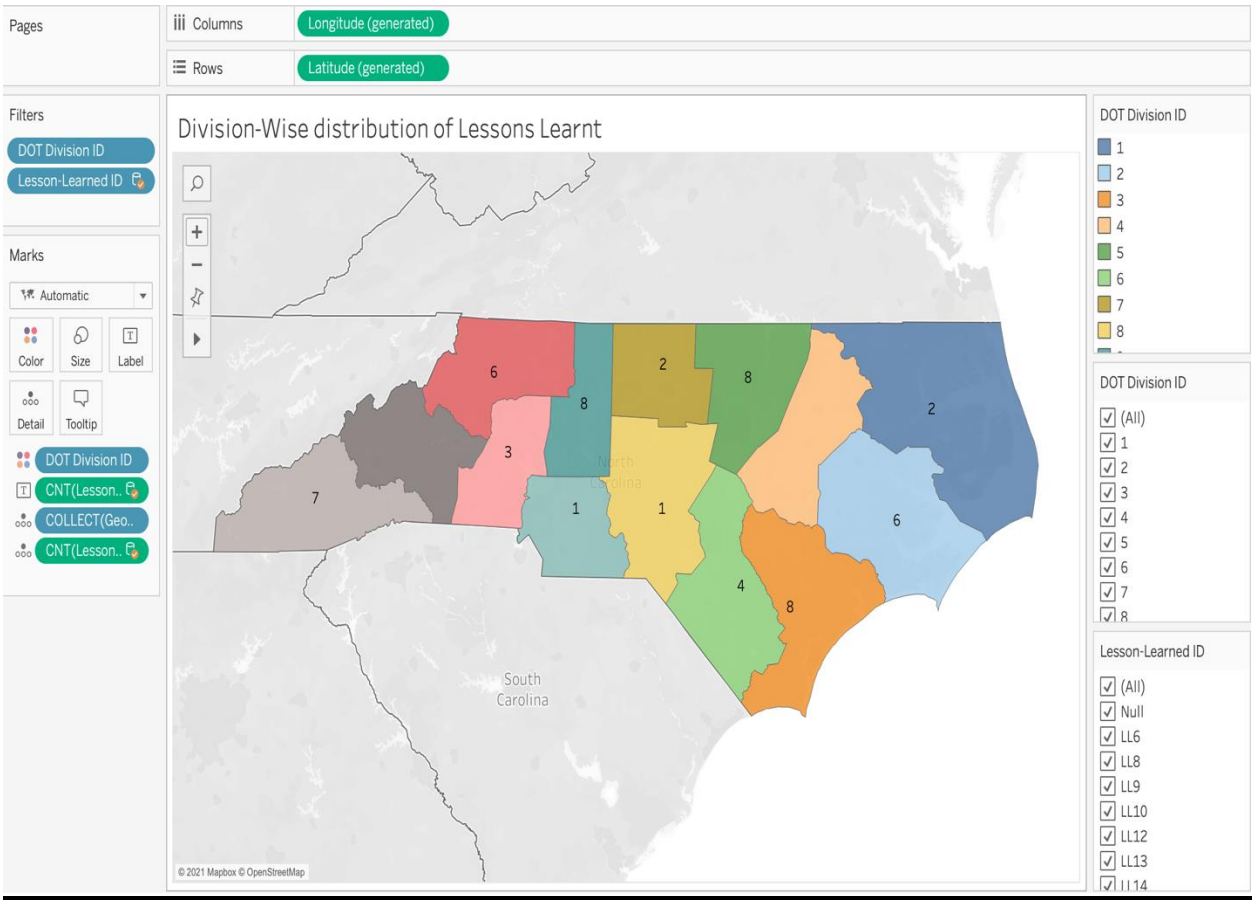
Once you have specified the data sources, you may want to look at the sample data values column exhibited by Tableau within the same 'Data' tab to check that all attributes and their corresponding values are being input correctly within Tableau.



Abc query (3) Accepted Item	Abc query (3) Division	Abc query (3) Summary	Abc query (3) Implementation P...	Abc query (3) Applicable Discipli...	Abc query (3) Ad 2
BP10	*null*	Database of which P...	Implementation	Professional Service...	Project Management
BP11	*null*	DB documents shoul...	Evaluate	Design-Build	*null*
BP14	*null*	Research project con...	Review	Erosion Control	*null*
BP16	*null*	Outlook calendar sho...	Evaluate	Knowledge Transfer	*null*
BP17	*null*	Establish a regular w...	Implementation	Telecommuting	*null*
BP18	*null*	Set up a work area w...	Implementation	Telecommuting	*null*
BP19	*null*	Get up and stretch d...	Implementation	Telecommuting	*null*
BP20	*null*	Use online training t...	Implementation	Knowledge Transfer	*null*
BP22	*null*	Use TRB for continue...	Implementation	Knowledge Transfer	*null*
BP23	*null*	Have awareness whe...	Implementation	Telecommuting	*null*
BP24	*null*	ASLA has good insigh	Implementation	Telecommuting	*null*

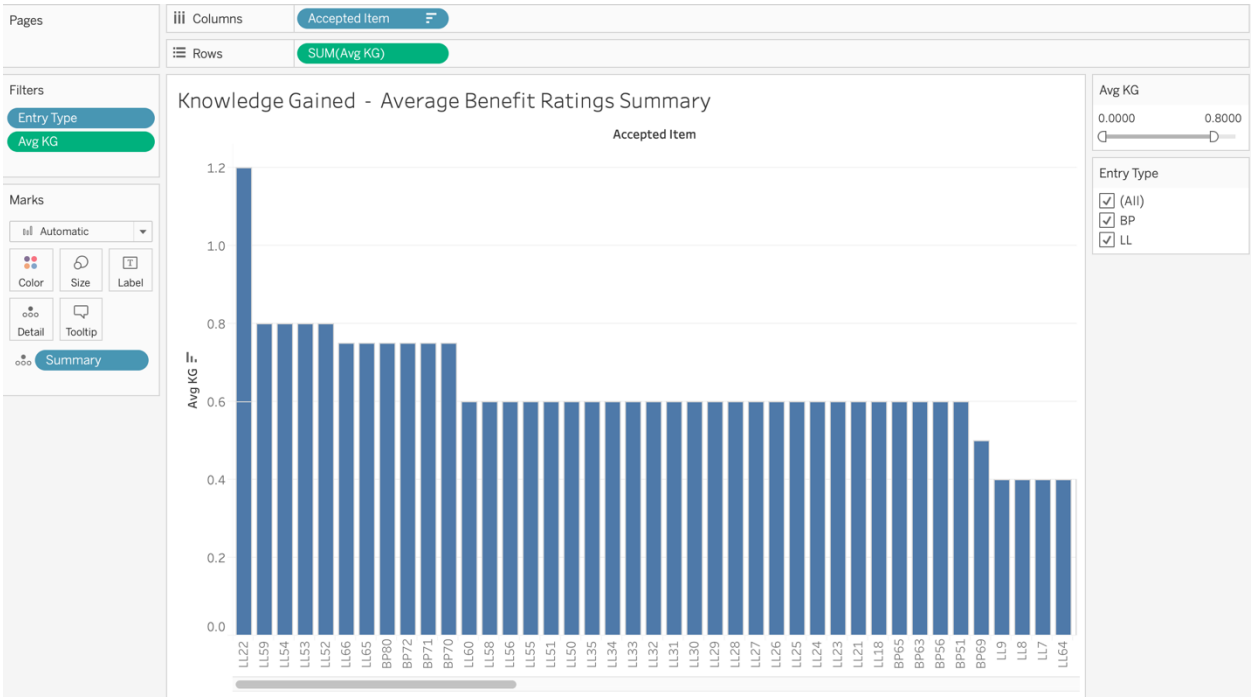
Step 3: **Edit the Geolocation visualization within the dashboard.**

As soon as the ‘NCDOT Division Boundaries.json’ and the ‘LL_Geo_Division.xlsx; files are added to the dashboard’s data sources, you will see the automatically generated latitude and longitude attributes for the cities within the dashboard and the corresponding NCDOT division boundaries. These two values are used respectively as the columns and rows for the visualization and can be dragged to the visualization from the Tables menu. The DOT Division IDs and Lesson Learned IDs are useful filters to help regulate the divisions that are shown on the map visualization. Additional attributes are specified in the Marks menu to control the level of detail exhibited within the map.


Pages
Columns
Longitude (generated)
Rows
Latitude (generated)
Filters
DOT Division ID
Lesson-Learned ID
Marks
Automatic
Color
Size
Label
Detail
Tooltip
DOT Division ID
CNT(Lesson..
COLLECT(Geo..
CNT(Lesson..
Division-Wise distribution of Lessons Learnt
North Carolina
South Carolina
© 2021 Mapbox © OpenStreetMap
DOT Division ID
1
2
3
4
5
6
7
8
DOT Division ID
(All)
1
2
3
4
5
6
7
8
Lesson-Learned ID
(All)
Null
LL6
LL8
LL9
LL10
LL12
LL13
LL14

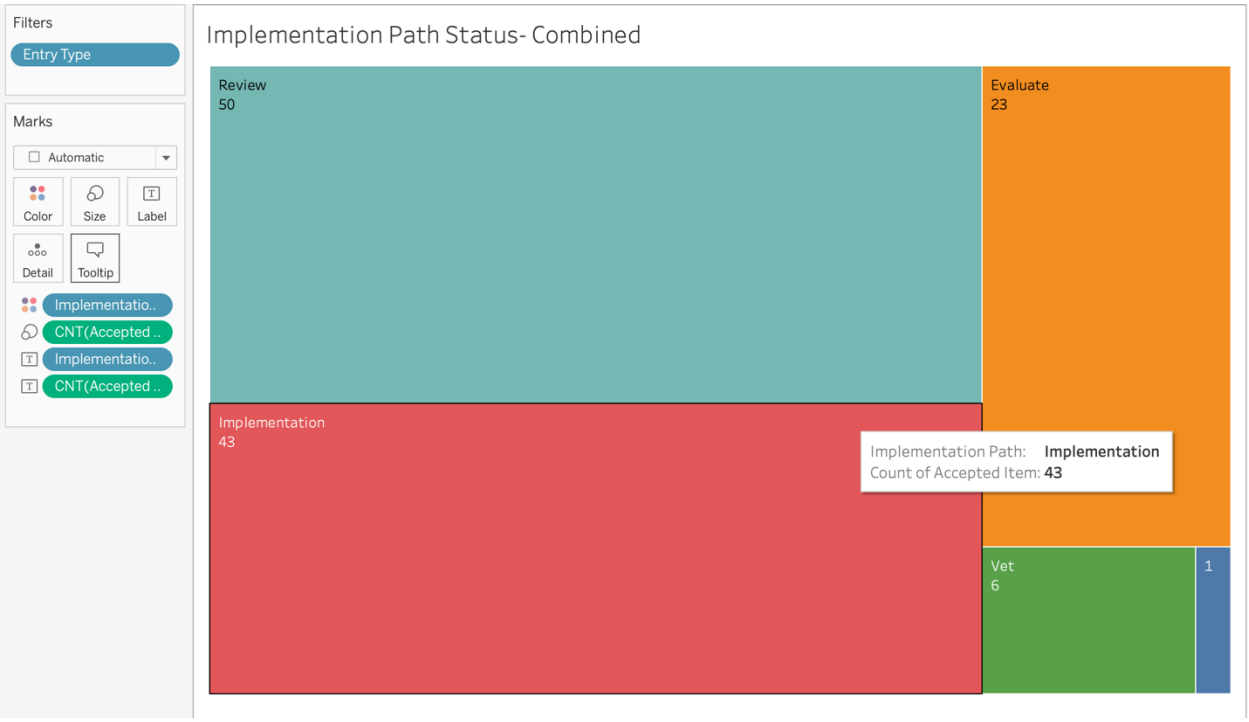
Step 4: **Edit the Knowledge Gained, Monetary, OM, Safety, and Combined Average visualizations within the dashboard.**

For the Average-oriented visualization, specify the Accepted Item attributes as the columns and the corresponding SUM (Avg(Benefit Rating)) as the rows. A filter allows you to see the data points that relate exclusively to lessons learned and best practices. The corresponding details are provided within the Marks menu of Tableau.



Step 5: **Edit the Implementation Path Status visualizations within the dashboard.**

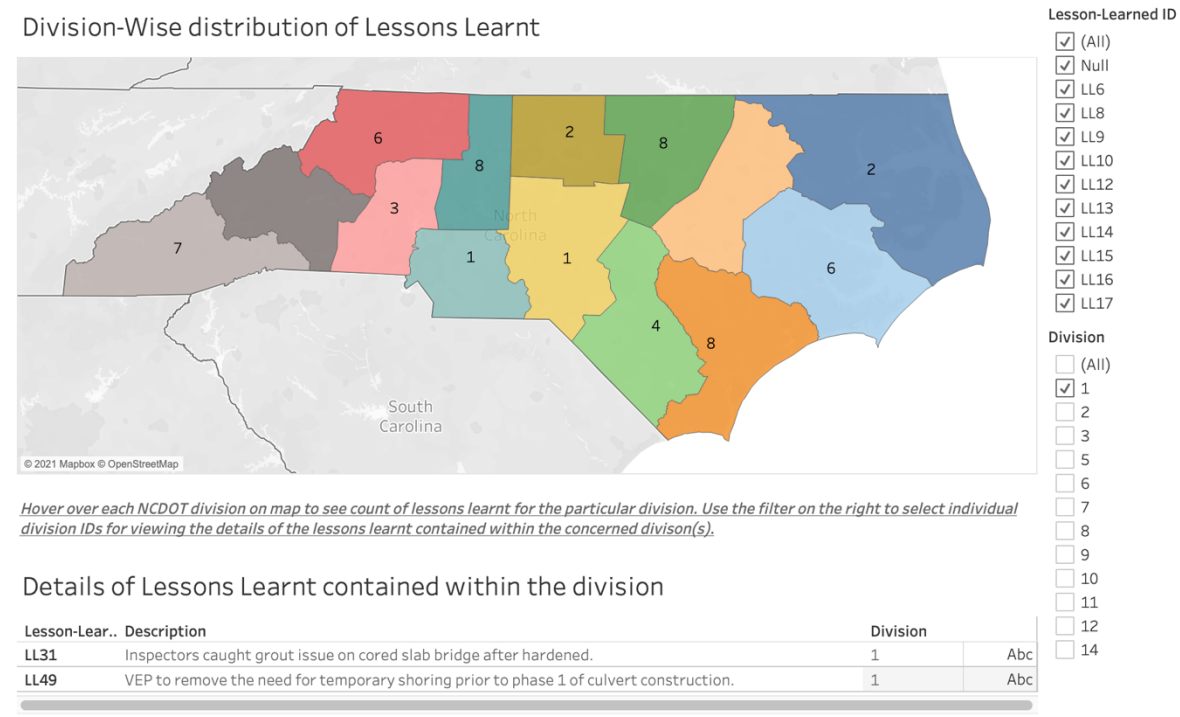
For the Implementation Path Status-oriented visualization, you do not need to specify any rows and columns values explicitly. Instead, you can use the Marks menu to add various attributes such as Implementation Path Status, Accepted Items, etc. to help the visualization. The Entry type is a filter for the visualization.



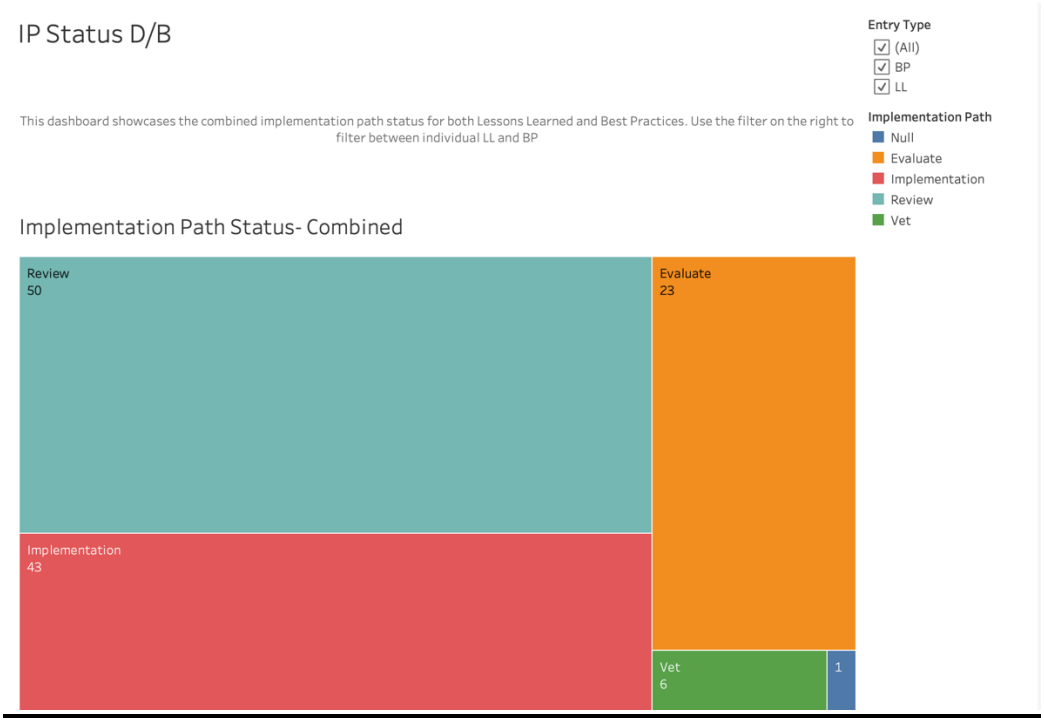
Step 6: **Access the dashboards that are generated through the visualizations.**

The visualizations are utilized in three separate dashboards within the Tableau file. You can navigate to these dashboards through the Navigation column at the bottom of the Tableau screen.

The first dashboard, LL-Geolocation D/B, is used to display a Division-wise summary of lessons learned and best practices. You can view further information by putting the mouse cursor on the elements within the dashboard to activate the ‘Tooltip’ option within the Tableau dashboard.



The second dashboard, IP Status – D/B, is used to display details of the various metrics associated with the Implementation Path Status.



Innovation Culture Index Data Visualizations

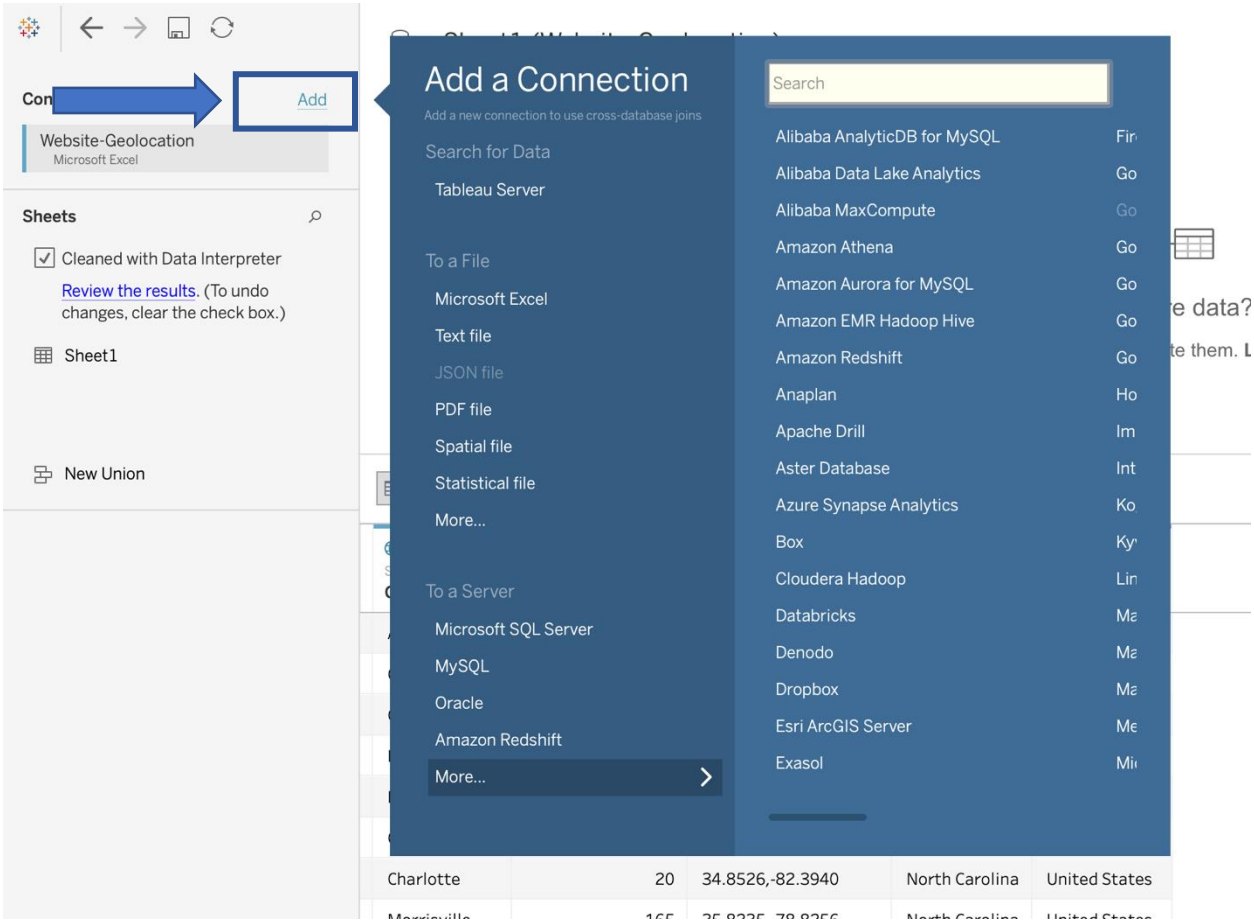
The following guidelines provide direction and instructions for the set-up, administration, and operation of the CLEAR Innovation Culture Index (ICI) Data dashboard. Thank you for your support of this important program.

Step 1: **Obtain the valid files and save them in a common folder.**

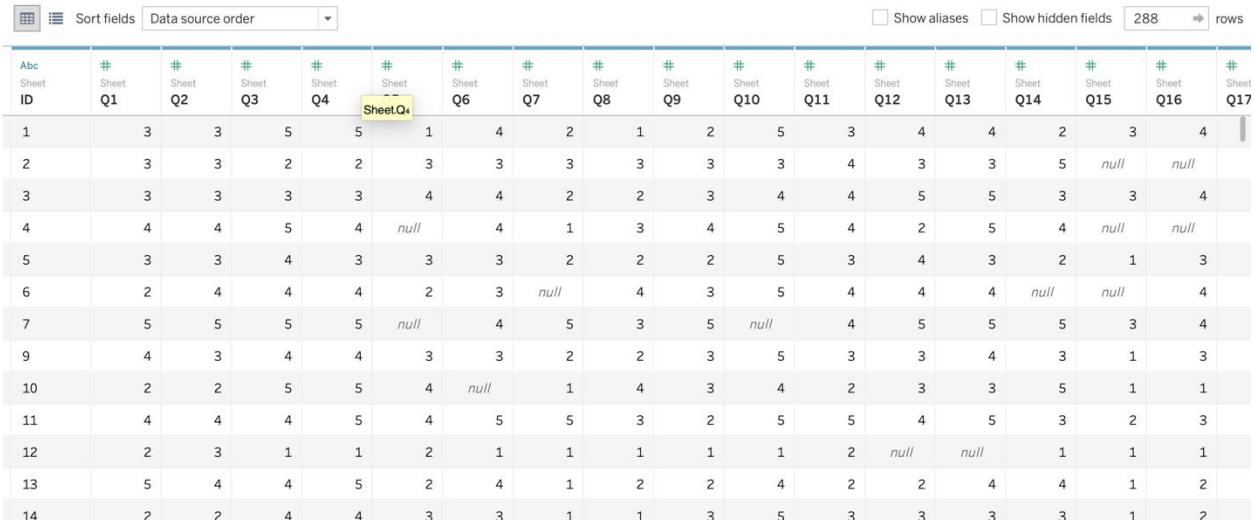
The workbook for the visualization of the website data is the Tableau file, ICI Data Visualization.twbx. It utilizes a single data source: ICI Results.xlsx. This Excel file can be edited and renamed to include the latest data to be sent to the dashboard.

Step 2: **Specify the data sources for the dashboard within the Tableau workbook.**

Within the Tableau workbook, open the Data Source tab. Use the 'Add' option to specify the three data sources for the ICI Data Dashboard. Once the data source has been added, it can be updated by clicking the arrow next to its name within the Data tab and using the 'Edit" option. You may find it useful to always toggle the 'Cleaned with Data Interpreter' option along with the data source. Use this option to add the Excel file to the website visualization dashboard.



Once the data source has been specified, you may find it helpful to look at the sample data values column exhibited by Tableau within the same Data tab. You can check to see that all attributes and their corresponding values are being ingested correctly within Tableau.

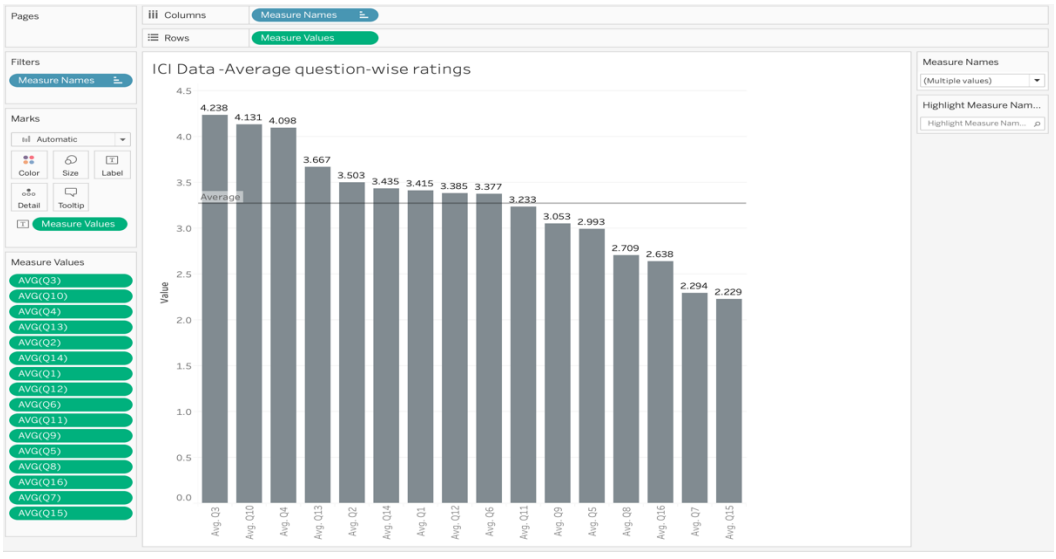


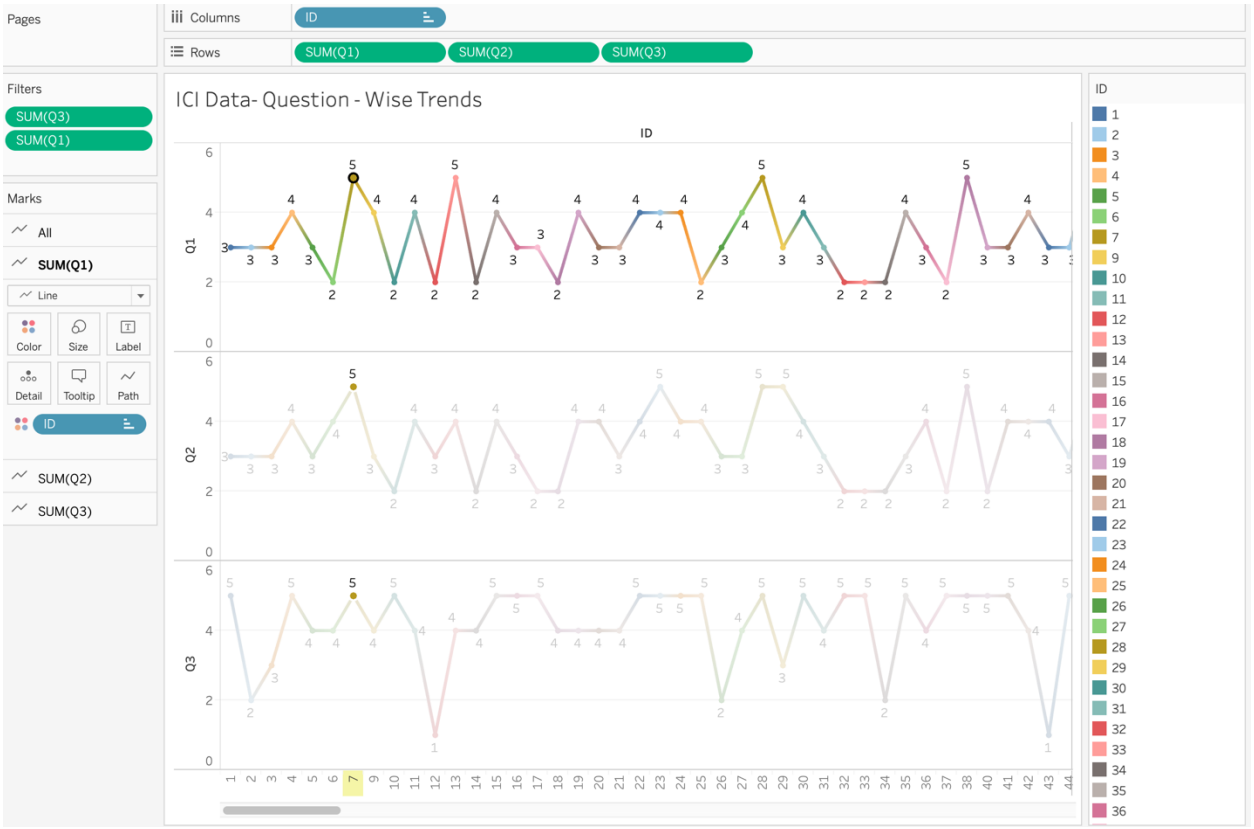
Sort fields | Data source order | Show aliases | Show hidden fields | 288 rows

ID	Q1	Q2	Q3	Q4	Sheet.Q4	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17
1	3	3	5	5	1	4	2	1	2	5	3	4	4	2	3	4	
2	3	3	2	2	3	3	3	3	3	3	4	3	3	5	null	null	
3	3	3	3	3	4	4	2	2	3	4	4	5	5	3	3	4	
4	4	4	5	4	null	4	1	3	4	5	4	2	5	4	null	null	
5	3	3	4	3	3	3	2	2	2	5	3	4	3	2	1	3	
6	2	4	4	4	2	3	null	4	3	5	4	4	4	null	null	4	
7	5	5	5	5	null	4	5	3	5	null	4	5	5	5	3	4	
9	4	3	4	4	3	3	2	2	3	5	3	3	4	3	1	3	
10	2	2	5	5	4	null	1	4	3	4	2	3	3	5	1	1	
11	4	4	4	5	4	5	5	3	2	5	5	4	5	3	2	3	
12	2	3	1	1	2	1	1	1	1	1	2	null	null	1	1	1	
13	5	4	4	5	2	4	1	2	2	4	2	2	4	4	1	2	
14	2	2	4	4	3	3	1	1	3	5	3	3	3	3	1	2	

Step 3: **Edit the visualizations for the various Question-oriented and Demographic-oriented questions.**

All the visualizations i.e., QW Trends, Average Q - Ascending, Average Q - Descending, Individual Question Ratings, Years of Work Experience, and Average Job Responsibilities, follow a common trend where the relevant attributes are specified respectively as the rows and columns for the Tableau visualization. Filters are provided where necessary to help you select the data points to be incorporated within the visualization.




Pages
Columns
ID
Rows
SUM(Q1)
SUM(Q2)
SUM(Q3)
Filters
SUM(Q3)
SUM(Q1)
Marks
All
SUM(Q1)
Line
Color
Size
Label
Detail
Tooltip
Path
ID
SUM(Q2)
SUM(Q3)
ICI Data- Question - Wise Trends
ID
Q1
Q2
Q3
ID
1
2
3
4
5
6
7
9
10
11
12
13
14
15
16
17
18
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21
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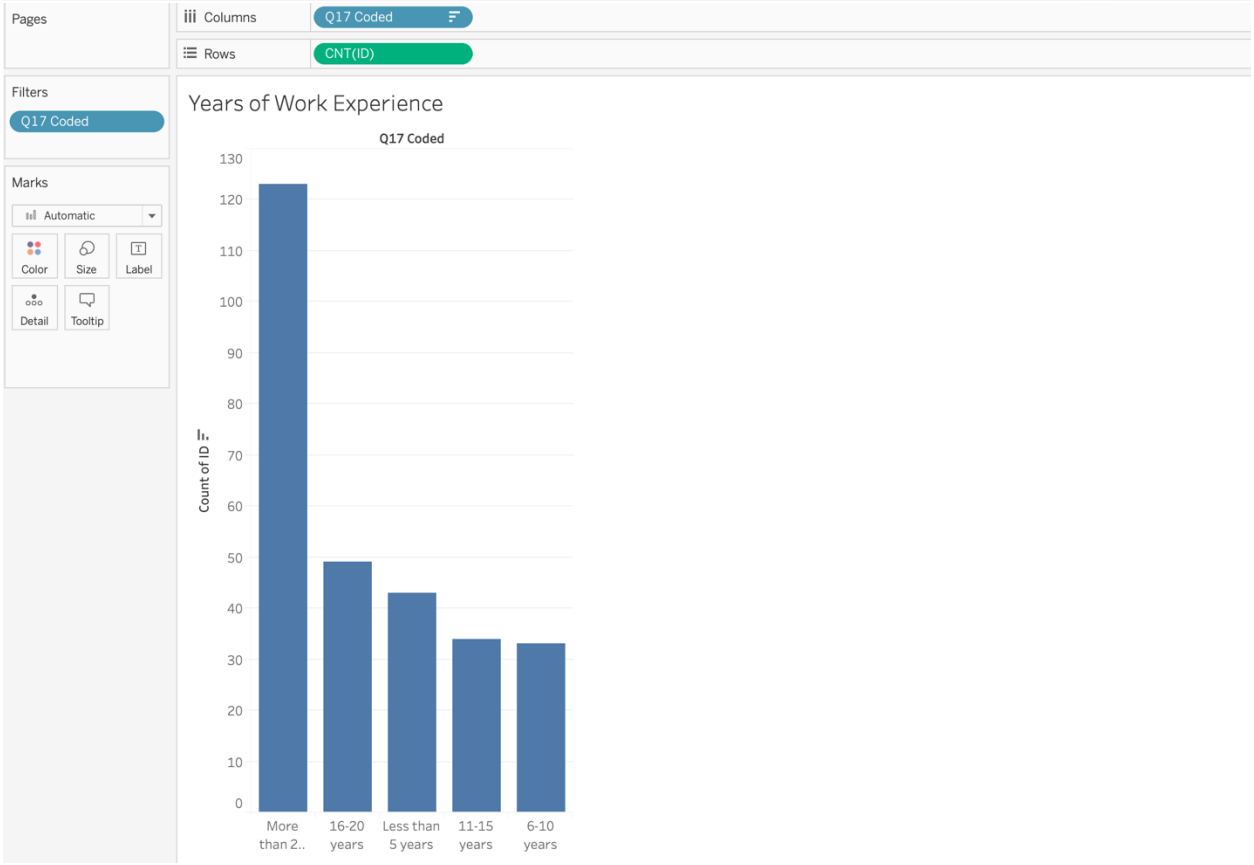
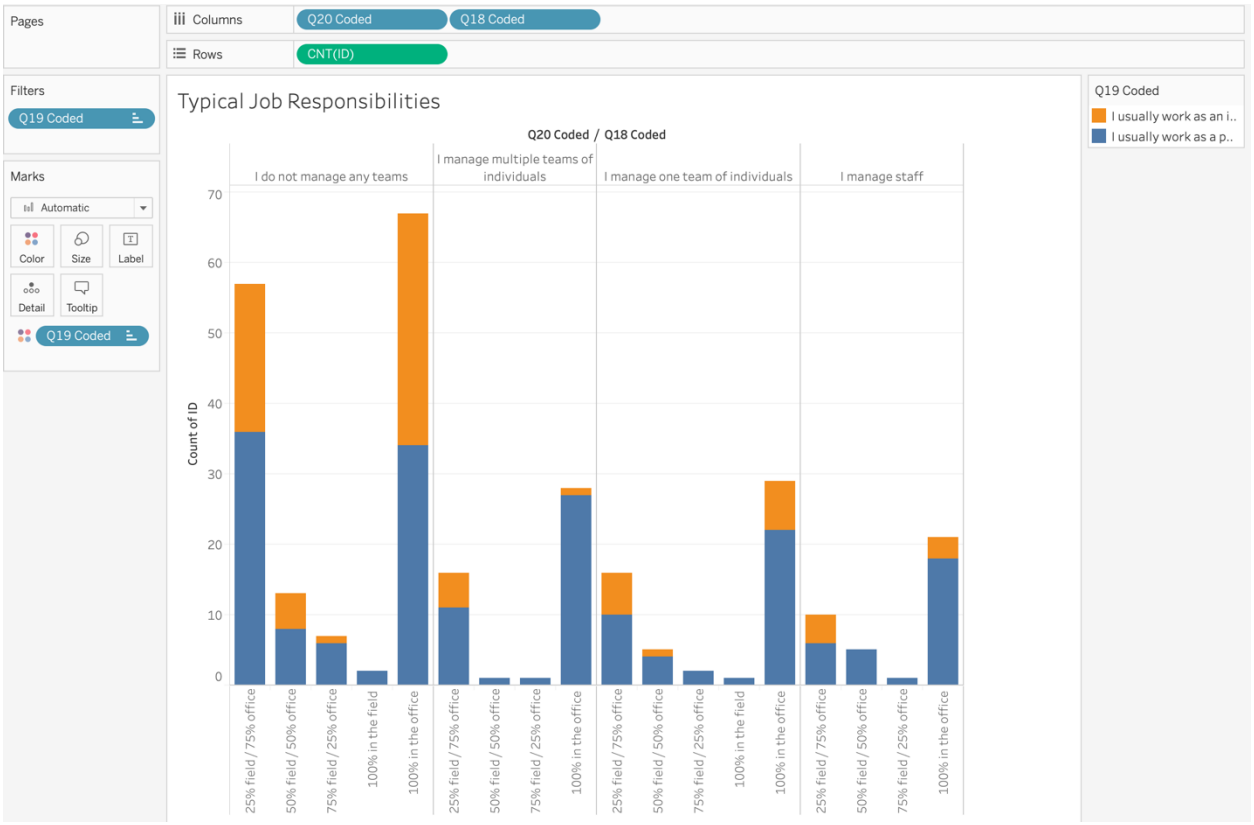
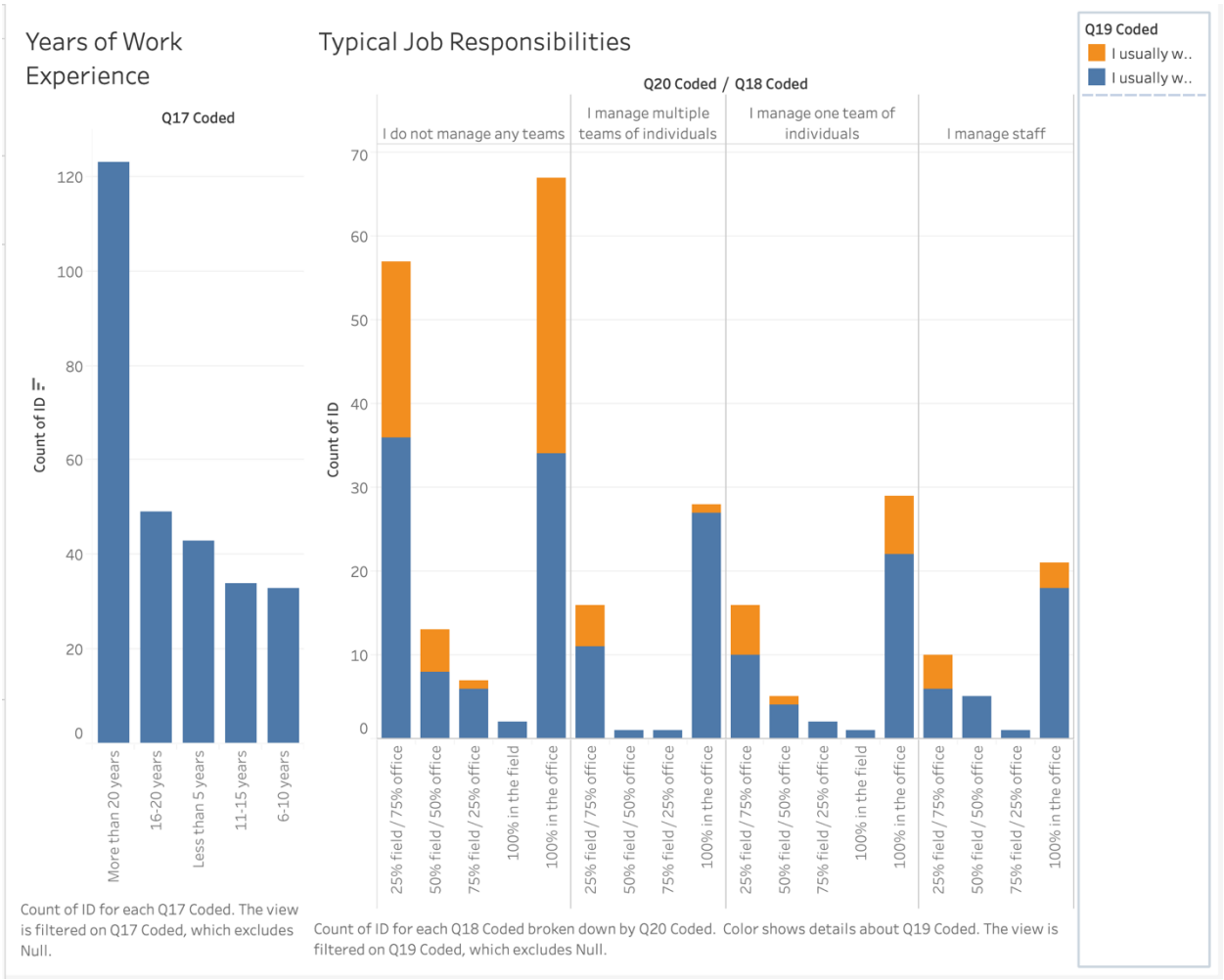

Pages
Columns
Q17 Coded
Rows
CNT(ID)
Filters
Q17 Coded
Marks
Automatic
Color
Size
Label
Detail
Tooltip
Years of Work Experience
Q17 Coded
Count of ID
More than 2..
16-20 years
Less than 5 years
11-15 years
6-10 years



Step 4: **Access the dashboard that is being generated through the visualizations.**

The visualizations are utilized in the ICI - Demographic dashboard within the Tableau file. Navigate to the dashboard via the Navigation column at the bottom of the Tableau screen.


Years of Work Experience
Q17 Coded
Count of ID
120
100
80
60
40
20
0
More than 20 years
16-20 years
Less than 5 years
11-15 years
6-10 years
Count of ID for each Q17 Coded. The view is filtered on Q17 Coded, which excludes Null.
Typical Job Responsibilities
Q20 Coded / Q18 Coded
I do not manage any teams
I manage multiple teams of individuals
I manage one team of individuals
I manage staff
Count of ID
70
60
50
40
30
20
10
0
25% field / 75% office
50% field / 50% office
75% field / 25% office
100% in the field
100% in the office
Count of ID for each Q18 Coded broken down by Q20 Coded. Color shows details about Q19 Coded. The view is filtered on Q19 Coded, which excludes Null.
Q19 Coded
I usually w..
I usually w..