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IMPROVING SAFETY PERFORMANCE OF HIGHWAY MAINTENANCE CREWS THROUGH PRE-TASK SAFETY TOOLBOX TALKS

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DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Engineering
at the University of Kentucky

By
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2019

ABSTRACT OF DISSERTATION

IMPROVING SAFETY PERFORMANCE OF HIGHWAY MAINTENANCE CREWS THROUGH PRE-TASK SAFETY TOOLBOX TALKS

The dangerous work environment in the construction industry and the inherent high risks associated with construction work make it the focus of safety training and regulations. Highway construction and maintenance has unique hazards but seemingly less directly applicable safety standards, regulations, and programs. Department of Transportation (DOT) employees working in highway maintenance are exposed to a variety of unique hazards specifically associated with their work and not relating to the adjacent traffic. Yet, highway construction and maintenance work has not received sufficient attention in terms of safety research and programs. The lack of safety training and education in highway construction and maintenance work leaves a significant portion of DOT employees prone to different work-related hazards that can be avoided with additional safety awareness.

As part of the efforts of the Kentucky Transportation Cabinet (KYTC) to improve safety of their employees, the study describes the design, implementation, and evaluation of a pre-task safety briefing toolbox. By analyzing recordable incidents of KYTC maintenance employees and identifying frequent hazards present within their typical work operations and the causes behind the frequent incidents, the final product of design phase is a toolbox that is relatable and relevant to KYTC maintenance crews. The toolbox presents these hazards along with incidents causes and the appropriate safety practices to avoid or mitigate the associated risk. The goal of this safety toolbox is to improve safety awareness of KYTC maintenance crews. The second part of the study is a comprehensive systematic evaluation of the effectiveness of the toolbox. Three evaluation phases including reaction and knowledge evaluation, implementation evaluation, and behavior change evaluation were carried out to assess the effectiveness of the toolbox.

With 22% improvement in workers safety knowledge, 23% improvement in workers hazards identification skills, and 33.24% increase in the likelihood of safe behavior, the results showed that pre-task safety toolbox talks can increase highway workers' safety awareness, improve their hazards identification skills, and increase their safe behavior. In addition to serving an underserved audience of the construction workforce, this study contributes to the body of knowledge in different ways. First, it sheds the light on a significant underserved portion of construction workers and the unique hazards present in their work environment. Second, it presents the design, implementation, and evaluation of a data driven safety intervention that addresses the most frequent safety issues in highway maintenance operations. Finally, it presents an empirical trial to evaluate the effectiveness of a common practice used in the construction industry in a unique sector of the industry that has not received sufficient research efforts.

KEYWORDS: Highway workers, Toolbox, Safety training, Evaluation, Maintenance.

Zamaan Al-shabbani

04/12/2019

Date

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DEDICATION

To my parents, wife, and son

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I would like to thank the people who helped me to complete this work.

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1 INTRODUCTION

1.1 Background and Motivation

The construction industry is well known for its dangerous nature. For decades, the construction industry has had high rates of injuries and fatalities among construction workers. As a unique part of the construction industry, highway construction and maintenance, while also characterized by high rates of injuries and fatalities, is considered especially hazardous. Work adjacent to high speed passing traffic, large construction and maintenance equipment, massive amounts of material movement, and extreme environmental conditions are some of the different types of hazards found at highway work sites. As a result, highway maintenance workers, who consist of government employees and contract workers, are at higher risk of work-related incidents compared with other construction workers. According to the Bureau of Labor Statistics, there were 844 worker fatalities in roadway work zones between 1995 and 2002 (Bureau of Labor Statistics 2017), 962 fatalities between 2003 and 2010 (FHWA 2016), and 609 fatalities between 2011 and 2015 (Hecker 2016). Road worker fatalities consistently accounted for 2% of all work-related fatalities in the nation with no descending trend. These numbers do not capture those workers who survived or who had close calls.

Safety is the responsibility of all project stakeholders from top management to the labor workforce. In highway construction and maintenance work, this responsibility extends from the field staff to the executives of the state departments of transportation (DOTs). Workers, supervisors, and others on the jobsite should be well trained and knowledgeable in recognizing potential hazards when present. At the management level, leadership should express a commitment to provide a safe work environment for everyone with the ultimate goal of providing a work environment with zero fatalities and injuries. However, this goal is not easy to achieve or maintain and today's statistics express a different reality. Although state DOTs have taken significant steps to improve safety performance and provide a safe working environment for their employees, the statistics show that highway construction and maintenance is still characterized with relatively high rates of injuries and fatalities. With more than 20,000 worker injuries and 133 fatalities in work zones in 2012 alone, the industry is still far from achieving its safety goals (Bureau of Labor Statistics 2017).

The state of Kentucky also has relatively high work zones injury incidence rates. In the 2013 annual safety issue of Transportation Builder, "*Statistics Show Work Ahead to Improve Highway and Bridge Construction Worker Safety,*" stated that USDOT Region 4, including Kentucky, has some of the highest work zone incident rates in the nation. Recently, the Annual Employee Safety Report and Recommendations issued by the Kentucky Transportation Cabinet (KYTC) states that their safety performance does not meet the desired goals (Hecker 2016). Although KYTC initially met their overall Total Recordable Incident Rate (TRIR) target of 5% or less, they reassessed this goal realizing that more than 60% of KYTC employees work in an office setting and most of the incidents are reported by maintenance employees. This further analysis led KYTC to conclude that their TRIR rate for 2015 is likely more than 15% (Hecker 2016). This problem triggers the need to develop new safety controls to address this issue.

In an effort to improve safety performance, state DOTs have dedicated numerous resources and implemented a variety of safety controls to create a safe work environment for their employees. Based on studying and analyzing the history of worker injuries and fatalities, state DOTs seek to understand the nature of safety hazards, the root causes that led to incidents, the types of incidents, the associated results, and what could be done to prevent such incidents. Therefore, reporting and archiving becomes a core pillar in most safety programs. In any data driven safety initiative, data on injuries and fatalities becomes the main source in understanding safety issues and developing or improving safety controls. Data driven safety controls have proven to be effective in different states across the country.

As part of the KYTC efforts to improve safety performance of their employees, this study seeks to increase safety awareness and improve safety performance among KYTC highway maintenance employees. To achieve this goal, the study was carried out to design, implement, and evaluate a safety briefing toolbox that can be used by KYTC maintenance superintendents to prepare for pre-task safety talks. Through a data driven design approach, the toolbox was developed and implemented in a three months pilot implementation period in one of the districts in the state of Kentucky. The effectiveness of toolbox in changing safety awareness and beahvior of highway maintenance crews was evaluated utilizing a comprehensive systematic evaluation model. The evaluation model included three evaluation phases: reaction and knowledge evaluation, implementation evaluation, and safety behavior change evaluation. This study sheds light on the safety and health of an underserved audience of the construction workforce and highlights the need for more studies and investigation to improve the poor safety performance of highway construction and maintenance workers. The study also address the gap found in literature by conducting a comprehensive systematic evaluation of a common safety intervention used in the construction industry.

1.2 Problem Statement

Within the larger construction industry, highway construction and maintenance has its own unique hazards and risks. Work adjacent to high speed passing traffic, large construction and maintenance equipment, massive amounts of material movement, and extreme environmental conditions are some of the different types of hazards found at highway work sites. Such hazardous work environments expose highway construction and maintenance workers to a higher risk of work-related injuries. This problem is evident in safety records. According to the Bureau of Labor Statistics, there were 2,415 fatalities, not including close calls and survivor workers, between 1992 and 2015 among US highway maintenance workers (Bureau of Labor Statistics 2017; Pegula 2004; Pegula 2013). In fact, the road worker fatality rate accounts for 1.5% to 3% of all work-related fatalities in the US with no descending trend (Gambatese et al. 2017).

Kentucky is one such state that manages the safety of their unique transportation system. The Kentucky Transportation Cabinet (KYTC), an executive branch agency, manages over 27,000 miles of this transportation system. With approximately 4,800 employees, KYTC continues to work on the objective of providing a "safe, efficient, environmentally sound and fiscally responsible transportation system that delivers economic opportunity and enhances the quality of life in Kentucky" (KYTC Mission Statement). KYTC is responsible for supervising the development and maintenance of the transportation system across the Commonwealth. With more than 2,000 maintenance employees, KYTC regularly performs a variety of maintenance operations across the state. This exposes their maintenance workers to different types of hazards that could easily lead to incidents. KYTC continues to work on improving their safety performance to provide a safe working environment and to protect their employees and the public. In fact, KYTC has achieved significant improvement in their safety performance. In a July 2016 safety report, KYTC reported that their TRIR declined from 5.5% to 4.2% since 2010, total days away from work declined 20%, worker compensation claims declined 30%, and the total number of claims decreased by 43%. In addition to the safety performance improvement, a significant reduction ($2.5 million per year) was achieved by reducing spending on worker compensation claims from $ 4 million to $1.5 million per year (Hecker 2016). However, KYTC realized that their safety performance is not achieving their desired goals. While KYTC aimed for 5% or less TRIR, their latest report revealed that their TRIR is higher than 15% when focusing more appropriately on field staff and removing office work hours. In 2015, 316 of KYTC maintenance workers were injured during work operations (Hecker 2016).

This effort seeks to address this problem by analyzing and understanding maintenance worker injury claims, creating safety measures to prevent and minimize similar injuries in the future, and evaluating the effectiveness of the proposed measures. By increasing workers' awareness of potential safety hazards and providing the proper safety measures to address these hazards, enhanced worker safety will result.

1.3 Objectives

The main goal of this study is to improve safety performance of KYTC highway maintenance crews through improving their safety awareness, knowledge, and behavior. To fulfill this goal, the following four primary objectives will be addressed in this research:

1- Improving hazard identification skills of maintenance crews within the typical maintenance work they frequently perform;
2- Improving their safety skills in analyzing hazardous situations and recognizing the frequent reasons that lead to work incidents;

3- Developing effective safety controls and practices to be used to mitigate and eventually avoid the risk of being involved in a work-related incident; and
4- Evaluating the effectiveness of the controls in light of the first two objectives

To fulfill the primary objectives and work toward the main goal, the following supportive objectives will be addressed in the study:

- Analyzing historical safety records of KYTC highway maintenance crews to understand the critical safety issues present in their typical work and assess their needs;
- Developing a safety toolbox to provide the required safety knowledge to be used in pre-task safety talks;
- Evaluating the reaction and attitude of participants to understand their level of motivation to participate in safety talks;
- Evaluating the learning of participants from the safety briefings to understand the knowledge gain resulted from the toolbox;
- Evaluating the implementation of the toolbox to address any shortcomings and improve the quality and delivery of the safety talks; and
- Evaluating participants' safety behavior change by examining the impact of the program on safety performance at the work site.

1.4 Research scope

This research is conducted to design, implement, and evaluate a pre-task safety toolbox for the highway maintenance crews in the state of Kentucky. Although safety toolboxes are common interventions in the construction industry, there are no standards that govern the design and development of such intervention. In addition, no evaluation framework has been developed to specifically evaluate the effectiveness of safety toolboxes. However, researchers utilized evaluation models that were developed for safety training programs to evaluate toolbox interventions. This research consists of two main phases: the design and development phase, and the evaluation phase.

A data driven approach is adopted in the design phase to develop the safety toolbox. Recordable incidents are analyzed to identify frequent pattern of work incidents and the associated hazards within highway maintenance operations. However, because of the limitations of available data, the final product of the design phase does not cover all highway maintenance operations. The selection of maintenance operations included in the toolbox is based on the availability of data associated with each operation.

The evaluation model adopted in this research project evaluate participants' reaction, knowledge gain (learning), behavior change, and optimally the change in injury rates. However, the model in this dissertation evaluates reaction, knowledge gain, and behavior change, but does not evaluate the change in injury rates due to time limitations and the unavailability of data.

The pilot implementation period to deploy the toolbox lasted three months in one of the twelve districts (henceforth district X) comprising the scope of KYTC's work. Therefore, participants who used the toolbox to conduct safety talks and participated in the evaluation phase include highway maintenance supervisors, supervisors' assistants, and workers of district X only.

1.5 Research Methodology

This research intends to improve safety awareness among highway maintenance crews through designing, implementing, and evaluating a toolbox safety intervention. The research consists of two main phases and their accompanying steps:

1. The design phase
    - Collecting and analyzing safety recordable incidents claims of highway maintenance crews to identify frequent incidents and hazards present.
    - Reviewing the available safety resources (literature, industry resources, standards and regulations) to identify the best practices to prevent the risk identified in the analysis results.
    - Designing a safety toolbox that presents the frequent hazards and causes of work incidents categorized by maintenance operation and provide safety

guidance that can be used by supervisors to prepare and conduct pre-task safety talks.

2. The evaluation phase
    - Short-term results evaluation: this stage consists of pre- and post-use knowledge assessments to evaluate the knowledge acquisition, if any, that occurred as a result of using the toolbox safety talks. The pre-use knowledge assessment is conducted before introducing the safety intervention (toolbox) while the post-use assessment is conducted three months after using the intervention. This stage also includes the evaluation of participants reaction to the toolbox safety talks.
    - Implementation evaluation: in this stage, the processes and procedures used to implement the toolbox talks are examined by evaluating the toolbox reach and delivery, participants recruitment procedures, the implementation context and fidelity, and participants satisfaction.
    - Behavior change evaluation: this stage intends to examine the transfer of safety knowledge gained from safety talks to the workplace. The safe/unsafe behaviors of maintenance crews are observed periodically throughout the pilot implementation period to examine any change in participants safety behavior.

1.6 Dissertation Structure

This dissertation consists of seven chapters presenting the design, implementation, and evaluation of the toolbox safety talks intervention used to improve safety awareness among highway maintenance crews.

The first chapter introduces the background, motivation, problem statement, objectives, research scope, and methodology.

The second chapter describes the analysis of safety records and the procedures followed to design the toolbox intervention.

The third chapter includes a literature review, discusses the need for evaluation, and describes the level of evaluation model adopted in this study

The fourth chapter presents the short-term results evaluation. It describes the pre- and post-use knowledge assessments used to evaluate knowledge acquisition. It also describes the evaluation of participants' reaction to the toolbox intervention.

The fifth chapter presents the evaluation of the processes and procedures used to implement the toolbox talks. It assesses the recruitment procedures, reach and delivery of the pre-task safety talks, the fidelity and context of the implementation, and participants' satisfaction.

The sixth chapter presents the evaluation of safety behavior change among highway maintenance crews in district X. It describes the behavior observation procedures used to examine the behavior change throughout the pilot implementation of the toolbox talks.

The seventh chapter concludes the dissertation with the contributions and limitations of the study.

2 DEVELOPING A PRE-TASK SAFETY BRIEFING TOOL FOR KENTUCKY HIGHWAY MAINTENANCE PERSONNEL

2.1 Introduction

Due to the hazardous nature and poor safety performance that characterize the construction industry, it has been the focus of safety research and regulations for decades. Researchers and occupational safety agencies, such as OSHA, have been focusing on occupational safety in the general construction industry leaving the highway construction and maintenance sector with insufficient research, standards, and regulations. This lack of investigation leaves highway maintenance workers to suffer from a hazardous work environment and risky work conditions. This is evident in their poor safety records. According to the Bureau of Labor Statistics, there were 2,415 fatalities, not including close calls and survivor workers, between 1992 and 2015 among US highway maintenance workers (Bureau of Labor Statistics 2017; Pegula 2004; Pegula 2013). In fact, the road worker fatality rate accounts for 1.5% to 3% of all work-related fatalities in the US with no descending trend (Gambatese et al. 2017). KYTC highway maintenance crews are no exception. In fact, KYTC is in USDOT Region 4 that has been reported to have one of the highest work zone incident rates in the nation. This poor safety performance of a unique audience of the construction workforce triggers the need for safety initiatives.

Previous studies have been conducted to address safety issues among KYTC employees. In a study conducted at the Kentucky Transportation Center (KTC) at the University of Kentucky, Hopwood and Palle (2004) provided a review of KYTC safety issues related to construction activities for both KYTC and contractor personnel. After interviewing KYTC resident engineers, as well as surveying and interviewing district safety coordinators, the authors recommended creating new safety programs and training, partnering with contractors and the Kentucky Department of Labor, promoting changes in KYTC policies, and increasing the role and support of safety coordinators. Another study conducted by Hancher et al. (2007) sought to address research questions with focus on the hazards associated with work zones and vehicular traffic. In this study, using surveys and focus group discussions, the authors addressed safety concerns and identified best safety practices for highway maintenance workers. The survey sought ideas and feedback from

KYTC and private highway construction and maintenance workers. Based on feedback, recommendations, such as closed cab tractors for mowers, LED stop signs in work sites, and additional lighting for nighttime work, were provided. Although both studies had their limitations in terms of relying totally on employees' feedback and focusing more on vehicular incidents than on other occupational work-related safety issues, they both recommended providing safety training for maintenance crews. The two studies help inform the current study.

In general, the primary approach introduced by several studies and regulations to address workers safety is the development of safety interventions that include any form of accident prevention. Heinrich et al. (1980) defined accident prevention as ‘‘an integrated program, a series of coordinated activities, directed to the control of unsafe personal performance and unsafe conditions, and based on certain knowledge, attitudes, and abilities’’. One widely used safety interventions is the training and education concept. Occupation safety and health training and education programs have been extensively used in different industries. The construction industry is no exception where different safety and health training programs have been used to improve safety performance. However, the highway construction and maintenance workforce, an important worker group of the construction industry, has not been served with sufficient safety interventions.

As part of the efforts of the KYTC to improve safety performance of their employees, this part of the study describes the data driven design and the development of a pre-task safety toolbox that can be used to increase safety awareness among KYTC maintenance crews. This toolbox is designed based on previous incident data of KYTC maintenance workers making it relatable and true-to-form for KYTC. The toolbox is intended to be used prior to any workday task among ten of the typical work operations of KYTC maintenance workers found in their Field Operations Guide (Kentucky Transportation Cabinet 2016). The goal of this safety toolbox is to improve safety performance of KYTC maintenance crews by increasing thier awareness of potential hazards to expect at the worksite and introducing safety controls to be practiced to prevent or minimize the associated risk.

2.2 Objectives

The purpose of this part of the study is to improve safety performance of KYTC maintenance crews by increasing workers' awareness of the potential hazards present within their work operations and presenting best practices to prevent or minimize the possibility of incidents and risks associated with such hazards.

The following tasks were undertaken to achieve the objective:

1) Review available literature and other DOT safety programs to identify similar effective safety measures that could be of use in designing a safety tool;
2) Analyze historical health and safety data (data provided was from 2005 to 2015) of KYTC maintenance workers to understand the nature of hazards, incidents, their consequences, and potentially the incident causes;
3) Identify available safety best practices to address the hazards identified from the data analysis; and
4) Design a pre-task safety toolbox that can be used prior to the start of any workday to increase workers' awareness of the potential hazards and preventative safety controls.

The above-mentioned tasks led to the development and delivery of the pre-task safety toolbox described in following sections of this chapter.

2.3 Federal Safety Standards and Regulations

At the federal level, nationwide policies and standards are imposed to minimize risks for the public and workers in roadway construction and maintenance work zones. The Manual on Uniform Traffic Control Devices (MUTCD) presents the mandatory work zone practices (Ferderal Highway Adminstration (FHWA) 2009). These standards include guidance on areas such as the setup of temporary traffic controls in work zones. The focus of federal standards associated with highway construction and maintenance trends toward controlling traffic in work zones due to the high number of fatalities associated with vehicular accidents. This focus on vehicle worker interaction to reduce workers' and drivers' risk in highway work zones is a trend in highway construction safety research in general. The Occupational Safety and Health Administration (OSHA) presents standards and regulations for the overall construction industry with little specifics on highway operations. These standards also apply to state DOTs but do not always cover the entirety of the work involved in highway construction and maintenance. Twenty-one states have developed individual state specific safety and health plans that cover local and state government workers, including DOT employees (Gambatese et al. 2017). In Kentucky, this body is the Kentucky Occupational Safety and Health office (KYOSH) which is still generalized when considering highway construction and maintenance. It is apparent that there are minimal federal safety standards and practices directly addressing the safety of highway construction and maintenance workers. As a result, and due to the uniqueness of each state transportation system, state DOTs often develop their own safety programs and practices.

2.4 Effective safety practices in other states

In an effort to improve safety performance, state DOTs have dedicated numerous resources and implemented a variety of safety controls to create a safe work environment for their employees. Based on studying and analyzing the history of worker injuries and fatalities, state DOTs seek to understand the nature of safety hazards, the root causes that led to incidents, the types of incidents, the associated results, and what could be done to prevent such incidents. Therefore, reporting and archiving becomes a core pillar in most safety improvement programs. In any safety initiative of this type, data on injuries and fatalities become the main source to understanding safety issues and creating or improving safety controls. Data driven safety controls have proven to be effective in different states across the country.

A recent National Cooperative Highway Research Program (NCHRP) synthesis study reviewed existing state DOT safety programs with interviews of six states to identify effective safety controls and programs across the nation. The six states interviewed included California, Maine, North Dakota, Oregon, South Carolina, and Washington. The states' safety programs were explored and discussed to find examples of safety improvements and highlight elements of these programs viewed as effective (Gambatese et al. 2017). The safety programs varied because each state DOT developed their safety program to address their specific conditions.

For example, California has its “Design for Safety Initiative,” which is a data driven program. This program focuses on using data to identify safety aspects requiring improvement and to inform landscape architects and engineers of such issues, so they might address them in the design phase. This is a proactive measure that helps to minimize the risk of potential hazards in work zones. This program also seeks ideas and feedback from maintenance workers and communicates these ideas to designers to help them better understand which actions need to be taken to improve safety performance (Caltrans 2014). This program resulted in high continuous support of leadership, which increase the overall program fund from $1.9 million in 2010 to $90 million in 2017 (Gambatese et al. 2017). This increase in fund and support indicates that leadership realized the benefits of such initiatives. Another advantage of this program is the change in design and the modification in the construction plans to not only improve safety but also to save construction and maintenance expenses.

Maine initiated the “Safety Idea Incentive Program” in 2012 where DOT employees are encouraged to participate as crews in the development of the safety program through safety discussions. Every month, the safety ideas are collected and evaluated to determine which idea is the most valuable and applicable. Every member of the winning crew receives 50 points, which is equivalent to $25. This program continued from 2012 to 2014 and resulted in many safety best practices that have been implemented with less intervention from management since the ideas come with buy-in from the work crews. Although this program lasted for three years only, it led many safety ideas that were implemented, such as creating the poisonous plant pocket guide, providing tick removal kits with the first aid kits, and marking the sidewalks at snow and ice drop zones (Gambatese et al. 2017).

North Dakota created the “Leading Indicators Initiative,” where the state DOT recorded and analyzed different leading indicators, such as employee participation in self-inspections, first aid training, and employee suggestion programs. Other leading indicators, such as employees’ participation in safety audits were evaluated through employee activity in safety programs. The main objective of this program is to adopt a new safety culture that looks for proactive controls other than counting the consequences and evaluating lagging indicators. One advantage of this program was a 50% reduction in insurance premium over the last six years (Gambatese et al. 2017).

One common aspect found within these practices is the data driven decision approach. Most existing state programs are based on some combination of past health and safety data and feedback or ideas from employees. This highlights the importance of data accuracy in future decision making. In fact, data driven decision approaches have been emphasized at the federal level. FWHA has made data driven decision approaches a policy priority (Gambatese et al. 2017). This policy is evidenced by FHWA developments in the Highway Safety Improvement Program (HSIP), which as part of the Fixing America's Surface Transportation (FAST) Act became a much more data driven decision program. Regardless of the effectiveness of the safety programs and practices, it can be concluded that data driven decision making is an effective approach to design safety controls to improve safety performance, as in the case of this study.

2.5 Methodology

This study seeks to develop a tool with the intent of improving safety in KYTC highway maintenance operations. The expectation was that analysis of the recordable incident data would identify areas of safety needs. The literature review would then identify best practices to mitigate those safety needs. The tool would present this information in a clear and concise form such that employees would begin the workday knowledgeable of the typical hazards present for the operations to be performed, and they would be equipped with knowledge of effective practices to mitigate the associated risks. To achieve this, the study methodology included collection and in-depth analysis of KYTC incident data relative to maintenance operations, categorizing this according to typical maintenance operations, and then organizing best practices according to the hazards present for typical operations. These steps are further defined in the following sections and were amalgamated to form a comprehensive tool for implementation with KYTC maintenance employees.

2.5.1 Data Collection

KYTC works with the Risk Management Services Company to collect and track recordable incidents and their associated severity, lost-time, and costs. KYTC recordable incident data was collected for a ten-year period (2005 – 2015). This data, while including incidents for all KYTC employees, was pared down to only KYTC highway maintenance employee incidents. The data was categorized according to the code of National Council of Compensation Insurance (NCCI) and included a total of 3,876 claims. The available information included claimant information, such as age and work title, and incident information, such as the location of incident, the date and time, causes of incident, and an incident description. Some of the data entries were missing information. Where possible, the data was reviewed such that it could be included in the following analysis, but a few records had to be removed due to lack of detail. The remaining data, provided in Microsoft Excel, still included over 3,000 records. The data detail was a leading factor in recommending an improved process and requirements for incident data collection and reporting.

2.5.2 Data Analysis

The data was analyzed through three phases in working toward the development of a safety tool. The data was first analyzed for trends regarding the maintenance operations during which the incident occurred. These incidents were further analyzed to draw out the main causes of the incidents within the separate operations. Finally, effective safety practices were aligned with these causes and incidents to present methods to mitigate the hazards present.

2.5.2.1 Phase I: Incident Categorization by Maintenance Operation

According to the KYTC Field Operations Guide for Maintenance, KYTC has 17 maintenance work operations. The purpose of this phase was to categorize the incident data according to these 17 work operations. Doing so would work toward the design of a tool that would provide best practices to KYTC maintenance workers according to their maintenance work operations. Unfortunately, there was no systematic reference within the incident data that drew a link between the claim and the work operation it belonged to. Therefore, the research team manually categorized the injuries according to the work operations through a careful examination of the information provided within the incident data, such as the incident description and causes, incident location, and claimant work title. The incident description and causes were especially helpful in this intensive data analysis.

Due to the missing information in some of the claims and the lack of accuracy regarding the collection and recording of the data, there appeared to be data available only aligning with ten operations of the 17 KYTC typical maintenance work operations shown in Table (2.1). The seven remaining operations include herbicide and pesticide application, landslide repairs, rock falls and sinkhole work, structural repairs, roadside landscaping, ditching and ditch cleaning, and traffic control maintenance. The lack of information in the data for the remaining seven operations resulted in the tool not currently being applicable to them. Again, this highlights the need to further standardize incident recording and reporting practices and potentially establishing "operation" as a field for incident data.

Through categorization of the data, the research team was able to convert some of the qualitative aspects of the incident data into quantitative data and enable the determination of the frequency of incidents within each of the ten selected operations. In addition, categorizing the data paved the way to identify the top frequent causes behind incidents within each work operation.

Table 2.1 Selected KYTC maintenance work operations

Selected KYTC typical maintenance work operations
1- Concrete repairs and Bridge maintenance
2- Equipment maintenance
3- Guardrail maintenance
4- Litter and debris removal
5- Mowing
6- Pipe / drain clearing and replacement
7- Road and Shoulder repairs
8- Sign inventory and replacement
9- Snow and ice removal
10- Tree and brush trimming

2.5.2.2 Phase II: Identification of Leading Incident Causes

After the data categorization and organization according to the ten applicable maintenance operations, the research team worked to identify the most frequent causes leading to the incidents within each of the selected operations. These causes were classified according to NCCI codes. Some similar causes, such as lifting, holding or carrying, object being lifted, etc. were combined since they represent similar activities and are related to similar injuries. Microsoft Excel was used to identify frequent causes according to the NCCI code followed by manual identification of the causes to confirm the results. Within each of the selected operations, 5 to 6 of the most frequently cited causes were identified. Collectively, twelve causes were identified as the most frequent causes within the ten operations and data available. These causes and their frequency over the data period (2005-2015) are shown in Table (2.2) below.

Table 2.2 Overall Top Frequent Incident Reasons

Top Frequent incident causes	**Frequency**
1- Object being lifted or handled	641
2- Falling or flying objects	313
3- Fall from different level	239
4- Hand tool or machine in use	189
5- Pushing or pulling	149
6- Foreign matter in the eye	143
7- Fall on ice or wet floor	141
8- Chemicals, liquids, or vapors	115
9- Vehicle upset	106
10- Animal or insect	99
11- Stationary or sharp objects	62
12- Hot object and temperature extreme	47

Some of these causes, such as lifting, appear in all the operations and ranks at the top of this list with the highest frequency (64.1 incidents/year). Many of the incidents appear to be caused by human factors and ergonomics. For example, most of the "fall from a different level" incidents were caused by either exiting a vehicle or getting in or out of a truck bed. In these incidents, human factors, such as expectancy, are important contributors to the behavior of the workers. This is a critical highlight of this study since there are minimal practices that address human factors and ergonomics for such scenarios. OSHA requires workers to use fall protection when working from a height of more than 6 feet. However, most of the fall incidents in this study occurred from heights less than 6 feet. These incidents cause varying types of injuries with varying levels of severity. While OSHA guidance may be effective in preventing more severe incidents at heights greater than 6 feet, the findings of this study suggest a need for addressing the human factors and ergonomics aspect possibly through considerations in the design phase.

2.5.2.3 Phase III: Identifying Safety Best Practices

As previously mentioned in the literature review, each state develops its own safety programs to address issues in their own unique transportation system. In addition, federal regulations and standards do not offer much to address the needs found in this study. There seems to be a sizable knowledge gap in standardized effective safety practices directly applicable to specific highway maintenance operations, especially for addressing human factors and ergonomics. To compensate for this, the research team reviewed and collected safety practices resources according to the following criteria:

1- Practices addressing specific frequent safety issues (operation specific when possible);
2- Safety resources produced through academic research;
3- Safety practices presented in industry guidance; and
4- Government regulations and standards.

After outlining the above criteria for collecting effective safety practices, several resources were identified including the following:

- 29 CRF 1926 OSHA regulations
- OSHA Ergonomics E-tool
- Safety tool kits from Kansas State University
- Safety tool kits from the University of New Hampshire
- Safety tool kits from the University of Washington
- Roadway Safety training program
- Construction solutions by CPWR
- NIOSH standards
- Other states employees' health manuals
- Others

Once these resources were reviewed and practices were collected, practices were consolidated, and the details were condensed to abbreviate the presentation within the safety toolbox. In other words, the intent of the safety toolbox is not to be a training mechanism of the safety practices but to present practices in a quick and fundamentally complete manner such that use of the toolbox would be effective but not time consuming.

2.6 Design of the Safety Tool

The final product and central deliverable of this study is a pre-task safety toolbox that could be reviewed prior to the workday's planned operations to highlight potential hazards and mitigation measures for maintenance forepersons and supervisors. The forepersons and supervisors could then use the presented information to prepare for a customized pre-task safety talk catered to the workday's operation, specific hazards present, how those hazards have historically injured KYTC maintenance workers, and practices to mitigate those hazards. The purpose of using the toolbox is to increase workers awareness of the potential hazards related to the work they are preparing to do and suggest safety practices to avoid or minimize the potential risk of these hazards.

The toolbox was designed with the following considerations in mind:

1- Be simple and intuitive to use and understand;
2- Be quick to complete;
3- Address the top frequent potential hazards;
4- Expandable to all maintenance operations; and
5- Be adjustable so it can be improved based on safety performance.

A Microsoft Excel macro-enabled spreadsheet was used to design the toolbox since it is easy to use and accessible to KYTC employees. Incompatibility and platform accessibility concerns also steered the research team away from a mobile device platform and web-based applications.

Throughout the design process, different display design and cognitive principles were considered to enhance the usability of the tool. For example, to reduce visual and motor work and to maintain simplicity, the number of buttons was minimized. This in turn is expected to provide an easy to use and pleasant interface (Galitz 2007). To improve navigation and flow, information and elements on screen were organized in rhythmic, guiding the user's eye orientation through the display. Main navigation buttons, such as

“Main Menu”, “Back”, etc. were placed at similar locations throughout the toolbox to maintain predictability and consistency.

The toolbox consists of three main sections beside the introductory instructional sheet. The opening sheet includes brief instructions on how to navigate throughout the toolbox (Figure (2.1)). The first section of the toolbox is the main selection page that includes the ten maintenance operations along with the overall incidents statistics of KYTC maintenance employees for a ten year period (Figure (2.2)). The main purpose of this section is to select the desired operations from the list of typical operations. The second section is more specific to the operation and includes a statistical summary of previous injuries of KYTC maintenance employees within each operation and the associated top frequent incident causes (Figure (2.3)). This section helps users to understand the trend and frequent causes of incidents within each operation to place more focus on specific safety issues when developing their safety talks. This also helps superintendents and forepersons in identifying what to look for at the worksite to make it safer. The third section of the toolbox presents examples of previous work incidents for each of the frequent causes and the suggested safety practices to minimize or eliminate the associated risk (Figure (2.4)). In accordance with OSHA recommendations, the written language of each section is not complex and can be easily understood by users. In addition, the toolbox includes some pictorial demonstrations for practices potentially requiring additional explanation (Figure (2.5)) with the goal of increasing workers’ understanding and reducing the verbiage and time required to use the toolbox. These sections are formatted to fit an individual’s computer screen without the need for scrolling. Coloring and organization of each section are kept similar throughout the toolbox to maintain consistency, regularity, balance, and unity. Adopting such display design and cognitive principles makes the toolbox aesthetically pleasing and reduces visual clutters (Galitz 2007).

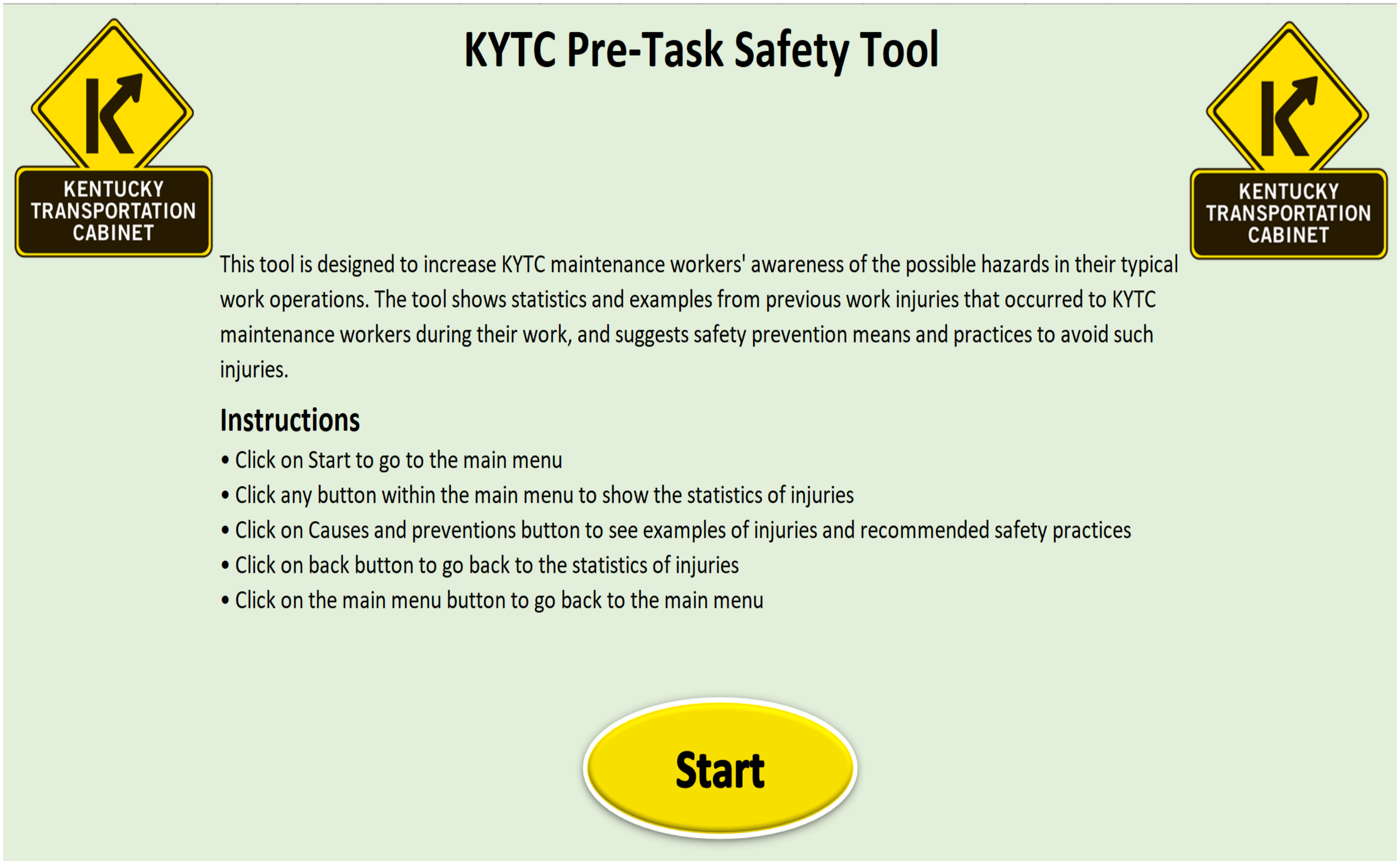


Figure 2.1 Introductory User Form of the Tool

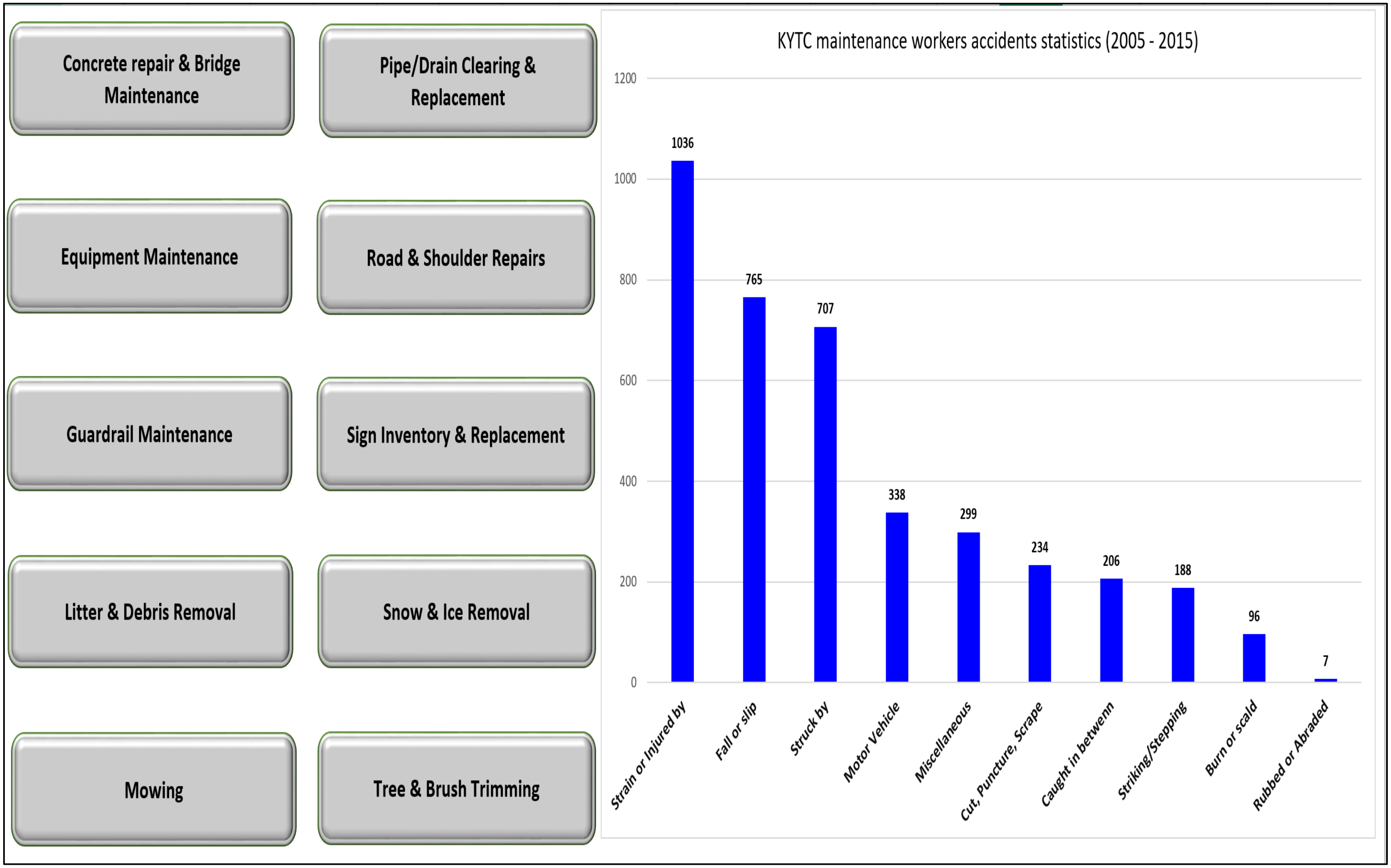


Figure 2.2 Operation Selection and Total Incident Frequency

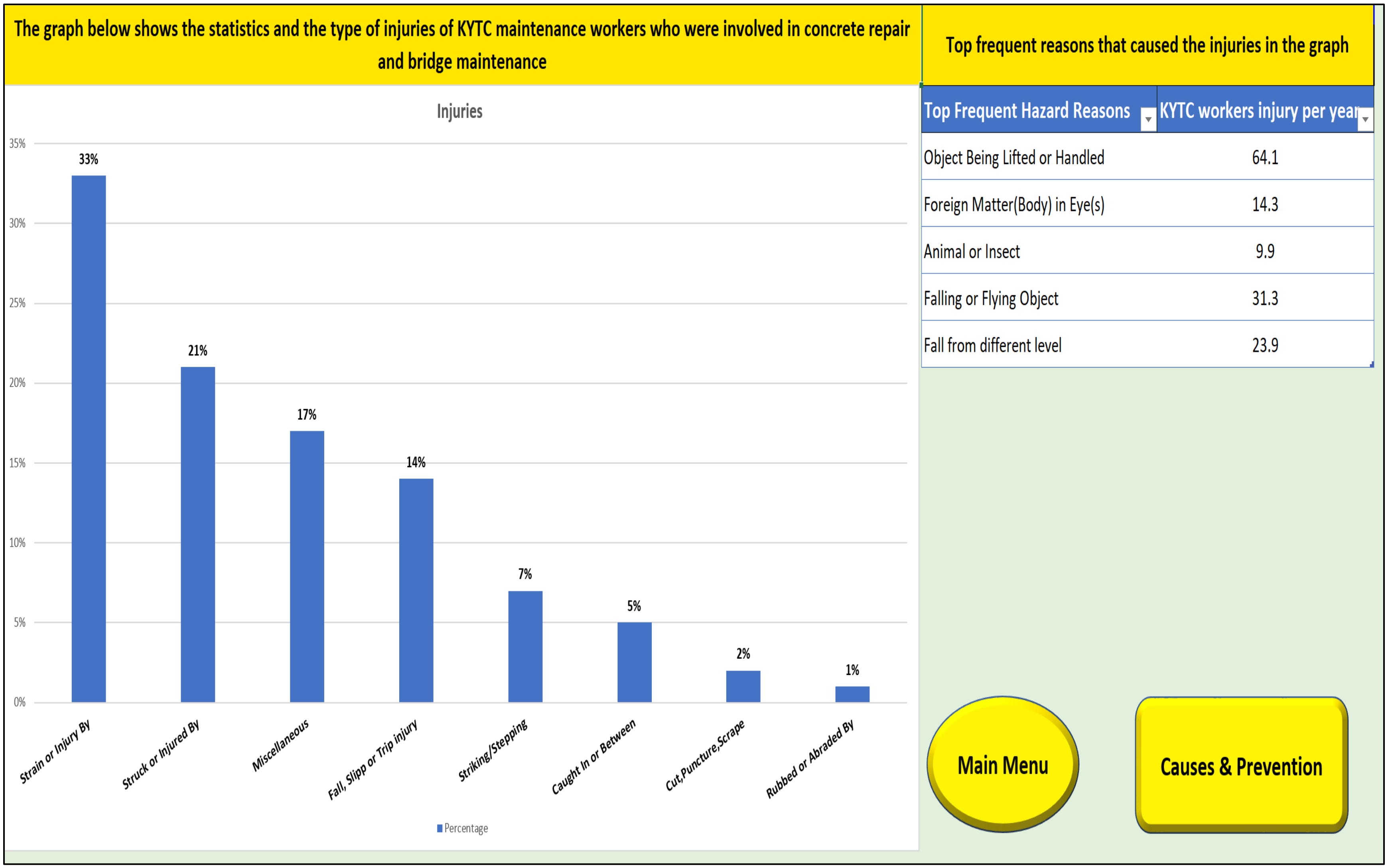


Figure 2.3 Statistics of Injuries and Associated Reasons of KYTC Maintenance Employees

Top Frequent Hazard Reasons	KYTC workers injury per year	Examples	Safety Best Practices Back Demo Main Menu
Falling or Flying Object	31.3	• Falling tree limbs and branches • Tree landing in the workers direction • Tree bouncing after being cut • Tree kick back and falls in the wrong direction	1- Identify the fall direction, the tree felling danger zone, and your escape area (Click Demo for details) 2- Limbs that cannot be dropped safely should be lowered by safe hoisting 3- Safely drop or lower cut branches and do not leave them in a tree 4- always face the onging cutting operation and do not turn your back to it. 5- When felling limbs or a tree, apply the two-trees rule (no one other than the feller should be within two tree lengths of the tree falling tree). 6- Allow greater distance when felling on a slope where logs may roll or slide 7- Wear PPE, such as hard hat, gloves, safety glasses, and facial shield 8- Wear long pants and non slip sturdy boots to protect your lower body parts
Object Being Lifted or Handled	64.1	• Lifting heavy logs and tree branches • Lifting or handling heavy tools • Lifting in awkward posture • Rolling over trees that were cut • Feeding brush into the chipper	1- Use safe hoisting, rigging for logs and limbs 2- Minimize manual materials handling with dollies, hoists, other equipment 3- plan and maintain a clear, level walking path when lifting 4- Don't lift too much by yourself; get help 5- Use proper lifting techniques; lift with your legs not your back whenever possible (Click Demo for details). 6- Avoid working in awkward postures 7- Do stretching exercise before work
Pushing or Pulling	14.9	• Pulling or pushing logs or tree branches after being cut • Pulling brush to the chipper • Dragging brush that are tangled together • Pushing brush into the chipper	1- Use safe hoisting, rigging for logs and limbs 2- Avoid working in awkward postures 3- Do stretching exercises before work
Chemicals, Liquids, or Vapors	11.5	• Contact with poison Ivy or poison Oak	1- Try to identify and avoid poison ivy and poison oak (Click Demo for details) 2- Wear long sleeved gloves, shirts, and pants. 3- Wash the affected area and everything touched the plant including clothes and tools. 4- Do not scratch the affected area to avoid infection 5- Mitigate the itching by hot and cold compresses. 6- Keep rubbing alcohol accessible. It removes the oily resin up to 30 minutes after exposure. 7- Go to a doctor if the rash is on face, inside the mouth, or on a large part of your body
Hand Tool or Machine in Use	18.9	• Saw slip and cut hand or leg • Chain Saw kick back and cut or struck worker • Pulling stuck saw from tree and strain back or shoulder • Cutting trees in awkward posture	1- Familiarize yourself with the directions that come with trimming tools and equipment 2- When carrying the chain saw, always turn it off 3- Start the chain saw on the ground; not against your body 4- Always wear leg and feet protection 5- Do not operate the saw above your chest level 6- When operating the saw, make sure you are standing on a dry, flat, solid surface 7- Insert the saw fully and avoid cutting with the upper tip of the saw 8- Make sure your chain saw is equiped with constant pressure switch to shut off the saw when needed 9- Always keep your fingers on the handle not on the trigger to prevent serious injury if you fall or slip 10- Feed the branches into the chipper butt end first to keep the chipper from being jammed and to reduce the kickback of material

Figure 2.4 Examples of Previous Incidents and Recommended Best Practices

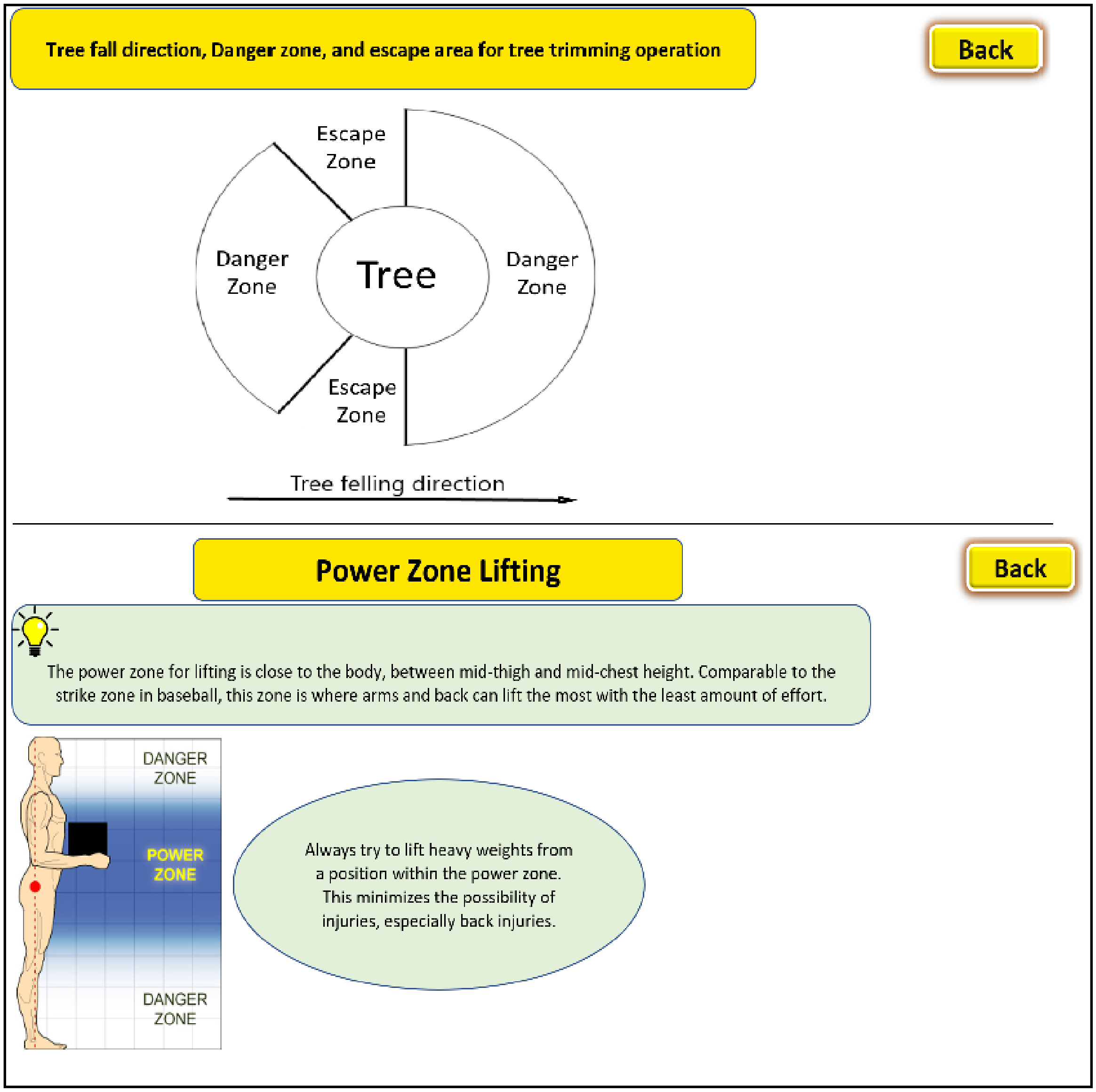


Figure 2.5 Demonstration of Recommended Lifting and tree trimming Practices

2.7 Conclusion

Highway maintenance has unique hazards, but seemingly less directly applicable safety standards, regulations, and programs compared to the whole construction industry. This work is dangerous due to the proximity of work sites to the passing traffic. In addition, this work is normally performed outside and occasionally at nighttime. DOT employees and contractors working in highway maintenance are exposed to a variety of unique hazards specifically associated with their work and not relating to the adjacent traffic.

Highway site safety does not receive sufficient attention in terms of safety research and programs. Additionally, the data analysis of the study highlighted that human factors and ergonomics play a role in the injuries related to the subject population, yet there is little guidance or standards for addressing these factors. This study attempted to focus on the work-related hazards present specifically for highway maintenance workers.

By analyzing data associated with incidents involving KYTC maintenance employees over a period of ten years (2005-2015), this study was able to develop a pre-task safety toolbox applicable to ten different operations these employees perform. Using this toolbox will assist supervisors in communicating safety concerns and increasing KYTC maintenance workers' awareness of the potential hazards in their work environment. Additionally, the toolbox suggests safety practices specific to their work task to prevent or mitigate the risk of such hazards. The design of the toolbox was based on careful examination and analysis of incident data. After determining the leading causes of incidents within each maintenance operation and identifying the best practices to address these hazards, the final product of this study is an electronic toolbox that can be used by KYTC maintenance crews prior to any work day. The toolbox is simple to use and would ideally help prepare forepersons or supervisors for a pre-task safety talk specific to the workday's activities, their associated hazards, and specific measures for mitigating the associated risks. This toolbox can be expanded to include all KYTC maintenance operations once data is available and can be improved based on safety performance.

3 SAFETY PROGRAM EVALUATION

3.1 Introduction

The burden of workplace injuries and fatalities is relatively large in the construction industry. Safety performance has been widely recognized as poor in this industry when compared with other industries. One approach to improve safety performance is occupational safety and health training and education programs. The conclusion of narrative reviews is that most of these programs lead to increase in safety knowledge, adoption of safe behavior and practices, and better safety outcomes (Burke and Sarpy 2003; Burke et al. 2006; Cohen et al. 1998; Colligan and Cohen 2004). Occupational safety and health training and education programs have been in practice for more than three decades in the construction industry. They vary from passive, information based techniques, to computer assisted techniques, to user or learner centered, to performance based techniques (Burke et al. 2006). Although such programs have been frequently appraised in the research literature and promoted in different federal standards governing occupational safety and health, their effectiveness is still debatable and differs from case to case. Therefore, the evaluation of effectiveness of training and education programs became a core element in the planning of such safety interventions.

One of the commonly used safety interventions in the construction industry is the safety toolbox talk or tailgate meeting. It is an informal work-site safety talk that often deliver critical safety message to work crews prior to or at the beginning of the workday. Safety messages often convey critical, time sensitive safety information tailored to the type of work to be performed (Kaskutas et al. 2016). Although this type of safety interventions has been frequently used and reported as an effective safety practice in the literature (Harrington et al. 2009; Jeschke et al. 2017; Kaskutas et al. 2016; Olson et al. 2016), evaluation studies have not adequately addressed the effectiveness of pre-task safety programs. Most of the available evaluation studies focused on certain aspects of the evaluation and overlooked the rest. For example, Harrington et al. (2009) developed and evaluated a toolbox training program that targeted construction supervisors in California to train them on the frequency and quality of toolbox talks. Although the authors used a robust approach to design the program, the evaluation was limited to reaction and attitudes of participants and did not address all aspects of evaluation. In their review for the available literature, Olson et al. (2016) stated that there is a lack of evaluation studies that address the toolbox interventions in the construction industry. Therefore, their work included reaction and attitude evaluation of two scripted toolbox materials but did not cover all aspects of evaluation. A recent study was conducted by Jeschke et al. (2017) to develop and evaluate a toolbox training program for construction foremen in Denmark. The evaluation approach in this study was limited to the implementation and some short-term outcomes. It can be concluded that there is a clear gap in the literature where a comprehensive systematic evaluation of safety toolbox programs is absent from the evaluation scene.

Following a theory-based evaluation model, the second part of this study is dedicated to conduct a comprehensive systematic evaluation of the effectiveness of the toolbox designed in the first part. The evaluation model consists of three major phases: reaction and safety knowledge (learning) evaluation, process (implementation) evaluation, and behavior change evaluation.

3.2 Literature review

3.2.1 The Definition of evaluation

Although evaluation is a frequently reported term in the literature, it does not have one universal definition in the body of knowledge. Different researchers proposed different definitions of evaluation. From an education standpoint, Grotelueschen (1980) and House (1983) argued that the definition of evaluation is driven by the philosophy of education, the methods used to evaluate, and the audience of evaluation. Grotelueschen (1980) and House (1983) provided a list of definitions of evaluation, which was also reported by McDemott and Sarvela (1999), of some distinguished evaluation theorists. One definition was proposed by Tyler (1949) where he stated that evaluation is the process of assessing whether or not the learning outcomes meet a prespecified set of objectives. Tyler recommended achievement tests as a methodology to evaluate programs. A possible audience of this definition include managers and psychologists (McDemott and Sarvela 1999). This definition will be utilized in one level of the current project evaluation. Other theorists defined evaluation as the process of assessing the actual performance against commonly accepted standards. According to this definition, programs' efficiency or cost, for instance, may be assessed against specific requirements. Managers and economists occasionally use system analysis as a methodology to conduct such evaluations (McDemott and Sarvela 1999). Another definition of evaluation was introduced by Scriven (1972) where he defined evaluation as the process of comparing the results of a program to specific population needs. Scriven recommended the examination of the intended effects and the side effects of the program rather than focusing only on the desired intended effects. Unlike other evaluation approaches that focus on the attainment of the program objectives, this approach does not overlook the unintended effects or unexpected results of the program that may lead to innovative ideas and improvements. Another definition was introduced by Stake (1976) where he defined evaluation as the process of comparing the program merit (value) with the values of stakeholders. Eisner (1985) defined evaluation as the process of critically examining the program by expert knowledge. Evaluation was also defined as the process of obtaining data to compare decision alternative. McDemott and Sarvela (1999) argued that the type of evaluation and the use of evaluation data will significantly be influenced by the definition of evaluation. Therefore, it is important to specify which definition(s) will be utilized to evaluate the intended programs. It is also important to understand that no single definition can serve all the purposes of evaluation. As a result, researchers and practitioners often use combinations of definitions when evaluating programs. For example, evaluators can use Scriven's definition to fulfill the needs of specific population and use Tyler's definition to see whether the intended program has met their pre-specified objectives or not.

3.2.2 The need for evaluation

Evaluation is an integral part of the planning, development, and implementation of training programs (Ruttenberg and Weinstock 1997). Health educators and safety trainers plan evaluation as a core part in their work to measure the effectiveness of their programs. Evaluation not only informs developers about the effectiveness of their programs but also helps managers make informed decisions. The fact that different parties with different interests are often involved in training programs makes evaluation a critical part of these programs.

Within the health education context, Shortell and Richardson (1978) explained the rationales of evaluation from different stakeholders' viewpoints. According to Shortell and Richardson (1978), organizations require the evaluation to justify or determine the programs' expenses, demonstrate their effectiveness to different groups, provide guidance for future efforts, and/or acquire support for the programs. Similarly, funding agencies may require evaluation to ensure programs' efficiency and to justify programs' effects for political reasons. From Programs' administrators' standpoint, evaluation is required to promote the program, increase control of the program, and show evidence to gain support. Evaluators conduct evaluation to contribute to the body of knowledge, obtain evidence to support the program, ensure the match of the program's results with the development and societal objectives, and to advance their professionality. Evaluation could also be conducted for public purposes, such as demonstrating the value of planned change, justifying the taxes spent, promote public participation in health or educational programs, etc. Windsor (2015) provided a similar perspective where he identified the following ten reasons to evaluate health programs:

- To measure the extent to which the program achieves the intended objectives;
- To establish criteria to monitor staff performance;
- Identify the programs' strengths and weaknesses;
- To justify costs and demonstrate accountability;
- Provide guidance for future evaluation;
- Identify opportunities for program expansion;
- Contribute to the body of knowledge;
- Advance the staff skills and professionality;
- Meet the demand of funding or contracting agencies; and
- Increase community awareness and support positive public relations.

Within the safety training context, the purpose of evaluation does not significantly differ from what has been reported in the health education literature. In the Resource Guide For Evaluating Worker Training: A Focus on Safety and Health, Ruttenberg and Weinstock

(1997) argued that safety training evaluation is often conducted to open opportunities for programs expansion, provide guidance to improve future training efforts, determine when and what type of training refresher is needed, identify areas where improvement is needed, measuring the short- and longer-term outcomes of the program, assess the extent to which the program brought positive change to the work place, document the training motivators that help trainees to use what they have learned, and to fulfill the contractual of lawful obligation.

As a major part of this project, the evaluation of the pre-task safety toolbox is conducted to:

1. Assess the impact of the toolbox on KYTC highway maintenance employees' safety knowledge and skills;
2. Identify the strength and weakness in the content, format, and delivery of toolbox;
3. Identify areas where improvements are needed;
4. Assess the extent to which the program brings positive change to the work site; and
5. Provide recommendation and guidance for KYTC future training efforts.

3.2.3 Levels of evaluation

Regardless of who requires evaluation and for what reasons, the evaluation of safety and health education program should fulfill two purposes; formative and summative purposes. Within a formative purpose, the development and implementation of the program should be evaluated through what is called implementation and process evaluation. A typical formative evaluation seeks to answer questions like whether or not the training program's content was developed in a way that supports or matches the program's objectives or whether or not the program was implemented as planned (McDemott and Sarvela 1999). This type of evaluation is usually conducted while the program is being developed or implemented to identify deficiencies and take corrective actions. Evaluators seek to understand the relationship between the program's materials, delivery method, trainers, and trainees' abilities, and how this relationship could alter the program from its ideal or intended performance. The formative evaluation can be considered as a control technique or monitoring approach to prevent the program from divagating away from its intended objectives. Summative evaluation on the other hand is more associated with the program's outcomes. It has a different timeframe and is usually conducted for a different purpose (Ruttenberg and Weinstock 1997). In this type of evaluation, evaluators are more concerned about whether the program has met its objectives. According to Basarab Sr and Root (2012), summative evaluation "provides information to show the merit and worth of a training program". In summative evaluation, evaluators typically measure short-term effects (impact) such as reaction, attitudes, and knowledge acquisition, and long-term outcomes such as behavior change, use of new skills and knowledge, and performance data. This evaluation takes place after completing the course or program. More participants are involved in this type of evaluation including trainers, trainees, and some other stakeholders.

To fulfill both formative and summative purposes of the evaluation, this study includes three phases of evaluation: Reaction and Knowledge assessment (short-term outcomes), process and implementation evaluation (formative evaluation), and behavior evaluation (long-term outcomes). This model of evaluation is consistent with the four levels evaluation model introduced by Kirkpatrick (1975).

4 REACTION AND KNOWLEDGE ASSESSMENT

4.1 Introduction

Developing knowledge and skills of the workforce continues to be a priority for most organizations in the United States. Every year, organizations spend considerable amounts of time and money on training and educating their employees. However, significant portion of the training efforts do not yield the desired outcomes (Cromwell and Kolb 2004). Occupational safety and health training programs are no exception. Therefore, evaluating the effectiveness of these programs became an essential requirement for organizations to assess the impact of such investments.

Because the effectiveness of training programs is required by different stakeholders, program developers use different evaluation criteria to prove and improve the effectiveness of their programs. One of the frequently used techniques to evaluate safety training programs is the assessment of short-term results. Short-term results typically include outcomes that can be measured immediately after the program completion. Such outcomes include skills and knowledge acquisition and participants' reactions and attitudes toward the program activities and content (Jeschke et al. 2017). Short-term results are critical elements of the evaluation process since they indicate whether the program is working as intended. They also help in identifying potential shortcomings and pave the way to the next phase of evaluation. If the short-term results are negative or not positively significant, training developers may not proceed to the next level of evaluation unless necessary modifications take place.

This chapter discusses the evaluation of short-term results of the toolbox talks. Pre- and post-training knowledge assessments were conducted prior to and after a three months pilot implementation period of the toolbox in district X of the state of Kentucky. Knowledge acquisition was evaluated based on the measurable change in participants safety knowledge and hazards identification skills. Participants' reaction towards the toolbox talks was evaluated after the toolbox implementation. The chapter describes the methods used for data collection, presents the results of evaluation, and concludes with a discussion of the results in light of the entire evaluation model utilized in this study.

4.2 Literature review

4.2.1 Reaction assessment

Reaction refers to the participants' perception of the program and their attitudes toward the training experience. In his evaluation model, Kirkpatrick (1975) introduced reaction evaluation as the first and basic level of the training evaluation process. In reaction evaluation, evaluators seek to understand how participants react to the program and what are their thoughts of the program's materials, delivery mechanism, trainers or instructors, teaching methods, content, etc. (Basarab Sr and Root 2012).

Some researchers argue that evaluating reaction does not provide sufficient information about the effectiveness of training programs. Arthur Jr et al. (2003) stated that "there is very little reason to believe that how trainees feel about or whether they like a training program tells researchers much, if anything, about (a) how much they learned from the program (learned criteria), (b) changes in their job-related behaviors or performance (behavioral criteria), or (c) the utility of the program to the organization (results criteria)." This argument sounds valid if the purpose of reaction evaluation is solely to assess the training transfer. However, participants reaction is often evaluated for several reasons other than assessing the transfer of the training content. Kirkpatrick (1975) stated that reaction evaluation is a measurement of customer satisfaction and can inform future decisions. It is an important element of the evaluation process because it provides useful information to guide trainers' and evaluators' efforts. Although learning is not measured at this level of evaluation, participants' reaction can provide information about learning. Positive reaction may not ensure learning, but negative reaction is a significant indicator that learning may not occur. In other words, if trainees do not react positively to the program, they will not be motivated to learn (Kirkpatrick 1975). In fact, evaluating participants reaction can provide useful information about the potential barriers to training transfer. One of the barriers that could discourage participants to use the skills and knowledge acquired from a training program is the resistance or openness to change (Holton III et al. 2000; Noorizan et al. 2016), which occurs based on trainees attitudes towards the training program

(Chevalier 2007). Therefore, it is important not only to collect reaction data, but to obtain a positive reaction.

Another reason to evaluate reactions is to communicate the importance of participants' feedback and contribution in improving the program's effectiveness. Otherwise, participants may get the sense that trainers know what they need without trainees' input, which may reduce the latter motivation to participate in the training program. In addition, evaluators can utilize trainees' comments and suggestions obtained during reaction evaluation to modify and improve the program and to guide future training efforts. Evaluation of reaction is also used in formative evaluation since part of the latter includes participants' satisfaction. In a formative evaluation of safety toolbox, Jeschke et al. (2017) found that participants' negative reaction or lack of satisfaction is a contextual factor that can hinder the implementation and reduce the effectiveness of toolbox training. Moreover, reaction evaluation helps evaluators and trainers to set standards of performance for future programs (Kirkpatrick 1975). If this level of evaluation reveals a negative attitude toward the training, root reasons should be identified, and necessary modifications should take place. However, if the evaluation resulted in positive reaction, evaluators should move to assess participants' learning and evaluate knowledge and skills acquisition. Therefore, the first main question to be answered in this phase of evaluation is how do participants react to the safety toolbox experience?

4.2.2 Knowledge gain (learning) assessment

Learning is defined as " the extent to which participants change attitudes, improve knowledge, and/or increase skills as a result of attending the program" (Kirkpatrick and Kirkpatrick 2006). Within the context of occupational safety and health training, the main measure in learning evaluation is safety knowledge. Safety knowledge can come from different sources including previous incidents, new regulations, standard training, etc. (Bye et al. 2016; Jørgensen 2016; Kongsvik et al. 2016). In general, safety knowledge is divided to two types: tacit knowledge that is acquired from work experience and injury exposure (Hallowell Matthew 2012; Koskinen et al. 2003; Podgórski 2010), and explicit knowledge that is mainly gained from safety training (Aboagye-Nimo et al. 2012) safety records, regulations, and guidelines (Hadikusumo and Rowlinson 2004). Although researchers differ on which type of safety knowledge has the highest impact on workers safety performance, there is a consensus among researchers that safety knowledge plays a major role in improving workers' hazards identification skills and guiding their attention and responsive actions (Hasanzadeh et al. 2017). The importance of safety knowledge in incidents prevention and control lies in the core of incident causation and prevention theories. In incident causation theories, incidents occur due to three root causes: failure to identify unsafe condition, deciding to process after identifying the unsafe condition, or deciding to act unsafely regardless of the existing conditions (Abdelhamid and Everett 2000). This means that lack of knowledge to identify a workplace hazards is a root cause of workplace incidents, which makes safety knowledge an integrated part of incident prevention. A good example of the importance of safety knowledge is the role of safety knowledge in safety risk assessment, a typical practice used in the construction industry to control workplace hazards. Risk assessment generally includes three steps: estimating the probability of occurrence for the hazard (i.e. frequency and severity); evaluating the associated risk based on frequency and severity; and responding with the suitable controls. These three steps are based on the assumption that the hazard is already identified (Carter and Smith 2006). However, failure to identify the hazards impede the risk assessment leaving the hazard free of safety controls. This in turn highlights the importance and role of safety knowledge in hazards management and control. Due to the importance of safety knowledge, one of the main purposes of occupational safety training programs is to improve participants' safety knowledge and skills and change their attitudes toward safety. In fact, increasing workers safety awareness through such programs is essential to change their attitude and safety behavior. Therefore, it is important to evaluate learning prior to assessing trainees behaviors and actions in the workplace. Kirkpatrick and Kirkpatrick (2006) argued that no change in behavior is expected without learning taking place in advance. The required knowledge to recognize an existing hazard is a prerequisite to informed safe behaviors. Having the right safety information helps workers to plan for safety by identifying potential hazards and choosing the appropriate safety measures (Zhang et al. 2015). As a result, the second main question to be answered in this level of evaluation is do participants learn new knowledge and/or skills and to what extent?

4.3 Objectives

Working towards evaluating the effectiveness of the safety toolbox and to answer the main questions raised in the first phase of this evaluation, the main objectives of reaction and knowledge evaluation are:

1- Understanding participants (KYTC supervisors and employees) reaction to the safety toolbox and their attitudes towards the participation in this program.
2- Assessing participants' hazards identification skills prior to and after conducting the toolbox talks.
3- Assessing participants' responsive skills to potential hazards prior to and after conducting the toolbox talks.
4- Evaluating Participants' safety knowledge within the maintenance operations included in the safety toolbox.
5- Collecting participants feedback on the safety toolbox to be utilized in the implementation (process) evaluation.

4.4 Methods

This phase of evaluation consists of two parts: reaction and knowledge gain (learning) assessments. To evaluate participants' learning, pre- and post-training safety knowledge assessments were conducted before and after the pilot implementation of the toolbox. A pre-training assessment of participants safety knowledge was conducted to assess the baseline level of safety knowledge prior to the use of the safety toolbox. A short scale safety climate measure was incorporated within the baseline assessment to examine the existing safety climate in district X. To measure knowledge gain, a post-training safety knowledge assessment was conducted three months after using the toolbox. Participants feedback was collected during the second knowledge assessment to evaluate their reaction to the safety toolbox intervention. The following subsections include a detailed description of participants, and the means and methods used to evaluate the short-term results of the pilot implementation of the safety toolbox.

4.4.1 Participants

KYTC has about 2,000 maintenance employees across the 12 districts in the state of Kentucky. The pilot implementation of the safety toolbox was conducted in one of the districts that has 16 maintenance crews. For confidentiality purposes, the selected district is referred to as "district X" in this study. District X has 16 maintenance crew. Each crew has one supervisor, 1-3 assistants, and 4-12 workers. Crew size varies between counties based on location and responsibilities. Each county has one maintenance crew, and there are four additional crews in the district including two bridge crews, a roadside crew, and a traffic signs crew. Participants were recruited from district X and included first line supervisors, supervisors' assistants, and maintenance workers. The number of participants varies in each stage of the assessment. The exact number of participants in each assessment will be noted in the relevant subsection. Participation in this study was voluntary, and participants were asked for their consent prior to taking part in the study. The University of Kentucky's Office of Research Integrity (ORI), the University of Kentucky's in-house Institutional Review Board (IRB), approved the study protocol prior to conducting the pilot implementation and the evaluation phases.

4.4.2 Study design and data collection

4.4.2.1 Baseline knowledge assessment

This part of the knowledge evaluation was conducted to establish a baseline level of participants safety knowledge. 150 participants of KYTC highway maintenance crews in district X including supervisors, their assistants, and workers were invited to participate in this assessment. Supervisors and their assistants were invited to the district office to take the assessment and to be trained on the use of safety toolbox. The supervisors baseline assessment consists of two main parts. The first part was designed to assess supervisors' safety knowledge in the following three main areas:

1- Identification of frequent incidents present in highway maintenance operations.
2- Identification of frequent causes of incidents in highway maintenance.
3- The best practices used to avoid, mitigate, or prevent the associated risk.

The assessment of safety knowledge within the three areas was conducted using three types of questions. In the first type of questions (Type I), six photographs of different highway maintenance work scenarios were introduced to participants with brief description of each work scenario. Participants were asked to identify the potential incidents on the photographs, rate their likelihood of occurrence on a scale of 1 to 5, identify the possible causes of these potential incidents, and suggest the best practices to avoid the associated risk as shown in figure (4.1). Instructions and an example of a typical answer were included in the assessment.

In this photo, workers are doing concrete work repair under bridge in high wind day.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

Figure 4.1 Sample question of supervisors' knowledge assessment

The second type of questions (Type II) presents a list of the 12 frequent causes of incidents identified in the safety toolbox and ask supervisors to rate them based on a scale of 1 to 5 according to their frequency to cause incidents, where 1 refers to a very low frequency and 5 refers to a very high frequency. The purpose of the rating question is to compare supervisors rating of incidents causes to the rating obtained from the ten years safety records in the design phase.

The third type of questions (Type III) in supervisors' knowledge assessment includes six multiple choice questions; three traditional textual questions and three photographic multiple choice questions. In the photographic multiple choice questions, hazards and prevention practices were presented to participants without related work scenarios and participants were asked to select the correct answer as shown in figure (4.2).

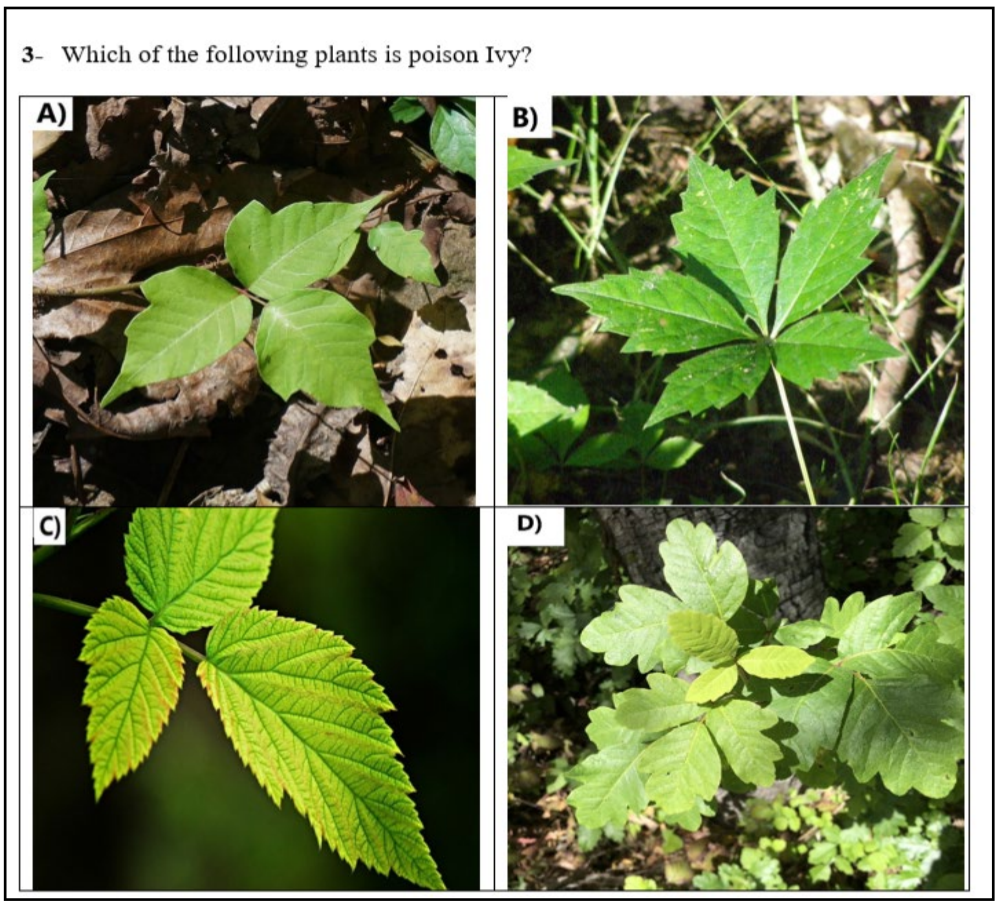


Figure 4.2 Sample of photographic multiple choice questions

Four multiple choice questions were designed to assess participants safety knowledge in the same safety areas (incidents, causes, prevention), but with introducing relevant information through multiple choices. Two questions required participants to identify, from multiple choices, the most frequent incident and the most frequent cause of work incident in highway maintenance work.

The second part of the assessment included six open ended questions that were designed to examine supervisors' perspective and understanding of the frequent safety issues they face in maintenance work. The purpose of the open-ended questions was to explore supervisors' insight of workplace safety issues to enrich the content of safety toolbox and reveal the potential aspects that have not been addressed during the design of the toolbox. Two open-ended questions were specifically designed to assess supervisors' awareness of ergonomic practices used to prevent tow frequent incidents found in the records (falling from vehicles, and strain due to lifting).

A short scale of safety climate consisting of six statement was adopted from Hahn and Murphy (2008) and included in the assessment to examine the prevalent safety climate in district X. In this scale, participants were asked to indicate whether they agree or disagree with each statement based on a scale of 1 to 4, where 1 refers to "strongly disagree" and 4 refers to "strongly agree". A sample of supervisors' baseline assessment questions along with the safety climate scale is shown in Appendix A.

For workers baseline assessment, only one type of questions (Type I in supervisors' assessment) was utilized in addition to the safety climate scale. However, 18 different photographs of maintenance work were used in workers baseline assessment. The photographs present typical maintenance work scenarios within the ten highway maintenance operations included in the safety toolbox. Workers assessments were delivered to their workplace in each county maintenance garage. A sample of workers assessment questions is shown in Appendix A.

4.4.2.2 Post-training reaction and knowledge assessment

Three months after a pilot implementation of the safety program in district X, a post training assessment was conducted to evaluate participants knowledge gain (learning) and their reactions to the pre-task safety toolbox talks. The same 150 maintenance employees in district X, who were invited to the baseline assessment, were invited to participate in the post-training assessment. The safety climate scale was not used in the post-training assessment. Instead, reaction questions were included to examine participants reaction to the three months safety talks program.

Utilizing the same questions used in the baseline assessment to evaluate participants knowledge and skills within the three safety areas (incidents, causes, prevention practices), supervisors completed the assessment in the district office. Reaction questions were added to the post-training assessment. To evaluate participants' reaction and examine their feedback, supervisors and assistants were asked to rate the toolbox, indicate whether it was a help or a hinderance to their work, report areas of improvement, and rate how well the toolbox did in addressing workplace safety issues.

In addition to the post-training assessment, 15 supervisors were interviewed individually in a semi-structured interview. The interview was designed to:

- Gain a better understanding of supervisors' feedback on the toolbox;
- Examine relevance of toolbox to maintenance work from supervisors' perspective;
- Identify the weaknesses and areas of improvement in the toolbox; and
- Identify any contextual/environmental barriers that prevent or hinder the implementation of the toolbox safety talks.

The flow of the interview questions followed the interview structure shown in figure (4.3). The questions associated with identifying toolbox weaknesses and implementation barriers were designed based on the supervisors' feedback collected during the pilot implementation period. As will be explained in chapter 5, supervisors were asked to report their notes every time they conduct a pre-task safety talk. The feedback was then used to design the interview questions. Interviews with all 15 subjects were transcribed to facilitate the analysis of data. The interview questions are shown in Appendix A.

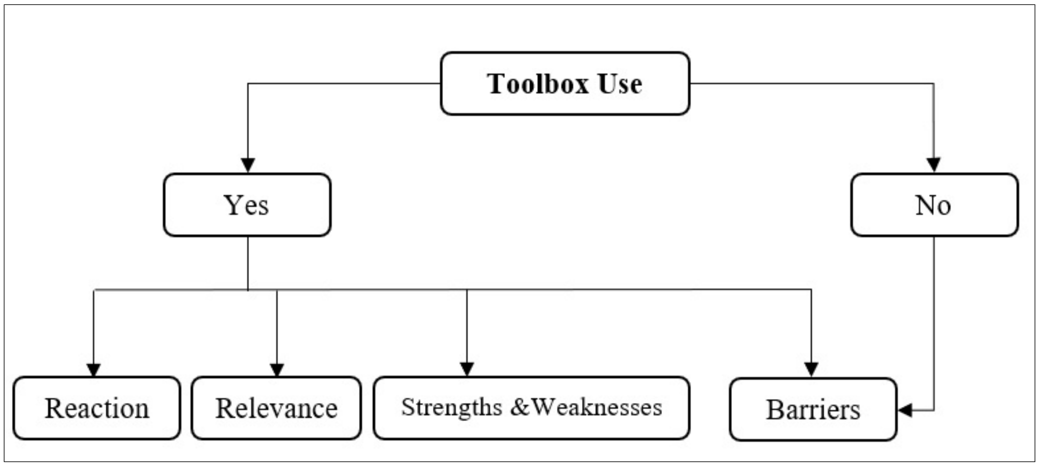


Figure 4.3 Interview questions flow

The post training assessment of maintenance workers included the same questions used in the baseline workers assessment in addition to 10 additional questions to evaluate workers reaction to the pre-task safety talks. The reaction questions were designed to evaluate workers reaction in light of the objectives of the pre-task safety talks. Therefore, workers were asked to rate the safety talks in terms of improving their skills and knowledge in hazards identification, incidents causation, best safety prevention practices, and getting the job done safely. In addition, workers were asked questions related to the presentation of the safety talks to assess the quality of the toolbox talks delivery as will be explained in detail in chapter 5. A sample of the post training assessment questions along with the reaction questions is shown in Appendix A. It is worth noting that baseline and post-training knowledge assessments questions were examined by maintenance supervisors and workers from another district, and necessary modifications were made prior to conducting any assessment. It is also worth noting that the toolbox usage data used in the inferential analysis in this chapter were collected during the implementation period.

4.5 Data analysis

4.5.1 quantitative data analysis

Using SAS software, version 9.4. Copyright © 2019. SAS Institute Inc., Cary, NC, USA, workers assessment data were analyzed to evaluate the effects of the toolbox talks on workers safety knowledge. Four logistic regression models with mixed effects were fitted to examine the effect of safety talks on participants general safety knowledge, incidents identification, causes identification, and safety practices identification. Blocking by subject and crew and controlling for the type of operation and the potential interaction effect between the toolbox talks and the type of operation, the first model used the toolbox talks as the regressor to participants' general safety knowledge. Participant safety knowledge represents the difference in participant's total score between the baseline assessment and the post training assessment. The same blocking and controls were used in the other three models. However, incidents identification was used as the dependent variable in the second model while the third and fourth models used causes identification and practices identification as the dependent variables respectively. Blocking by subjects and crew number facilitates controlling for any random effect stemming from participants heterogeneity. Controlling for the type of maintenance operation helps in examining work type effect and quantifying the effect of toolbox talks within each maintenance operation. As a result, the logistic regression models used in the analysis helped in:

- Examining and quantifying the effects of pre-task safety talks on participants safety knowledge, incidents identification, causes identification, and controls identification skills;
- Examining and quantifying the effect of safety talks on participants safety knowledge within each highway maintenance operation; and
- Examining and accounting for any random effect that can be introduced by subjects.

It is worth noting that only workers assessment data were included in the inferential statistical analysis while supervisors' assessments results are reported in the descriptive statistics and were not included in the statistical analysis due to the small sample size.

4.5.2 qualitative data analysis

Qualitative data collected from supervisors' interviews were analyzed using NVivo qualitative data analysis Software; QSR International Pty Ltd. Version 12, 2019. As the interview data were transcribed, the interviewees answers to each question were coded based on the main components of the interview structure shown in figure (4.3). Answers were coded according to their relevance to four categories including participant's reaction, toolbox relevance, toolbox strengths and weaknesses, and contextual factors. Using NVivo12, a word frequency query was generated for the aggregate data to identify any emerging theme in participants answers that could fall within or beyond the four main categories utilized to code data. Data were recoded again using the results of word frequency. The purpose of recoding data was to categorize answers into more specific subcategories and interpret the results in relation to the four main categories of the interview design structure.

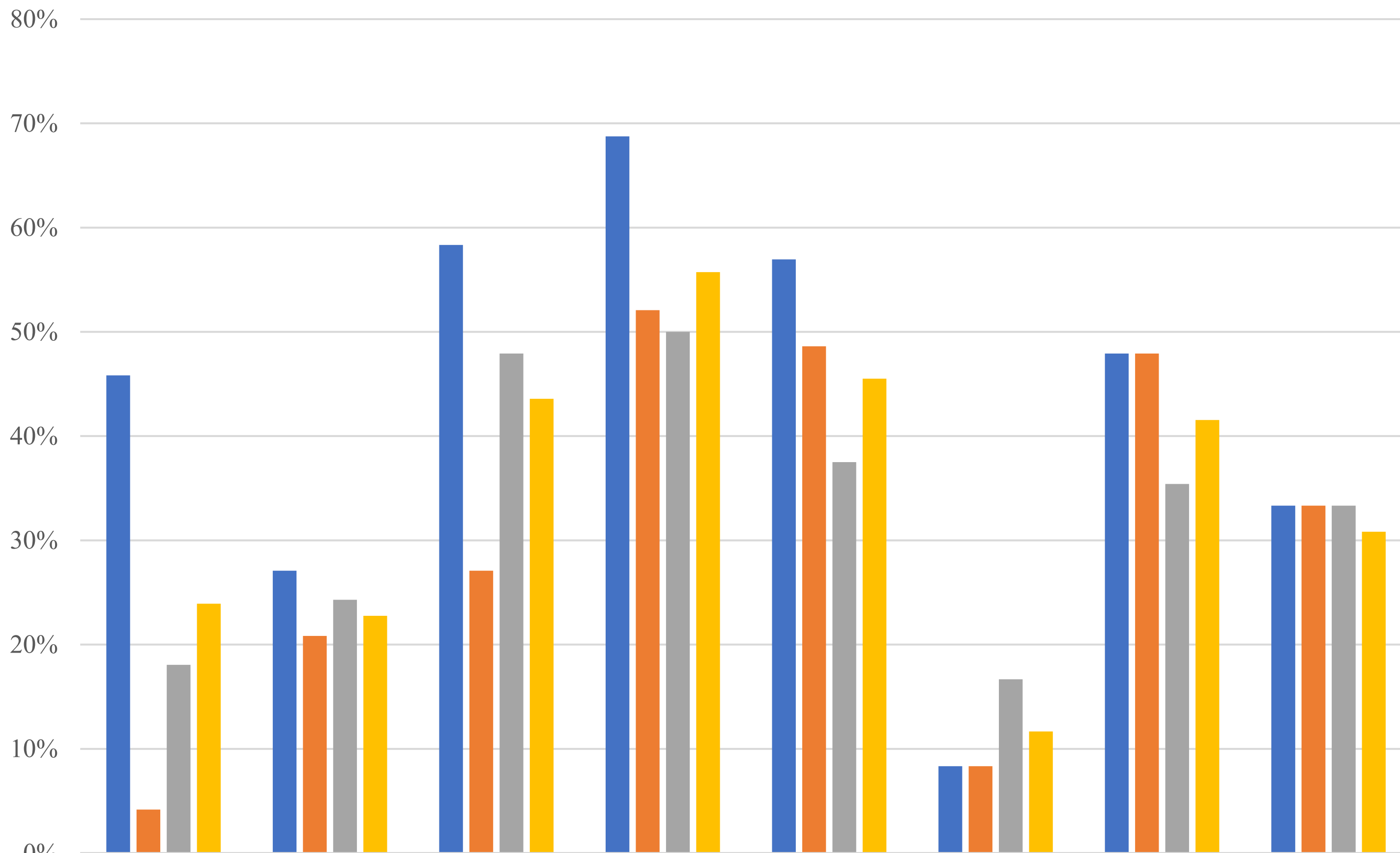
4.6 Results

4.6.1 Baseline knowledge assessment

4.6.1.1 Supervisors baseline assessment

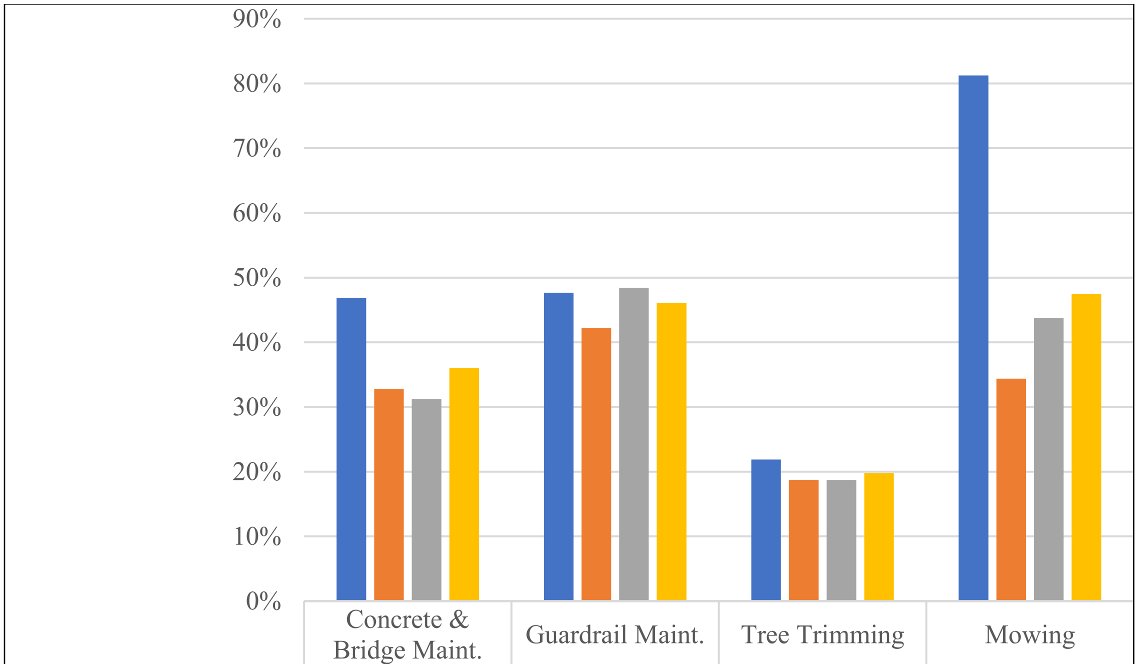
The participation in the baseline knowledge assessment was slightly lower than the participation in post-training assessment. With 53.3% participation rate (16 supervisors), the baseline knowledge level of each participant was established based on participant score in incidents identification, causes identification, and safety practices identification. Workers scores were calculated differently from supervisors scores.

Supervisors safety knowledge score was calculated based on the proportion of potential incidents, causes, and practices identified in the hazard identification questions. Based on different maintenance operations presented in six photographs, supervisors were able to identify, on average, 49% of potential incidents, 34% of incidents causes, and 37% of safety control practices. The average total score of supervisors who participated in the baseline knowledge assessment is 39%. The average total score significantly differs among supervisors. Figure (4.4) shows the results of baseline knowledge assessment of supervisors categorized by the maintenance crews. Supervisors in crew 1, 3, 4, 5, and 7 showed relatively better incidents identification skills than the rest of their coworkers in other crews. When categorized by maintenance operations, supervisors were able to identify potential incidents more than incidents causes and prevention practices especially in the mowing maintenance operation. Figure (4.5) shows the results of baseline knowledge assessment for supervisors categorized by maintenance operations presented in the six photographs.



	1	2	3	4	5	6	7	8
Incidents Identified	45.8%	27.1%	58.3%	68.8%	56.9%	8.3%	47.9%	33.3%
Causes Identified	4.2%	20.8%	27.1%	52.1%	48.6%	8.3%	47.9%	33.3%
Prevention Identified	18.1%	24.3%	47.9%	50.0%	37.5%	16.7%	35.4%	33.3%
Total Score	23.9%	22.8%	43.6%	55.7%	45.5%	11.7%	41.5%	30.8%

Figure 4.4 Results of baseline safety knowledge assessment of supervisors by maintenance crew



	Concrete & Bridge Maint.	Guardrail Maint.	Tree Trimming	Mowing
Incidents Identified	46.9%	47.7%	21.9%	81.3%
Causes Identified	32.8%	42.2%	18.8%	34.4%
Prevention Identified	31.3%	48.4%	18.8%	43.8%
Total Score	36.0%	46.1%	19.8%	47.5%

Figure 4.5 Results of baseline safety knowledge of supervisors by maintenance operation

To compare the frequency of incidents causes from supervisors' perspective to the frequency obtained from the recordable incidents data, supervisors were asked to rate incidents causes based on their frequency on a list previously identified from the design phase. Table (4.1) shows the results of comparison where the incidents causes are shown in a descending order based on the frequency obtained from safety records and the supervisors rating. There appear to be some differences between how supervisors rated frequent causes of work incidents and how the frequency of these causes looks like in safety records. While supervisors rated "Lifting" at the top of the list, which is consistent with what has been found in the safety records, they rated "Pulling or Pushing", which ranked the fifth according to the safety records list, as the most frequent cause of work incidents in highway maintenance work. In addition, although "Falling from different level" is found to be a very frequent cause of incidents in the safety records, supervisors rated it at the bottom of the list.

Table 4.1 Comparison of incidents causes frequency

Based on safety records		Based on supervisors rating	
Incident causes	**Freq/year**	**Incident causes**	**Rate**
1- Object being lifted	64.1	1- Pulling or pushing	3.69
2- Falling or flying objects	31.3	2- Object being lifted	3.56
3- Falling from different level	23.9	3- Stationary or sharp objects	3.38
4- Hand tool or machine in use	18.9	4- Falling or flying objects	3.25
5- Pushing or pulling	14.9	5- Fall on ice or wet floor	3.13
6- Foreign matter in the eye	14.3	6- Hand tool or machine in use	3.06
7- Fall on ice or wet floor	14.1	7- Foreign matter in the eye	2.94
8- Chemicals contact	11.5	8- Vehicle upset	2.75
9- Vehicle upset	10.6	9- Hot object & temperature extreme	2.69
10- Animal or insect	9.9	10- Falling from Different level	2.31
11- Stationary or sharp objects	6.2	11- Animals or insects attack	1.94
12- Hot object & temperature extreme	4.7	12- Chemicals contact	1.88

When asked to select the most frequent injury in the multiple choice question, 50% of supervisors chose "Fall or slip", 25% chose "Cuts", 12.5% chose "Strained by", and 12.5% chose "Struck by" as the most frequent work incident in the highway maintenance work. The results of selection for the most frequent injury are inconsistent with the safety records as "Strained by" is the most frequent injury found in their safety records followed by "Struck by". When asked about the most frequent cause of incidents in highway maintenance work, 44% of supervisors chose "Lifting", 31% chose "Hand tools and Equipment", and 25% chose "Falling from different levels". Although this selection is consistent with safety records, it is inconsistent with their selection for the most frequent injury because "Lifting" is often associated with "Strained by" injuries, which only 12.5% of supervisors chose as the most frequent injury.

When relevant knowledge was introduced in multiple choice questions, 37.5% of supervisors were able to identify the correct hazard and control practices. However, the results show better skills for supervisors in identifying technical practices, such as the "danger zone" (37.5%) and the "falling distance" (56.3%) in the tree trimming operation, than ergonomic practices, such as the "Power zone" (18.5%), which is a common ergonomic term in manual lifting techniques.

In the last part of the assessment, supervisors were asked six open-ended questions; in four questions, supervisors were asked to report the most frequent work incident in highway maintenance, its causes, and the potential practices used to avoid the risk. The results were consistent with safety records as most supervisors reported lifting related incidents, cuts, and falls as the most frequent incidents in maintenance work. Table (4.2) shows the results sorted by incidents, associated causes, and suggested preventions.

Table 4.2 Frequent incidents, their causes, and suggested preventions by supervisors

Incident (Freq.)	**Causes**	**Prevention**
Cuts (8)	• No safety gloves • Shortcuts • Insufficient attention • Tools and equipment	• PPE
Lifting related (8)	• Lifting improperly • Tolerance to get the job done	• Lift with legs • Team lifting • Use equipment
Falls (7)	• Ice • Wet concrete floor • Inclined surfaces • Banks	• Three points of contact • PPE

When asked about prevention practices used to avoid the risk associated with "lifting related" and "falling off vehicles" incidents, most supervisors were able to identify at least one prevention technique to prevent or mitigate the associated risk. Table (4.3) shows the suggested practices along with the frequency of time each practice was reported.

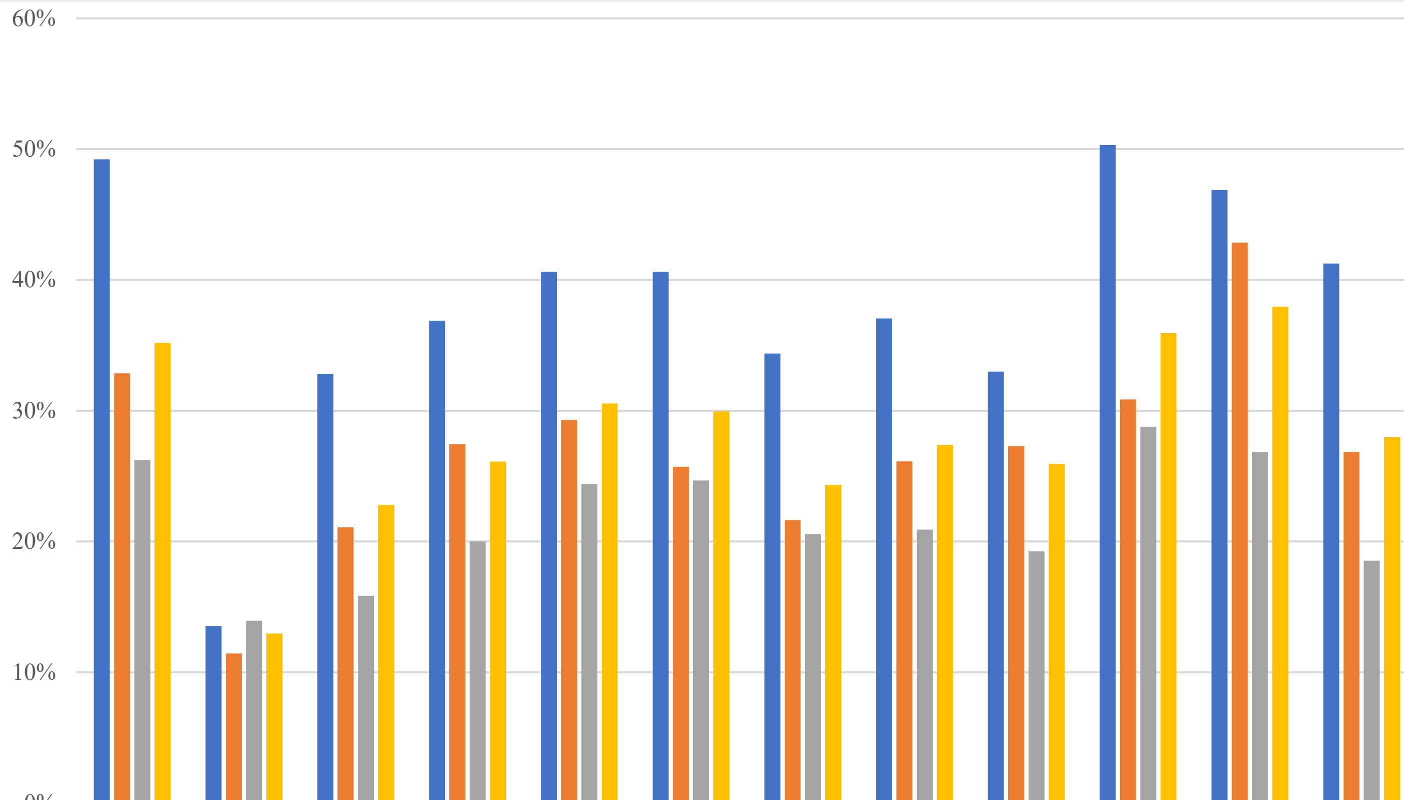
Table 4.3 Practices suggested by supervisors to prevent frequent work incidents

Question	**Suggested practices**	**Freq.**
• What are the safety practices to avoid back injuries caused by lifting heavy items?	Using equipment	8
	Team lift	8
	Lifting with legs	4
	Using back brace	3
• When climbing in and out of work vehicles and equipment, what technique can be used to avoid falling, tripping, and sliding incidents?	Maintaining three points of contact	11
	Using ladder	2
	Using handrail or steps	1

4.6.1.2 Workers baseline assessment

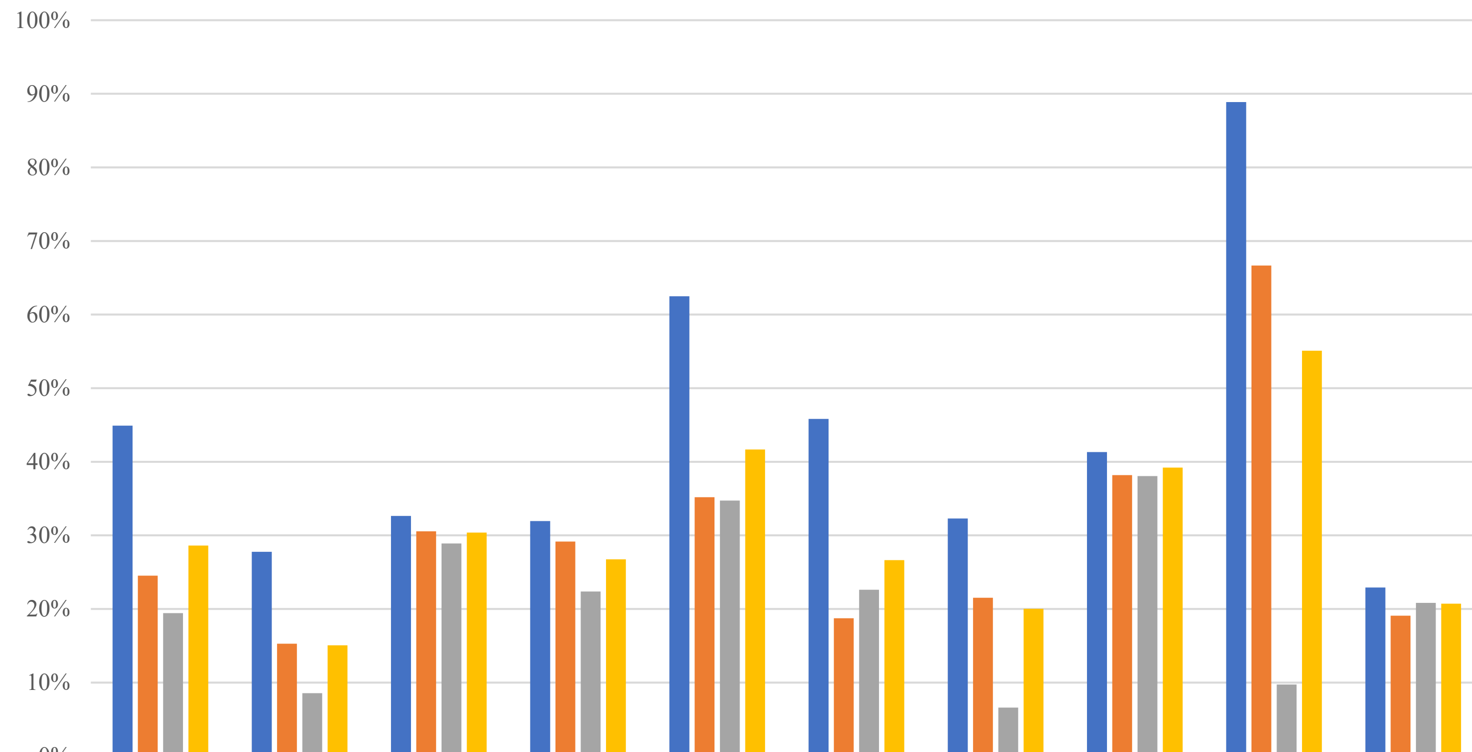
With participation rate of 60% (72 worker), the baseline safety knowledge level for workers was established based on their ability to identify work incidents, incident causes, and prevention practices within 10 maintenance operations presented in 18 different photographs of maintenance work scenarios. The total score of a worker was calculated by adding the number of potential incidents, causes, and practices identified and divided by the total number of incidents, causes, and practices presented in the photographs. The same calculation method was used to calculate workers score in incidents identification, causes identification, and prevention identification. On average, workers were able to identify 38.4%, 26.6%, and 21.7% of the total incidents, incidents causes, and prevention practices respectively. The average total score for workers in the baseline assessment is 28%.

When categorized by crew, workers' total score, the proportion of incidents, causes, and practices identified varied among crews. However, there is a clear trend in the results that suggests a better ability for workers to identify potential work incidents and the associated causes than their ability in identifying prevention controls as shown in figure (4.6). When categorized by maintenance operation, workers' total score, the proportion of potential incidents, causes, and practices identified also varied among operations. A similar trend is detected in the results of some operations with a better average score for workers in incidents identification compared to their score in causes and prevention identification as show in figure (4.7).



	Crew 1	Crew 2	Crew 3	Crew 4	Crew 5	Crew 6	Crew 7	Crew 9	Crew 10	Crew 11	Crew 12	Crew 13
Incidents Identified	49.2%	13.5%	32.8%	36.9%	40.6%	40.6%	34.4%	37.1%	33.0%	50.3%	46.9%	41.3%
Causes Identied	32.9%	11.4%	21.1%	27.4%	29.3%	25.7%	21.6%	26.1%	27.3%	30.9%	42.9%	26.9%
Prevention Identified	26.2%	13.9%	15.9%	20.0%	24.4%	24.7%	20.6%	20.9%	19.2%	28.8%	26.8%	18.5%
Total Score	35.2%	13.0%	22.8%	26.1%	30.6%	29.9%	24.3%	27.4%	25.9%	35.9%	38.0%	28.0%

Figure 4.6 Average baseline crew scores sorted by crew number



	Concrete & Bridge Repair	Equipment Maint.	Guardrail Maint.	Litter and Debris removal	Mowing	Pipe & Drain Maint.	Road & Shoulder repair	Signs Maint.	Snow Removal	Tree trimming
Incidents Identified	44.9%	27.8%	32.6%	31.9%	62.5%	45.8%	32.3%	41.3%	88.9%	22.9%
Causes Identied	24.5%	15.3%	30.6%	29.2%	35.2%	18.8%	21.5%	38.2%	66.7%	19.1%
Prevention Identified	19.4%	8.6%	28.9%	22.4%	34.7%	22.6%	6.6%	38.1%	9.7%	20.8%
Total score	28.6%	15.1%	30.4%	26.7%	41.7%	26.6%	20.0%	39.2%	55.1%	20.7%

Figure 4.7 Average baseline workers scores sorted by maintenance operations

4.6.1.3 Safety climate assessment

Safety climate was measured using a short scale of six statements. Workers and supervisors were asked to rate each statement on a scale of 1 to 4, where 1 represents a strong disagreement and 4 represents a strong agreement. The score of safety climate was obtained by calculating the average of rating. The overall average safety climate score reported by 88 participants was 3.26. Participant average rating for each statement is shown in table (4.4).

Table 4.4 Participants rating of safety climate scale statements

Statement	**Rate**
1. New employees learn quickly that they are expected to follow good health and safety practices.	3.17
2. Employees are told when they do not follow good safety practices.	3.13
3. Workers and management work together to ensure the safest possible conditions.	3.25
4. There are no major shortcuts taken when worker health and safety are at stake.	3.2
5. The health and safety of workers is a high priority with management where I work.	3.33
6. I feel free to report safety problems where I work.	3.48

4.6.2 Post-use knowledge assessment

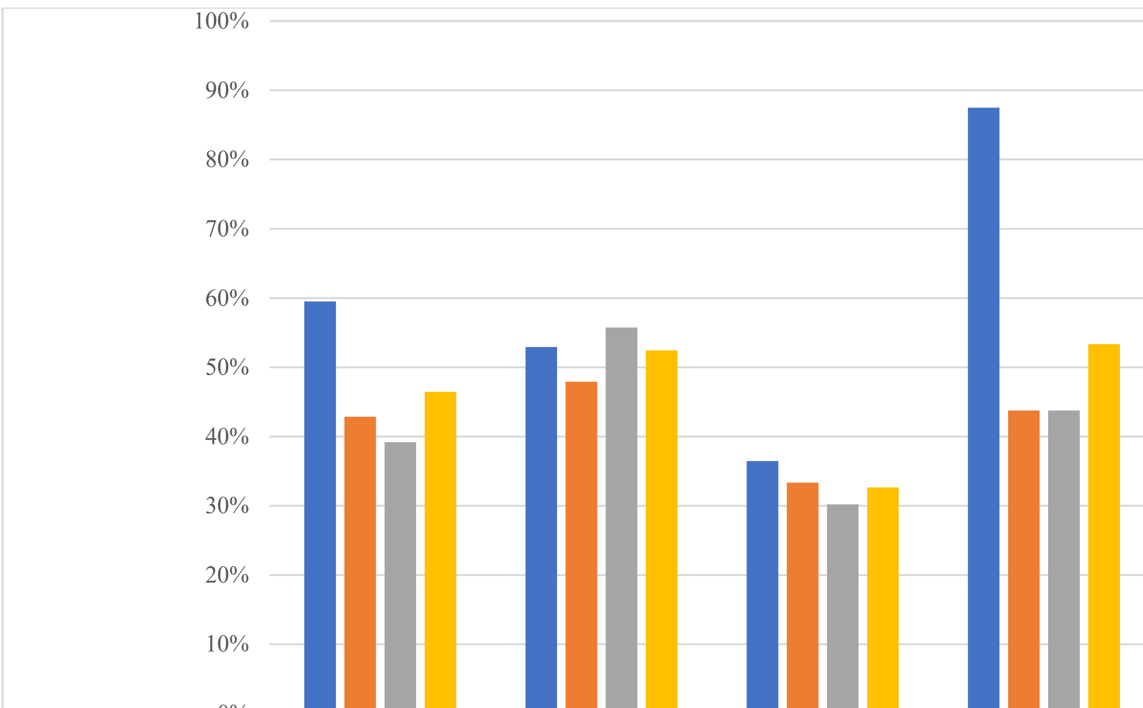
4.6.2.1 Supervisors post-use assessment

The participation rate of supervisors in the post-use assessment was higher compared to the baseline assessment. With 80% participation rate (24 supervisors), the post-use knowledge assessment was conducted after the baseline assessment. During this time, supervisors used the toolbox to present pre-task safety talks to highway maintenance crews. The level of participants safety knowledge was calculated using the same criterion used in the baseline assessment.

The results of post-use assessment show a clear improvement in the overall average score of participants as well as their average scores in incidents, causes, and preventions identification. With an average total score of 47.2%, incidents identification score of

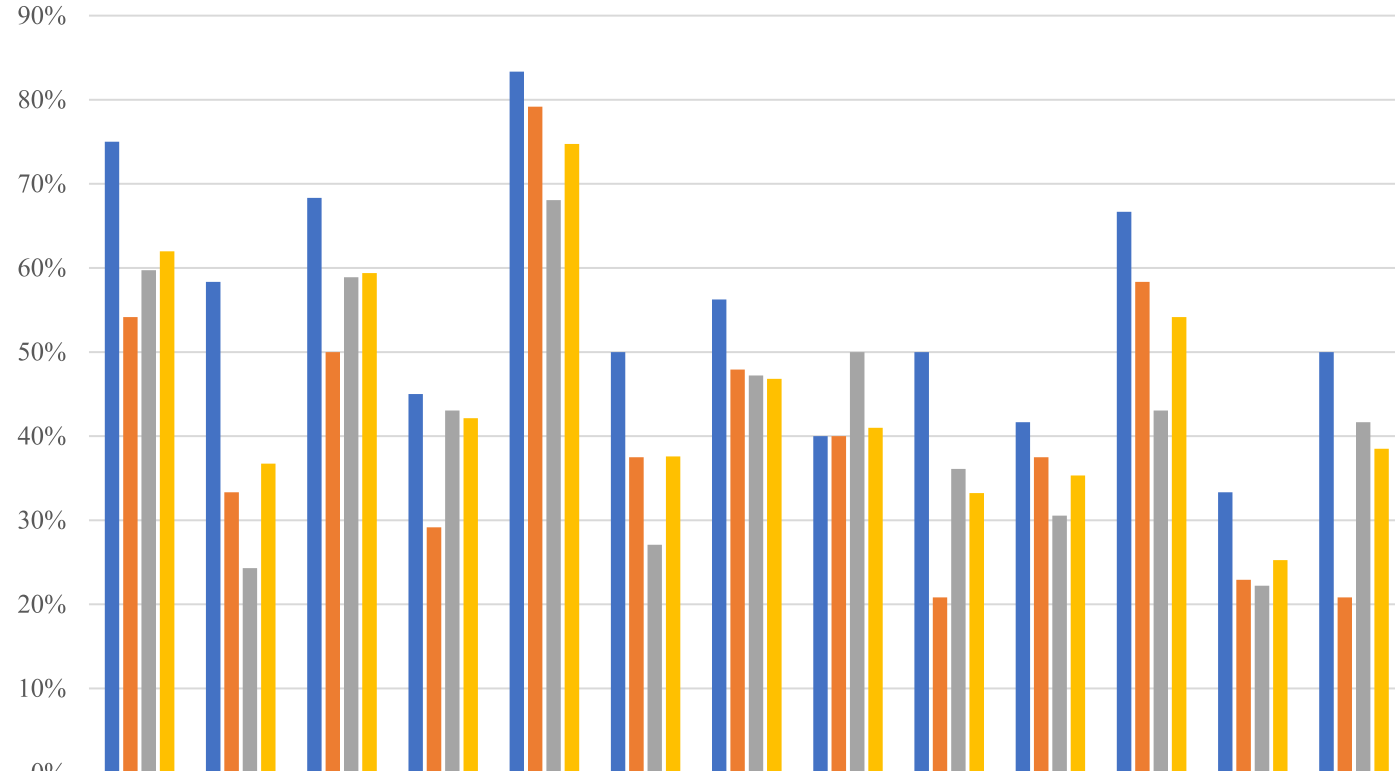
58.1%, incidents causes score of 43%, and prevention identification score of 43.9%, supervisors demonstrated a better performance in the first part of the assessment.

When categorized by maintenance operation, the supervisors scores increased, compared to the baseline scores, across all operations with some variations. The variation in supervisors scores increase is consistent with the frequency of toolbox talks delivered. The highest increase in supervisors scores was detected in “Tree trimming” operation, where several safety talks were reported by supervisors. Figure (4.8) shows the results of post-use assessment categorized by maintenance operations. When categorized by crew, the results show significant increase in supervisors scores compared with baseline assessment except for crew 4. Figure (4.9) shows the results of post-use assessment categorized by the crew number.



	Concrete & Bridge Maint.	Guardrail Maint.	Tree Trimming	Mowing
Incidents Identified	59.5%	52.9%	36.5%	87.5%
Causes Identified	42.8%	47.9%	33.3%	43.8%
Prevention Identified	39.2%	55.7%	30.2%	43.8%
Total Score	46.5%	52.4%	32.6%	53.3%

Figure 4.8 Results of supervisors’ post-use assessment by maintenance operations



	1	2	3	4	5	6	7	8	9	10	11	12	13
Incidents Identified	75.0%	58.3%	68.3%	45.0%	83.3%	50.0%	56.3%	40.0%	50.0%	41.7%	66.7%	33.3%	50.0%
Causes Identified	54.2%	33.3%	50.0%	29.2%	79.2%	37.5%	47.9%	40.0%	20.8%	37.5%	58.3%	22.9%	20.8%
Prevention Identified	59.7%	24.3%	58.9%	43.1%	68.1%	27.1%	47.2%	50.0%	36.1%	30.6%	43.1%	22.2%	41.7%
Total Score	62.0%	36.7%	59.4%	42.1%	74.7%	37.6%	46.8%	41.0%	33.2%	35.3%	54.2%	25.3%	38.5%

Figure 4.9 Results of supervisors’ post-use assessment by crew

In the second part of supervisors' assessment, the results of post-use assessment did not significantly change from the results of baseline assessment. Supervisors rating of incident causes frequency stays the same with some minor changes. "Pulling or Pushing" and "Lifting" stayed on the top of the list in both assessments while "Falling from different level" stays at the bottom of the rating list although it has been reported as a very frequent cause of work incidents in the toolbox. Table (4.5) shows a comparison of the results of supervisors rating for incidents causes between pre- and post-use knowledge assessments.

Table 4.5 Comparison of incidents causes rating prior and after using the toolbox by supervisors

Post-use rating		**Baseline rating**	
Incident causes	**Rate**	**Incident causes**	**Rate**
1- Pulling or pushing	3.92	1- Pulling or pushing	3.69
2- Object being lifted or handled	3.79	2- Object being lifted or handled	3.56
3- Hand tool or machine in use	3.38	3- Stationary or sharp objects	3.38
4- Fall on ice or wet floor	3.13	4- Falling or flying objects	3.25
5- Stationary or sharp objects	3.08	5- Fall on ice or wet floor	3.13
6- Falling or flying objects	3.08	6- Hand tool or machine in use	3.06
7- Hot object & temperature extreme	3.08	7- Foreign matter in the eye	2.94
8- Foreign matter in the eye	2.71	8- Vehicle upset	2.75
9- Vehicular Upset	2.63	9- Hot object & temperature extreme	2.69
10- Animals or insects attack	2.54	10- Falling from Different level	2.31
11- Falling from Different level	2.42	11- Animals or insects attack	1.94
12- Chemicals contact	2.00	12- Chemicals contact	1.88

In the last part of post-use assessment, the results show significant improvement in participants ability to identify hazards and prevention techniques. The difference in the proportion of correct answers between the two assessments was clear with 79% of participants were able to identify the presented hazard compared to only 37.5% in the baseline assessment. The same improvement was detected with respect to safety practices with 65% of participant were able to identify technical prevention practices compared to 47% of correct answer in the baseline assessment, and 54% of them were able to identify ergonomic techniques compared to only 19% of correct answer in the baseline assessment.

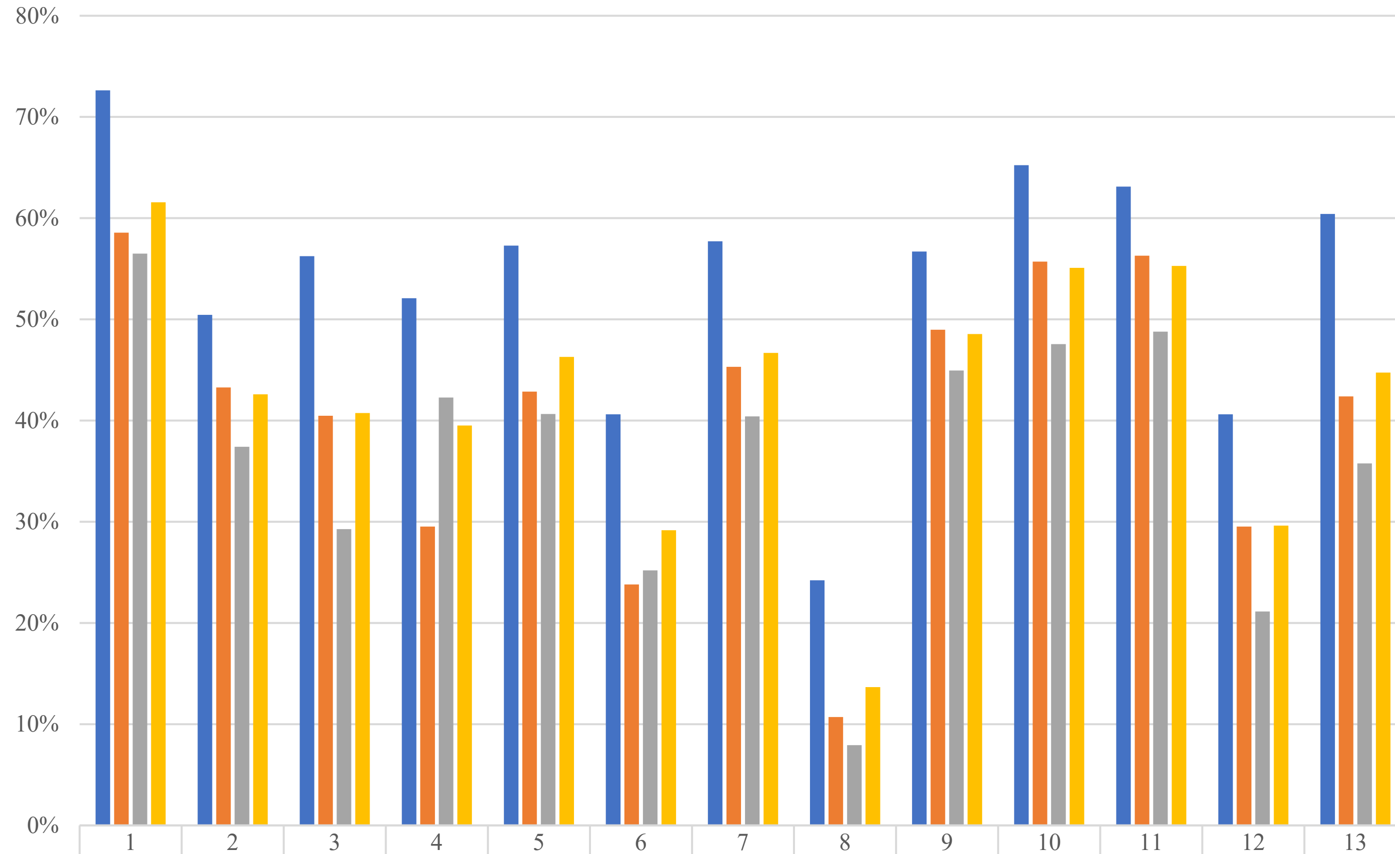
When asked to identify the most frequent injury in multiple choice questions, 54% of supervisors chose “Strained by”, 21% chose “Fall or Slip”, 21% chose “Cuts”, and 4% chose “Struck by” as the most frequent injury in the highway maintenance work. The results are consistent with what has been found in safety records, except for “Struck by” because the most frequent injury claimed by maintenance workers was “Strained by” followed by “Struck by”. More consistency was found in the results of post-use assessment as 83% of supervisors chose “Lifting” as the most frequent cause of incidents in maintenance work. The selection of “Lifting” as the most frequent cause of work incident is consistent with what has been reported in the safety records and with supervisors rating for the most frequent injury.

4.6.2.2 Workers post-use assessment

With participation rate of 63.3% (76 worker), the post-use safety knowledge level for workers was calculated based on the same criterion used in the baseline assessment. The total score of a worker was calculated by adding the number of potential incidents, causes, and control practices identified and divided by the total number of incidents, causes, and practices presented in the photographs. The same calculation method was used to calculate workers score in hazards identification, causes identification, and prevention controls identification. On average, workers were able to identify 55.6%, 43.6%, and 38.3% of the total incidents, incidents causes, and prevention controls respectively. The average total score for workers in the post-use assessment is 45%. The results of post-use assessment show significant increase in workers total score as well as their scores in of incidents, causes, and preventions identifications.

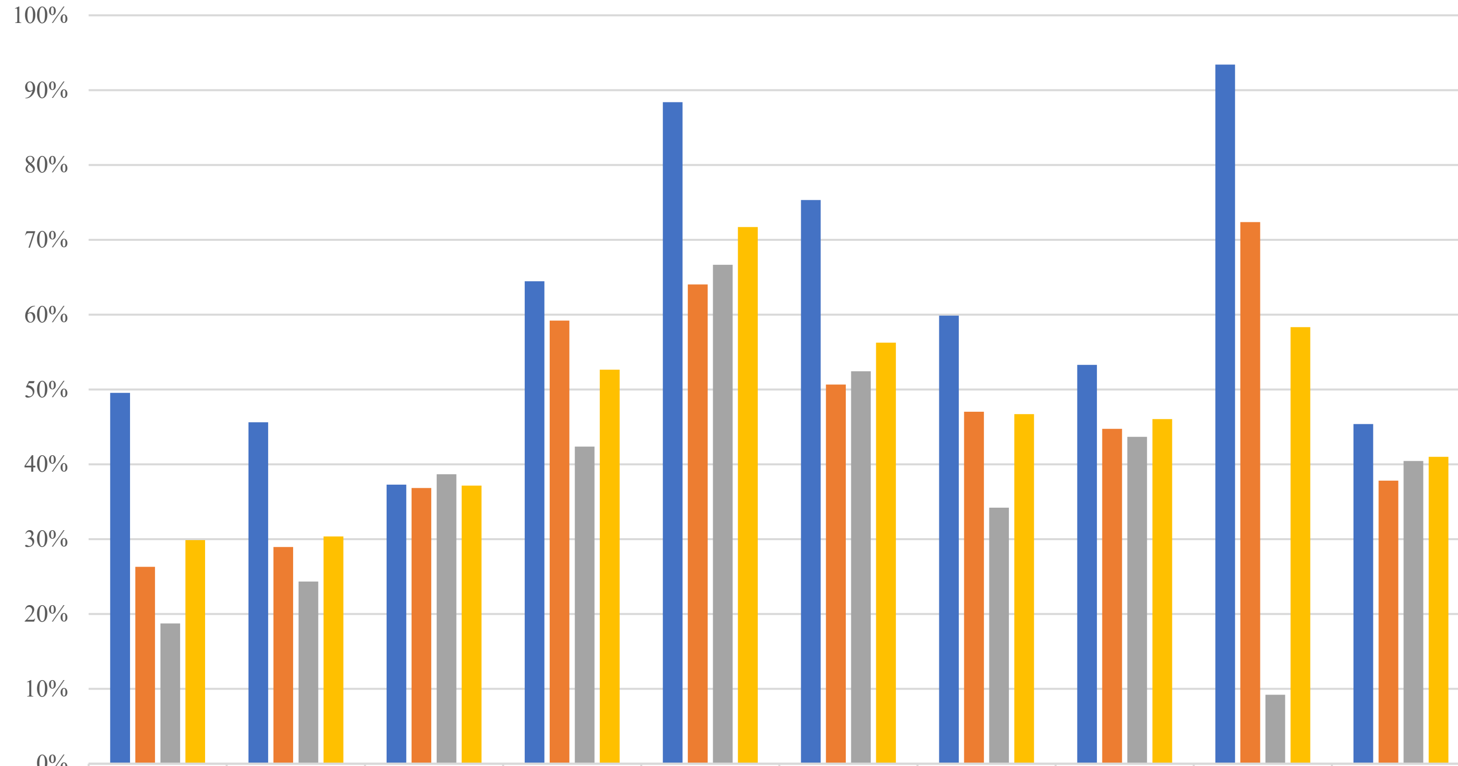
When categorized by crew, workers’ total score, the proportion of incidents, causes, and practices identified increased compared to the results of baseline assessment. However, no increase was shown in the results for crew 4,6 and 12 as shown in figure (4.10). In addition, because crew 8 did not participate in the baseline assessment, change in the results cannot be detected since no baseline knowledge level was established.

When categorized by maintenance operation, the results show increase in workers' total score, the proportion of incidents, causes, and practices identified. The improvement in workers scores was detected in seven maintenance operations including "Equipment Maintenance", "Litter and debris removal", "Mowing", "Pipe and Drain Maintenance", "Road and Shoulder repairs", "Signs Maintenance", and "Tree trimming" as shown in figure (4.11). However, no significant improvement was found in workers total score in "Concrete & Bridge Maintenance", "Guardrail Maintenance", and "Snow removal" operations.



	1	2	3	4	5	6	7	8	9	10	11	12	13
Identified Hazards	72.6%	50.4%	56.3%	52.1%	57.3%	40.6%	57.7%	24.2%	56.7%	65.2%	63.1%	40.6%	60.4%
Identified Causes	58.6%	43.3%	40.5%	29.5%	42.9%	23.8%	45.3%	10.7%	49.0%	55.7%	56.3%	29.5%	42.4%
Identified Preventions	56.5%	37.4%	29.3%	42.3%	40.7%	25.2%	40.4%	7.9%	44.9%	47.6%	48.8%	21.1%	35.8%
Total Score	61.6%	42.6%	40.7%	39.5%	46.3%	29.2%	46.7%	13.7%	48.5%	55.1%	55.3%	29.6%	44.7%

Figure 4.10 Post-use workers assessment scores sorted by crew



	Concrete & Bridge Repair	Equipment Maint.	Guardrail Maint.	Litter and Debris removal	Mowing	Pipe & Drain Maint.	Road & Shoulder repair	Signs Maint.	Snow Removal	Tree trimming
Identified Hazards	49.6%	45.6%	37.3%	64.5%	88.4%	75.3%	59.9%	53.3%	93.4%	45.4%
Identified Causes	26.3%	28.9%	36.8%	59.2%	64.0%	50.7%	47.0%	44.7%	72.4%	37.8%
Identified Preventions	18.8%	24.3%	38.7%	42.4%	66.7%	52.4%	34.2%	43.7%	9.2%	40.5%
Total Score	29.9%	30.4%	37.2%	52.6%	71.7%	56.3%	46.7%	46.1%	58.3%	41.0%

Figure 4.11 Post-use workers assessment scores sorted by maintenance operation

4.6.3 Logistic regression analysis results

In order to make a conclusion about the effectiveness of the pre-task safety talks in improving maintenance workers safety knowledge, four logistic regression models with mixed effects were fitted to examine the effect of toolbox safety talks on workers total score, incidents identification score, causes identification score, and prevention identification score. After blocking by crew and subject and controlling for maintenance operation and the interaction effects, the results show a positive statistically significant effects for the toolbox talks on workers total score ($F=373.94$, $P< 0.0001$), incidents identification score ($F=71.62$, $P< 0.0001$), incidents causes identification score ($F=105.21$, $P< 0.0001$), and preventions identification score ($F=207.76$, $P< 0.0001$). When sliced by maintenance operation, the analysis results show that the highest effect magnitude of the safety talks on workers total score was in the "Mowing" operation with (0.411) change in the average mean of total score. Similarly, the magnitude of the safety talks effects on workers scores in causes and prevention identification were the highest in the "Mowing" operation with (0.441) change in causes identification score and (0.456) change in prevention identification score. However, the magnitude of safety talks effects on incidents identification score was the highest in the "Litter and Debris removal" operation with (0.445) change in the average incidents' identification score.

The results of the four logistic regression models show significant effects for maintenance operations on workers total score ($F=75.73$, $P< 0.0001$), incidents identification score ($F=24.06$, $P< 0.0001$), causes identification score ($F=21.65$, $P< 0.0001$), and prevention identification score ($F=27.14$, $P< 0.0001$). In addition, the results show significant interaction effects between the intervention (safety talks) and maintenance operations on workers scores in incidents identification ($F=3.67$, $P= 0.0012$), causes identification ($F=4.88$, $P< 0.0001$), and preventions identification ($F=5.56$, $P< 0.0001$). The overall interaction effects on workers total score was also significant ($F=10.8$, $P< 0.0001$). It is worth noting that blocking by subject and crew helped in controlling and accounting for any heterogeneity among workers and random effects that could stem from workers experience or previous training.

4.6.4 Reaction assessment results

Reaction assessment questions were designed for supervisors as the users of the safety toolbox. Supervisors were asked to rate the toolbox, indicate their desire to continue the safety talks program, and report any areas of potential improvement in the toolbox. As the toolbox was delivered in two formats (hardcopy and electronic copy), 18 supervisors reported that they only used the hardcopy of the toolbox, 5 supervisors used only the electronic copy, and only one supervisor used both copies. When asked to rate the overall performance of the toolbox, 12 supervisors gave the toolbox "Good" rating, 8 supervisors reported "Fair" rating, 3 supervisors reported "Excellent" rating, and one supervisors rated the toolbox performance as "Poor". On a scale of 0 to 10, supervisors gave the toolbox an average rating of (5.8/10) in addressing common safety issues in maintenance work. In addition, 50% of supervisors indicated that they would like to continue using the toolbox while the other 50% indicated the opposite. Finally, 14 supervisors stated that the toolbox was a help to their work while 9 supervisors stated that using the toolbox was a hinderance.

Reaction questions were designed for workers as the receivers of safety talks. Workers were asked to rate the overall pre-task safety talks experience, indicate their desire to continue the program, and rate the effect of the safety talks on their skills in identifying hazards, causes, and prevention practices in the workplace. 59.5% of workers indicated that they would like to continue the pre-task safety talks while 40.5% indicated the opposite. On a scale of 0 to 10, workers rated the overall safety talks experience with a rating average of (6.96/10). Table (4.6) shows the results of workers reaction assessment with respect to the effect of safety talks on their skills and safety knowledge.

Table 4.6 Workers reaction results

Question	**Rating frequency**		
How helpful were the safety talks to you in the following areas?	Not helpful	Somewhat helpful	Very helpful
1- Recognizing work safety hazards	4	17	56
2- Identifying incidents causes	4	23	50
3- Knowing what to do to avoid work incidents	3	18	56
4- Get the job done safely	3	18	56

4.6.5 Results of qualitative data analysis

Participants answers to the interview questions were transcribed and coded according to the interview structure. Participants experience in maintenance work ranged between 6 to 25 years. All participants hold supervisors title except three who hold supervisor assistant title. Five participants reported that they did not use the toolbox, and 10 participants reported a delivery of at least one safety talk using the toolbox. All participants had the chance to review the content of the toolbox except one.

After coding participants answers into the four main areas of reaction, relevance, strengths and weaknesses, and barriers, a word frequency was generated using NVivo software. Data was recoded based on more specific terms that emerged from the word frequency query. The word frequency helped in identifying the following three underlying barriers frequently reported in participant answers:

- Time limits (n=11)
- Lack of man power (n=10)
- Irrelevance (n=4)

Time limits and lack of man power were intercorrelated barriers as most supervisors (n=9) attributed the lack of time to conduct a safety talk to the lack of man power and the urgency of work. One supervisor stated: *"Beyond the pressure to do this and that, when you have a crew of less than ten people doing about 15 maintenance operations across the county, you don't have time to study this binder and give safety briefings."*

Another supervisor stated: *"We don't have time keeper, I spend the first hour of my morning filling forms and doing administrative work. I have to send my assistant with crew and catch up later. Not much time available for safety talks. I would love to have enough crew to assign one of my assistants to give daily safety briefings"*

Three participants who did not use the toolbox in addition to one who used the toolbox indicated that the toolbox is irrelevant to their work. In addition, most of supervisors who conducted safety talks indicated that the toolbox content can be very helpful to "New hires" but may not offer significant help to experienced workers. One supervisor assistant stated:

"*This binder could be used to train new hires, but it honestly doesn't offer much to experienced crews. Most of my crew are experienced and know what they are doing. They are familiar with most of the stuff*".

Supervisors who used the toolbox reported a positive reaction on the toolbox. Phrases like "Good" and "It does the job", were frequently cited in supervisors' comments. Two aspects of the toolbox were frequently cited as strengths and were associated with the positive reaction comments. The first aspect is the inclusion of photographs to explain safety practices in the toolbox. One supervisor stated that *"It is a bit easy to demonstrate what is the power zone using the picture than using only your words. It is easier to grasp and make it less boring"*.

The second aspect that was associated with the positive reaction comments was the inclusion of narrative brief examples from previous data. One supervisor commented *"Examples and stories included from coworkers' injuries made the crew pay more attention"*

When asked to identify the weaknesses in the toolbox, supervisors did not point out any specific weakness. Instead, they provide suggestions to improve the toolbox content. Two suggestions were frequently cited in supervisors' comments including "More pictures" (8) and "More videos" (6), which is consistent with their positive reaction to the photographic demonstration of some safety prevention practices.

4.7 Discussion

The results of baseline safety knowledge assessment demonstrated a limited safety knowledge with limited hazards identification skills for highway maintenance crews. In addition, the results showed that although some crews were able to identify some potential incidents and workplace hazards, their ability to suggest the appropriate prevention controls was very limited. Failure to identify hazards indicates a lack of safety knowledge and information, which often occurs due to lack of resources, lack of information sharing, and reliance on tacit knowledge (Carter and Smith 2006). Therefore, the results of baseline assessment suggest two important explanations. First, participants failure to identify workplace safety hazards might stem from their reliance on tacit knowledge that often comes from their experience. This was evident by supervisors' feedback as some of them justified not conducting safety talks due to their familiarity with the toolbox content and their experience in their work. The second explanation is that the limited skills of maintenance crews to identify the appropriate prevention controls may be attributed to the lack of safety resources available for highway maintenance workers, which supports the main argument of this study. In addition, the results of baseline assessment suggest that the high rate of recordable incident claims associated with highway maintenance crews could be attributed to the lack of safety knowledge as the latter represents the first root cause of work incidents in the construction industry (Abdelhamid and Everett 2000).

Measurable improvements in safety knowledge and skills of maintenance crews were demonstrated after three months of introducing the toolbox with 22.1% increase in workers' total score, 23.1% in incidents identification, 22.9% in hazards (causes) identification, and 21.5% in prevention identification score. Conducting pre-task toolbox talks improved participant safety knowledge and skills in identifying work specific safety incidents, hazards, and prevention practices. In addition, the results demonstrated that the pre-task safety talks led to a significant improvement in participants awareness of the frequent work incidents and hazards present in highway maintenance work. This improved awareness was evident in the results of post-use assessment where supervisors demonstrated a significant improvement in prioritizing frequent injuries and incidents' causes in accordance with what has been found in the safety records. Developing such awareness is critical for workers and supervisors to conduct risk assessments as the latter require them to categorize hazards and assign frequency (Hadikusumo and Rowlinson 2004). In addition, the introduction of explicit knowledge in the form of safety talks and making the toolbox available as a resource to conduct safety briefings improved participants skills in identifying the appropriate prevention practices. The effectiveness of toolbox talks in improving participants' safety knowledge is consistent with what has been reported by previous studies (Eggerth et al. 2018; Harrington et al. 2009; Kaskutas et al. 2016; Olson et al. 2016).

The results of reaction and knowledge assessments indicated that the inclusion of examples from the records and simple photographic demonstration of prevention practices can be useful to engage workers in safety talks, improve the learning process, and conduct effective toolbox talks. Such results are consistent with what has been found in the literature. The inclusion of narratives, such as examples from the records, has been reported to increase knowledge gain in safety toolbox talks (Eggerth et al. 2018). One possible explanations for the positive effects of narratives on participants learning stems from the concept of engagement in the learning process and the concept of relevance found in the Elaboration Likelihood Model (ELM) (Petty and Cacioppo 1986). In the ELM model, Petty (2018) suggested that as message relevance increases, its impact increases because people motivation to process the relevant arguments increases. People engagement increases as the presented issue relevance increases. Consequently, increased engagement improves the learning process and the effectiveness of safety toolbox talks (Burke et al. 2006; Petty 2018). Another explanation for the positive effects of including examples from the records is the positive influence of stimulating the workplace in safety talks. Prasad et al. (2018) stated that commonalities between the training content and the workplace positively impact the transfer of the training.

Although participants showed both positive safety climate and positive reaction to the toolbox and safety talks, considerable proportion of supervisors (50%) and workers (40.5%) indicated their desire to stop using the toolbox. This could be an indication of the lack of motivation to learn from the available resources, such as the toolbox (Kirkpatrick and Kirkpatrick 2006). Causes cited included familiarity with the toolbox content as well as environmental barriers, such as work pressure and lack of and manpower. Familiarity with the toolbox content indicates participants reliance on their tacit knowledge that often comes from experience as supervisors cited in the interview. Tacit knowledge is important factor in hazards identification. However, since only experienced workers and supervisors hold relevant tacit knowledge, there needs to be a process to capture and share this knowledge across the organization (Hadikusumo and Rowlinson 2004). Work pressure and lack of man power were cited to cause a lack of time to conduct safety talks. Prioritizing work over safety is an indication of poor communication of management goals and commitment to safety.

4.8 Conclusion

The use of safety toolbox talks is a common practice in the construction industry. Because such interventions proved to be useful for the safety of construction workers, they can be utilized in the highway maintenance sector to improve safety awareness among highway maintenance crews. Evaluating the effectiveness of toolbox talks is an essential step to examine their impact on workers safety performance and identify any areas of potential improvements.

Like evaluating the effectiveness of safety training programs, evaluating the effectiveness of toolbox talks start with the assessment of the short-term results. This chapter presents the evaluation of reaction and attitudes of participants towards the toolbox and the pre-task safety talks. In addition, participants knowledge gain was evaluated to determine the effectiveness of the task-specific safety talks on safety awareness among highway maintenance crews. The results demonstrated that pre-task toolbox talks can significantly increase workers safety awareness and improve their hazards identification skills. In addition, the improvement witnessed in participants knowledge with respect to identifying the appropriate safety preventions and controls suggest that a safety toolbox tailored to specific highway maintenance operations is an effective resource for supervisors to conduct effective safety briefings.

In addition to evaluating the effectiveness of the toolbox, the assessment of short-term results helped in identifying the underlying barriers that hinder or prevent the implementation of pre-task safety talks in the highway maintenance work. This will help developers to improve the quality of the toolbox and helps the DOTs to address the barriers that could reduce the effectiveness of safety toolbox interventions.

5 PROCESS EVALUATION

5.1 Introduction

Safety training developers and evaluators often emphasize the evaluation of short- and long-term outcomes to evaluate the effectiveness of safety training and education programs. While it is important to evaluate such outcomes, evaluators often miss an important aspect of the evaluation that could reveal what hinders the programs' effectiveness and provide essential information to improve the program and increase its effectiveness. Formative evaluation, often called process evaluation, is an important integrated part of the systematic evaluation process of health and safety training and education programs. Although process evaluation was overlooked by evaluators in the past, its complexity has grown as its utility and importance have increasingly been recognized. It is a critical part of the evaluation process that is used to monitor and document the implementation of the training and education programs to understand the relationship and interaction between the program components and outcomes (Ruth et al. 2005). It is not enough to understand whether a program was effective or not. Understanding why a program was successful while others are not and what features distinguish effective programs is equally important to outcomes evaluation (Steckler and Linnan 2002). Identifying and documenting the features or elements associated with success and the barriers that hinder the intended effects during the implementation of safety programs is an essential concept to improve current programs and guide future efforts. Formative evaluation is a core element in the process of identifying such features (Steckler and Linnan 2002). In the literature of occupational safety and health training, formative evaluation studies systematically document how an intervention was carried out. Weak, incomplete, or inconsistent implementation are common issues in occupational health and safety training and education. Therefore, it is not recommended to conduct intensive and time-consuming studies to evaluate the outcomes before ensuring that the implementation procedures were sufficient and properly carried out (Goldenhar et al. 2001)

Although toolbox meeting programs are popular form of safety intervention in the construction industry, they did not receive significant attention in empirical evaluation studies (Jeschke et al. 2017). According to Olson et al. (2016), among seven studies that dealt with toolbox meeting programs found in the literature, only one (Harrington et al. 2009) evaluated the effectiveness of the intended program, which was focused on the quality and frequency of toolbox meetings. The most recent study that addressed process evaluation of safety toolbox meeting programs was conducted by Jeschke et al. (2017). In this study, the authors evaluated the implementation and short-term outcomes of a safety toolbox training program developed for construction foremen in Denmark. The authors also emphasized how minimal are the evaluation studies associated with toolbox training. It is evident from the literature that there is a lack of comprehensive systematic evaluation of occupational safety interventions in the context of construction industry.

As a part of evaluating the effectiveness of the safety toolbox, this chapter presents the implementation evaluation of the toolbox. Following a frequently used model of formative evaluation introduced by Ruth et al. (2005), the implementation of the toolbox was monitored and documented throughout the three months pilot implementation period. Data were collected and evaluated on six implementation dimensions including recruitment procedures, toolbox reach, toolbox delivery, implementation fidelity, contextual factors, and participants satisfaction. Based on the results of the formative evaluation and the feedback from stakeholders, necessary modifications will be implemented to improve the program effectiveness.

5.2 Literature review

The main purpose of process evaluation is to monitor and document the implementation of safety programs to understand the relationship between the program elements and outcomes. Understanding this relationship helps to explain why specific results were achieved (Steckler and Linnan 2002). Formative evaluation also helps to identify the contextual different factors that facilitate or hinder the implementation of the program. Moreover, it allows two ways communication that often help to address the program's shortcomings and improve its results. One of the widely recognized advantages of process evaluation is that it prevents what is called Type III error in health education studies (Steckler and Linnan 2002). To put that in perspective, Type I error occurs when rejecting a null hypothesis that it is true while Type II error occurs when failing to reject a null hypothesis that it is false. In this sense, Type III error arise from "evaluating a program that has not been adequately implemented" (Charles et al. 1985). In other words, process evaluation enables training developers and evaluators to avoid drawing erroneous conclusions about the effectiveness of their programs based on outcomes' evaluation while the implementation procedures may not be carried out as intended. As a result, a program may not be discarded or discontinued due to failure in results when the evaluators found implementation factors that hinder the achievement of desired results. Based on that, before asking whether the program works or not, the first question that should be answered is: was the program implemented as intended? If there is a variation between the planned and actual implementation, it should be described to explain how this variation could affect the desired results.

5.3 Objectives

The primary objective of this phase of the evaluation is to evaluate the process of implementing the designed safety toolbox talks. This evaluation was conducted to ensure that the toolbox talks were implemented as intended. It was also conducted to improve the toolbox and identify potential barriers and shortcomings. Working toward the fulfillment of the primary objective, the following supportive objectives are addressed in this phase:

1- Documenting recruitment procedures used to recruit participants for the program;
2- Measuring the delivery (dose-delivered and dose-received) of the toolbox;
3- Examining the extent to which the program will be implemented as planned; and
4- Identifying the potential barriers that hinder the program implementation.

5.4 Methods

5.4.1 The process evaluation model design

Process evaluation varies in complexity and extent according the complexity of training and education programs. It could include different aspects, such as recruitment, maintenance, context, resources , reach, barriers, exposure, initial use, continued use, and contamination (Tom and Gloria 2000). The use of these elements in health education studies depends on the complexity of the program. In the context of occupational safety and health in construction, researchers often use the six elements that are used in this project to evaluate the implementation of safety training programs. The process evaluation model that is used in this project is based on a framework introduced by Ruth et al. (2005) that is based on previous work of Tom and Gloria (2000) and Steckler and Linnan (2002). The model uses the following six elements to evaluation the implementation of the toolbox talks:

- Fidelity (quality): the extent to which the program was implemented as planned or as intended. Supervisors in this study were trained to use the toolbox to conduct pre-task safety talks. The pre-task safety talks are intended to be practiced at least twice a week for the entire three months implementation period. This usage was built upon the assumption that KYTC maintenance crews in district X are engaged in maintenance work five days per week. Supervisors were directed to conduct the safety talks in an engaging way. They were directed to ask questions and use role-playing and demonstration strategies available in the toolbox to engage workers in safety talks other than delivering the talks as quick lectures.

- Recruitment: the procedures and resources used to recruit participants to take part in the pilot implementation.

- Reach: the proportion of primary participants in the program that is often measured by attendance. Participants in this pilot implementation included maintenance superintendents as users of the toolbox and maintenance workers as receivers of the safety talks.

- Delivery: there are two components of delivery: dose-delivered (completeness), which represents the number of units provided in the program, and dose-received (exposure), which represents the extent to which participants received the content of the program. In this project, the dose-delivered is the safety training within the ten selected maintenance operations that are included in the toolbox. Dose-received represents the proportion of participants who participated in safety talks delivered within each operations during the pilot implementation period.

- Satisfaction: participants' reaction and attitudes toward the program and instructors.
- Context: environmental factors that may work as barriers or facilitators to the program implementation. For example, work pressure would be a potential barrier to implement the program as intended.

5.4.2 Data Collection

To conduct the process evaluation, different data collection procedures were utilized according to the type of data needed for each of the six evaluation elements. Below are the details of data collection techniques that were used for each element:

- Participants satisfaction: To measure participants satisfaction, data were collected from supervisors through reaction questionnaires included in the post-use interview after three months of using the toolbox. Since supervisors were not the only participants in this program, maintenance workers also provided their feedback through questionnaires of reaction evaluation in the post-use knowledge assessment.
- Recruitment and reach: recruitment resources and procedures used to attract participants were documented accordingly throughout the pilot implementation time period. Through KYTC administration and safety coordinator and staff in district X, maintenance employees and supervisors were informed about the participation in the program. After obtaining permission to meet with superintendents, an orientation was held to train supervisors on the use of toolbox.
- Program delivery: the toolbox delivery was measured for supervisors while safety talks delivery was measured for workers. Completeness of the program (dose-delivered) was already defined as the available safety training that covers the ten maintenance operations included in the toolbox. The exposure (dose-received) was recorded by supervisors in the field notes handout shown in Figure (5.1).

The first section of the handout addressed the exposure where superintendents can record the time, date, number of participants in the safety talks, and the intended work operation. Exposure data were also confirmed with what was reported in the workers post training reaction assessment where workers were asked to report the number of safety talks held per week.

Field notes of today's safety talk

No. of Participants in today's talk: _ _ _ _ _ _ _ _ _ _ _ _ _ _

Time: _ _ _ _ _, Date: _ _ _ _ _ _ _ _ _, Location: _

Today's maintenance work (Please circle)				
1. Concrete repair & bridge maintenance	**2.** Equipment maintenance	**3.** Guardrail maintenance	**4.** Litter and debris removal	**5.** Mowing
6. Pipe/Drain clearing & replacement	**7.** Road & shoulder repairs	**8.** Sign inventory & replacement	**9.** Snow Removal	**10.** Tree & brush trimming

1- Did you present today's safety talk in the same order (flow) found in the toolbox?	Yes	No
2- Did you tell examples about previous incidents from the toolbox?	Yes	No
3- Did you ask workers to demonstrate some safe techniques (i.e. power zones lifting, escape area in tree trimming, etc.) during the talk?	Yes	No
4- Did workers ask questions during or after the safety talk?	Yes	No
5- Did workers participate in any way to the safety talk?	Yes	No
6- Did you ask workers questions during or after the safety talk?	Yes	No
7- Did you encourage workers to participate or ask questions?	Yes	No
8- Did you find any difficulty in using the toolbox?	Yes	No
9- Do you think the toolbox content is relevant to today's work task?	Yes	No
10- How many crew members are assigned to today's maintenance work?		

11- What are the things that help or obstruct you while preparing and presenting today's safety talk?

- Toolbox content
- Urgency of work
- Short time available
- Work schedule pressure
- Place of safety talk
- Other: ____________________

12- Do you have any suggestion to improve the section of toolbox you talked about today?

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Figure 5.1 Implementation fieldnote form

- Fidelity: Supervisors were trained twice, in group and individually, on the use of toolbox and the preparation for safety talks. They were instructed to focus on three main goals while preparing and presenting safety talks. The first goal is to engage workers in safety talks by using different engagement techniques, such as role-playing, asking questions, etc. The second goal is to tell stories of previous incidents of KYTC maintenance crews using examples from the toolbox. The third goal is to allow feedback from participants and address their questions and concerns. Data on the program fidelity was collected using the field notes handout shown in figure (5.1). To account for the self-reporting bias that could arise from supervisors filling the handout, fidelity questions were included in the workers reaction assessment to confirm what was reported in the fieldnotes.

- Context: Data on contextual or environmental factors that could hinder or improve the implementation and effects of the safety talks were collected through the post-use interview with superintendents as well as the fieldnotes form shown in figure (5.1). Supervisors were asked in the fieldnote form (question 8,9, 11, and 12) to report any difficulty or potential barriers that hindered the preparation and presentation of safety talks. They were also asked to indicate the relevance of the toolbox to their typical maintenance work and to provide suggestions, if any, to improvement the toolbox. What was reported in the fieldnotes form helped in formulating the post-use interview questions.

5.5 Results and discussion

The results of the implementation evaluation will be presented and discussed in light of the evaluation objectives.

<u>Recruitment and reach</u>: By cooperating with KYTC safety personnel and district X administration, 150 maintenance employees, supervisors and workers, were invited to participate in the pilot implementation of the toolbox. 30 supervisors were invited to be trained on the use of toolbox to conduct safety talks. Only 16 supervisors attended the introductory training orientation. However, all supervisors were trained individually by the

researcher on the use of the toolbox and were provided with a hardcopy and electronic copy of the toolbox. Therefore, the reach of toolbox to supervisors was 100%.

The reach for workers was calculated based on the number of workers who participated in the study. Out of the 120 workers invited to participate in the study, only 76 workers agreed to participate. Therefore, the reach of the toolbox was 63.3%. It is worth noting that the reach might be more than 63.3% since some of the workers who did not agree to participate were part of the crews who conducted pre-task safety talks. However, data was not available to calculate the additional reach based on the actual number of workers who participated in the safety talks. Therefore, a conservative number was used to calculate the reach.

Delivery: Since every supervisor in the study received two copies of the toolbox and at least a training session on the use of toolbox, the completeness (dose-delivered) and exposure of the toolbox for supervisors were 100%. The delivery of the toolbox for workers was measured differently since workers are the receivers (not users) of the toolbox talks. Because the toolbox included 10 maintenance operations, the completeness (dose-delivered) for workers was calculated based on the number of safety talks conducted in each operation. For example, if at least one safety talk was conducted in "Road and shoulder repairs" operation for crew 5, the dose-delivered for this crew in this operation was given 100%. Exposure (dose-received) was calculated based on proportion of workers participated in a safety talk divided by the total number of workers in the crew. The results of completeness and exposure varied among crews and operations. Four crews (4,6,8,12) did not receive any safety talk. Safety talks were not given in three maintenance operations including "Concrete and Bridge maintenance", "Guardrail Maintenance", and "Snow removal". Therefore, the completeness and exposure in the aforementioned crews and operations were given 0%. Table (5.1) shows the results of delivery for workers within the remaining crews and operations. The letters C in table (5.1) stands for completeness (dose-delivered), and E stands for exposure (dose-received). The results show that the completeness of safety talks was not achieved for all crews except in "Pipe and Drain Maintenance" operation. However, high dose-delivered was achieved in "Mowing", "Road and Shoulder repairs", and "Tree trimming" operations. High exposure was observed in three crews including crew 1, 2, and 13 and three operations including “Mowing”, “Pipe and Drain Maintenance”, and “Road and Shoulder repairs”.

Table 5.1 Results of safety talks delivery for workers

Crew	Delivery by operation (%)													
	Equipment Maint.		Debris removal		Mowing		Pipe & drain		Roadway & Shoulder		Signs Maint.		Tree trimming	
	C	E	C	E	C	E	C	E	C	E	C	E	C	E
1	100	78	0	0	100	100	100	89	100	89	100	89	100	67
2	100	100	100	63	100	63	100	75	100	100	0	0	100	50
3	0	0	0	0	0	0	100	90	100	80	0	0	100	80
5	0	0	0	0	100	44	100	100	100	100	0	0	0	0
7	0	0	0	0	100	50	100	63	100	63	100	13	100	50
9	0	0	100	70	100	90	100	90	0	0	0	0	0	0
10	0	0	0	0	100	56	100	78	100	67	100	22	100	67
11	100	100	0	0	0	0	100	100	100	90	0	0	0	0
13	100	100	0	0	100	100	100	100	100	100	0	0	100	100

Fidelity: The quality of safety talks was assessed using the first seven questions in the fieldnote form. The questions were designed to assess the use of narratives, role-playing, and questions during the safety talks. The results of the fidelity assessment are shown in Table (5.2).

Table 5.2 Implementation fidelity results

Question	**Yes**	**No**
1- Did you present today’s safety talk in the same order (flow) found in the toolbox?	0.82	0.18
2- Did you tell examples about previous incidents from the toolbox?	0.76	0.24
3- Did you ask workers to demonstrate some safe techniques (i.e. power zones lifting, escape area in tree trimming, etc.) during the talk?	0.34	0.66
4- Did workers ask questions during or after the safety talk?	0.27	0.73
5- Did workers participate in any way to the safety talk?	0.54	0.46
6- Did you ask workers questions during or after the safety talk?	0.59	0.41
7- Did you encourage workers to participate or ask questions?	0.73	0.27

Although the majority of supervisors (76%) utilized narratives during their safety talks, only 34% used role-playing to engage workers in the safety talk. In addition, only 27% of supervisors reported that workers asked questions during the safety talks. Moreover, although 73% of supervisors indicated that they encouraged workers to participate or ask questions during the safety talks, only 54% of supervisors reported that workers participated in the safety talks. These results indicate that the safety talks were presented as lectures with one way communication and low engagement. Passive lecturing in safety training is the least engaging, and thus least effective, form of safety training (Burke et al. 2006). When the results were contrasted with what has been reported by workers, workers reported a better level of engagement with 59% of them indicated that they asked and were asked questions during the safety talks. In addition, 66% of workers reported that they were asked by supervisors to demonstrate safety practices during the safety talks.

Although a low level of engagement was reported by supervisors, the results obtained from workers combined with the improvement in workers safety knowledge indicate that the safety talks were delivered with high fidelity.

Satisfaction: workers satisfaction was assessed during the reaction assessment in chapter 4. The results showed a positive reaction to the toolbox safety talks with an average rating of (6.96/10) by workers. 73% of workers reported that the toolbox talks were very helpful in recognizing workplace hazards, identifying risk controls, and getting the job done safely. In addition, 65% of workers indicated that the toolbox talks were very helpful in identifying incidents causes. 59.5% of workers indicated that they would like to continue the pre-task safety talks.

Supervisors reaction to the toolbox was fairly positive. They gave the toolbox an average rating of (5.8/10) in addressing common safety issues in maintenance work. 50% of supervisors gave the overall performance of the toolbox “Good” rating, 33.5% gave it “Fair” rating, and 12.5% reported “Excellent” performance. However, only 50% of supervisors indicated that they would like to continue using the toolbox.

The results indicate an average positive reaction. However, there is also a clear attitude by significant number of workers and supervisors to stop using the toolbox, which indicates a lack of motivation that is often associated with negative reaction. Kirkpatrick and Kirkpatrick (2006) stated that negative reactions to the training program result in lack of motivation to learn. In addition, Jeschke et al. (2017) found that participants' lack of satisfaction is a contextual factor that can hinder the implementation and reduce the effects of toolbox training. Therefore, participants were interviewed after the pilot implementation to examine their feedback in detail.

Context: In the fieldnote form, supervisors were asked to indicate the relevance of the toolbox to highway maintenance work, report any difficulty or barrier that hindered the preparation and presentation of safety talks, and provide suggestions, if any, to improve the toolbox. The majority of supervisors (96%) indicated that they did not find any difficulty using the toolbox. However, 50% indicated that the toolbox content is not relevant to the specific maintenance operation. Supervisors identified four barriers that hinder or prevent the conduction of toolbox including toolbox content (n=14), short time available (n=9), work schedule pressure (n=6), and urgency of work (n=6). The reported barriers were utilized in designing the post-training interview questions.

The results of the interview were consistent with what has been reported in the fieldnotes and revealed more details about the underlying causes that prevented supervisors from conducting safety talks. Supervisors indicated that due to the shortage in manpower and the continuous workload pressure, they did not have enough time to conduct safety talks two times a week. One supervisor stated "*As you can see*, *we are small size* cr*ew. We come here every morning to pick our tools and equipment and go to work right away. No time to do any of that* [referring to safety talks] *if I have time, I would use it to take care of the paperwork aggregated in my office"*.

In addition to time and work pressure, supervisors indicated that the toolbox content is long and needs to be shortened. Although there was a positive reaction among supervisors on the use of narratives, they suggested using bullets for long text and including more photographic and videographic demonstration instead of text. One supervisor commented "*What would make better use of this tool is more pictures, more videos, and less dialogue. Stories of coworkers accidents is a great way to make the crew pay attention, but with the short time available, short and visual is better".*

The results of context assessment are consistent with what has been found in the literature. Berthelette et al. (2012) found that heavy workload due to shortage of manpower reduces the availability of workers to participate in training programs. Harrington et al. (2009) found that limited time to conduct toolbox talks was the most frequent barrier cited by supervisors. The results of the overall implementation evaluation showed that although the program did not reach all participants and was not delivered in all operations, it was implemented in acceptable quality compared to the implementation plan. The improvement in participants safety awareness associated with the toolbox talks is another indication of the quality of implementation.

5.6 Conclusion

Evaluation of safety training interventions is often conducted to improve the interventions and to ensure their effectiveness. Most of evaluation studies judge the effectiveness of safety interventions based on summative evaluation methods used to evaluate the change in results associated with the intervention, such as the change in knowledge, behavior, injury rates, etc. However, minimal attention was directed towards formative evaluation (Berthelette et al. 2012). Evaluating how a safety program/intervention was implemented is equally important to the evaluation of the effectiveness of the program in changing the outcomes.

In this chapter, we evaluated the implementation of a toolbox safety talks intervention that was used to improve safety awareness among highway maintenance crews. A formative evaluation model introduced by Ruth et al. (2005) was adopted to evaluate the implementation process. The model was used to assess six implementation dimensions including recruitment procedures, intervention reach, intervention delivery, implementation fidelity, participants satisfaction, and implementation context. The evaluation results provide informative examination of the implementation process and uncovered the environmental factors that prevent or hinder the implementation of the intervention as planned. The main contribution of this evaluation phase is that it provided useful information to improve the quality and effectiveness of the toolbox and smooth the conduction of pre-task safety talks.

6 BEHAVIOR CHANGE EVALUATION

6.1 Introduction

Safety incidents occur when workers fail to identify unsafe conditions or decide to take unsafe actions even when they have the knowledge of existing unsafe conditions (Abdelhamid and Everett 2000). Failure to identify and recognize unsafe conditions has been identified as a major reason in the failure of Behavior-Based Safety (BBS) management, one of the most effective techniques to improve safety (Carter and Smith 2006; Furnham 1994; Lingard and Rowlinson 1997). Failure to identify unsafe condition often indicates a lack of knowledge. As a result, every year, organizations allocate considerable amount of resources to train their workers and employees to improve their safety awareness. One of the main objectives of occupational safety and health training programs is to increase workers' safety knowledge. Learning is a core element of these programs. Safety practitioners and researchers often focus on providing the required safety knowledge when developing such programs because knowledge is the prerequisite for the desired behavior (Kirkpatrick and Kirkpatrick 2006). Therefore, researchers and evaluators focus on assessing knowledge acquisition (learning) when they evaluate safety interventions. However, gaining the required safety knowledge and skills does not ensure the transfer of the training content to the workplace. In other words, knowledge acquisition from training and education programs may not be reflected as safe behaviors on the workplace. Research show that more than 80% of the knowledge and skills gained from training programs are not applied in the workplace (Brinkerhoff 2006; Broad and Newstrom 1992; Noorizan et al. 2016; Patterson 2009). There are different factors that could prevent or impede the transfer of training content to the workplace, such as work pressure, communication and coordination, etc. (Burke et al. 2003). Therefore, it is important to evaluate behavior change to ensure that the training content has transferred to the work field. Another aspect that makes behavior evaluation a critical factor in occupational safety and health studies is the association between unsafe behavior and injury records. Unsafe behavior has been reported as a valid proxy of injury and "the best predictor of accidents/near misses as measured by self-report data" (Mearns et al. 2001). Studies and reviews of injury records showed that unsafe actions are associated with most injuries (Cavazza and Serpe 2010; Hinze 2002). As a result, evaluating behavior change not only assess the transfer of safety knowledge to the workplace, but also provide an indication of the future safety performance.

Although safety training and education programs are common practices in the construction industry, the lack of full comprehensive evaluation for such programs is evident in the literature. One of the frequently missed components in evaluation studies is the behavior evaluation. Researchers evaluate implementation and/or short-term results to examine the effectiveness of safety interventions, but they often overlook the safety behavior evaluation. This gap is apparent when it comes to pre-task safety initiatives that are common interventions in the construction industry. Evaluation studies that specifically addressed toolbox safety interventions, such as Harrington et al. (2009), Olson et al. (2016), and Jeschke et al. (2017), were limited to implementation and short-term results evaluation. The same gap was detected among these studies where the evaluation was limited to reaction, attitudes, knowledge gain, and/or implementation but did not address the behavioral change. The few studies conducted to evaluate the effect of safety interventions on workers' safety behavior used self-reported data (Gilkey et al. 2003; Kerr et al. 2007; Lingard 2002; Lusk et al. 1999; Neitzel et al. 2008; Seixas et al. 2011). Self-reported data is a continuing debate point in behavior analysis studies due to the bias associated with the data collection approach. In addition, none of these studies evaluated a toolbox safety intervention. Therefore, it can be concluded that safety behavior evaluation of toolbox initiatives is scarce in the available literature of construction research.

To assess the transfer of toolbox content to the workplace and to address the gap in the literature, this phase of the evaluation includes the evaluation of safety behavior change among KYTC highway maintenance crews who participated in the pilot implementation of the toolbox talks. Through field behavior observation sessions using time sampling and event recording, safety behavior of participants was recorded, analyzed, and examined before and after the delivery of the pre-task safety talks. This chapter presents the behavior evaluation starting with a review of the available literature to identify the relevant work and the existing gap in evaluation studies. The second section of the chapter describes the methods and techniques used to collect behavior observations. The third section presents the statistical analysis used to analyze the behavior observations Finally, the results of analysis are presented in the fourth section, and the chapter concludes with a discussion of the results. This phase of the evaluation model addresses the missing component in most evaluation studies, and the results provide a valid indicator to predict future safety performance of highway maintenance crews within the implementation region.

6.2 Literature review

6.2.1 Safety behavior

Safety incident is defined as an unplanned, unwanted, but controllable event which disrupts the work process and causes injury to people or damage to property (Raouf 2011). Incidents occur due to 1) failing to identify unsafe condition, 2) deciding to proceed with action after identifying the unsafe conditions, or 3) deciding to act regardless of the existing unsafe conditions (Abdelhamid and Everett 2000). Despite the differences in theories of incident causation, unsafe behavior/act has been reported either as the cause of an incident or the symptom of the root cause of an incident. In one of the early tries to conceptualize incident causation, Heinrich (1941), stated that unsafe behavior is one of the leading causes of incidents. In his theory, The Domino Theory, he proposed the ratio 88:10:2, which means that 88% of incidents causes are unsafe behaviors, 10% are unsafe conditions, and the rest 2% are uncontrollable causes. Recently this ratio was changed to become 80:20 meaning that 80% of causes are unsafe acts while the remaining 20% are unsafe conditions. Some researchers took the ratio even further by considering the influence of human factors on unsafe conditions through aspects like equipment design, work procedures, process design etc. Al-Hemoud and Al-Asfoor (2006) stated that human factors influence 80% of the 20% unsafe conditions, which changed the ratio to 96:4. Regardless of how much unsafe behaviors contribute to safety incidents, there is a consensus among researchers that unsafe behavior is a leading contributor to work incidents. Therefore, safety behavior has recently been a focal point for researchers either by directly addressing it through Behavior Based Safety (BBS) interventions or indirectly through regular training programs.

Regardless of the format and delivery method of safety training and education programs, designers develop their programs with the goal that knowledge transfers to the workplace to increase and maintain safe behavior and reduce unsafe behavior. Wexley and Latham (1991) and Newstrom (1984) defined positive transfer of training as the extent of applying the gained knowledge, skills, and attitudes into the work context. Baldwin and Ford (1988) stated that training transfer occurs if the learned behavior is generalized and maintained in the workplace. Therefore, it is important to evaluate behavior change on the jobsite to examine the degree to which training outcomes have been applied and sustained in the work context.

6.2.2 Behavior change evaluation

Every year, organizations dedicate considerable amount of money and efforts to train their employees aiming to improve their performance. However, research has shown that most of the training and education programs do not achieve their objectives. Training outcomes often are temporary and wane or diminish by the absence of the cause. Research shows that more than 80% of the knowledge and skills gained from training programs is not applied in the workplace (Brinkerhoff 2006; Broad and Newstrom 1992; Noorizan et al. 2016; Patterson 2009). Therefore, it is insufficient to focus the evaluation of training programs only on short-term results, such as reaction, attitudes, and knowledge and gain, as is the case in most training evaluation studies. Negative results of short-term outcomes evaluation may limit researchers from proceeding to the next level of evaluation, but positive results do not ensure the transfer of the training content to the workplace. As a result, behavior change evaluation becomes a critical integrated component of the evaluation process to ensure that there is a reflection of training programs on the workplace.

Evaluating behavior change helps programs designers to understand the degree of knowledge gain, retention, and transfer (Baldwin and Ford 1988; Kirkpatrick 1975). The same concept applies in the evaluation of safety and health interventions. Evaluating safety interventions tells researchers the extent to which interventions produces an observable and measurable desired behavior and reduces undesired behaviors (Basarab Sr and Root 2012). Although behavior change can be considered as immediate results of safety training, it provides an indication of future safety performance. According to Mearns et al. (2001), unsafe behavior can be considered as a valid proxy for injury and the best indicator of incidents and near misses. Behavior evaluation can also help training designers and evaluators to identify and address shortcomings in the training programs. According to Cohen et al. (1998), positive short-term results, such as knowledge and skills gain, with no application in the workplace may indicate lack of motivation, unfit training content, or conflict between training conditions and the actual practices. Identifying such barriers and weaknesses helps programs developers to focus efforts on the improvement areas.

Although several studies have been conducted to evaluate the effectiveness of safety interventions in the construction industry, most evaluation approaches were limited to immediate results, such as knowledge gain, reactions, and attitudes, and did not evaluate the behavior change to examine the training transfer. Few studies evaluated the effect of safety interventions on workers' safety behavior (Gilkey et al. 2003; Kerr et al. 2007; Lingard 2002; Lusk et al. 1999; Neitzel et al. 2008; Seixas et al. 2011). All these studies, except one (Lingard 2002), evaluated behavior change using the self-reporting approach, a data collection approach where workers either report their own safety behavior or co-workers behavior. The validity of self-reporting data is a continuing debatable point among researchers because of the bias associated with the self-reporting data (Donaldson and Grant-Vallone 2002).

Although safety toolbox interventions, sometimes referred to as tailgate briefings, are very common interventions in the construction industry, it can be said that there is a minimal research directed toward evaluating the effectiveness of such programs in changing safety behavior of construction workers. The gap is more significant in the highway construction and maintenance sector, where no previous research was conducted to address this gap. Therefore, in addition of fulfilling part of the requirements of the comprehensive evaluation model, this study was conducted to address this gap in the literature. Evaluating participants' behavior change helps to assess the effectiveness of the toolbox in reducing unsafe behavior. It indicates the degree of knowledge transfer and retention from the safety talks to the workplace.

6.3 Behavior Measurement

Behavior is technically defined as "that portion of an organism's interaction with its environment that is characterized by detectable displacement in space through time of some part of the organism and that results in a measurable change in at least one aspect of the environment" (Johnston and Pennypacker 1993). Since behavior occurs through time, it can be measured through three fundamental properties. Johnston and Pennypacker (1993) described these properties as follow:

- Repeatability (countability): it refers to the fact that instances of response class of behavior can occur repeatedly through time and can be counted.
- Temporal extent: it refers to the duration of time where behavior occurs.
- Temporal locus: it refers to certain point of time where behavior occurs with respect to other events.

For each of these features, applied behavior analysists use different types of measures to measure behavior based on the research interests. The following measures proposed by Cooper et al. (2014) are commonly used in applied behavior analysis:

1- Based on repeatability, behavior can be measured by:
    - Count: the total number of occurrences of behavior;
    - Frequency/Rate: the ratio of behavior counts to the observation period; and
    - Celeration: the measure of how rate of response could change over time.
2- Based on temporal extent, behavior can be measured by:
    - Duration: the amount of time in which behavior occurs, which can be duration per session or duration per occurrence.
3- Based on temporal locus, behavior can be measured by:
    - Response latency: the amount of time between certain motive or stimulus and the subsequent behavior.
    - Interresponse time (IRT): the amount of time that extend between two consecutive instances of a response class of behavior.

In applied behavior studies, researchers use different measurement procedures to measure behavior including event recording, timing, and different time sampling methods (Cooper et al. 2014). Depending on the research interest, study context, and other considerations, behavior analysts choose one or combination of these measurement procedures to measure behaviors of interest. In this study, a combination of event recording and time sampling methods were utilized to measure safety behavior of participants.

6.4 Objectives

The primary goal of this phase of the study is to evaluate the effectiveness of the toolbox talks in changing safety behavior of maintenance crews who participated in the pilot implementation of the toolbox. This goal was accomplished by achieving the following supportive objectives:

1- Observing participants' safety behavior against pre-defined behaviors from the toolbox;
2- Examining the change of safety behavior throughout the implementation period; and
3- Comparing participants' behavior change among maintenance operations to understand the toolbox performance among different maintenance operations.

6.5 Methods

This section briefly describes the experimental settings and targeted audience. It also discusses the data collection procedures including the sampling techniques and observation procedures. Definition and characteristics of the targeted behaviors are discussed in addition to the techniques and precautions used to ensure data reliability.

6.5.1 Experimental settings and the targeted audience

The intervention in this part of the study represents the safety toolbox that was designed to address safety hazards within highway maintenance operations in the state of Kentucky. There are 17 different operations in which maintenance workers are engaged throughout the year. Due to data limitation, the safety toolbox was designed to align with 10 maintenance operations. In a three months pilot implementation, maintenance supervisors in district X of the state of Kentucky were asked to use the toolbox to deliver pre-task safety talks to maintenance crews. The safety talks were intended to be task-specific, address hazards within each maintenance operation, and provide prevention and risk control guidance. Each supervisor was asked to use the safety toolbox to prepare and present a safety talk to his/her crew before they start working. For example, if the crew was engaged in bridge maintenance work, they should conduct a safety talk before they start working, to discuss the frequent potential hazards associated with this type of work, why incidents occur, and how to remove these hazards and reduce the associated risk. Supervisors were instructed on how to use the toolbox and conduct safety talks. They were also instructed to document their notes every time they deliver a safety talk.

There are 16 highway maintenance crews included in this study. Each crew has a supervisor and one or two assistants. The crew size ranges from 5 to 12 workers not counting supervisors and their assistants. Throughout the three months pilot implementation period, one or two observers were deployed to join the crews twice a week to conduct behavior observations. Observations were collected using a mobile version of an application called "Insight". Insight is a customizable application that was designed to conduct behavior observations. It enables users to design their own observation format, assign the desired observation labels and time intervals, and export the recorded data in different formats including Microsoft Excel files. The study was designed so that participants safety behavior was observed prior and after receiving the safety talks. The study design allowed each maintenance crew to work as its own control group.

6.5.2 Data Collection

6.5.2.1 Defining target behavior

The first step in human behavior evaluation is to define behaviors to be evaluated (Madaus and Stufflebeam 1988). Before observers can go to the field and record safety behavior, it is important to have clear definitions of safe/unsafe behaviors prior to the beginning of observation sessions. This enables observers to easily identify behaviors of interest and reduce potential ambiguity an observer may experience during the observation. In this study, safe behaviors are defined based on the content of the toolbox. Since pre-task safety talks specifically target frequent hazards within certain maintenance operations performed by KYTC highway maintenance crews, the definitions of safe behaviors was drawn from the content of the toolbox within each operation. That is, safe behaviors are defined based on the safety practices that address the frequent hazards of the different work activities and scenarios included in the toolbox. For example, within the "tree trimming" work operation, there is a recommendation included in the toolbox on where workers should position themselves when falling a tree as shown in figure (6.1). If workers are observed to perform the work as mentioned in the toolbox, behavior will be marked as "safe". However, if the observed worker violates the recommendations and stands in the "danger zone" instead, the behavior will be marked as "unsafe". All targeted behaviors included in the toolbox were precisely defined to ensure that observers do not have ambiguous situations where it is difficult to tell whether the behavior is safe or not. It is worth noting that behaviors outside the content of the toolbox were not observed since they could introduce bias to the results of the evaluation.

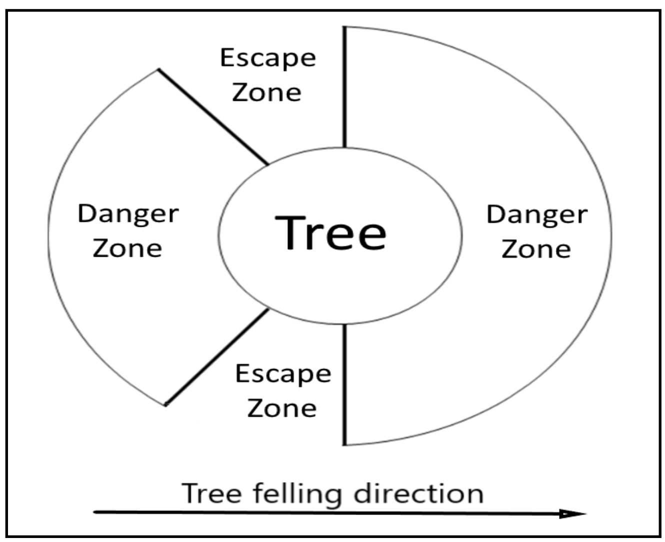


Figure 6.1 Tree felling direction

6.5.2.2 Sampling techniques

For the three months implementation period, observers conducted 25 observation session. Each observation session lasted 60 minutes and was designed to cover four workers. One hundred workers were observed throughout the implementation period. To conduct the behavior observation sessions, the following observation procedures were utilized:

1- Time sampling: although it suffers from some inherent limitations, this is one of the frequently used method in applied behavior analysis to collect behavior data. Time sampling refers to the procedures of dividing the observation session into time intervals and recording the occurrence of specific behavior within or at the end of each interval (Cooper et al. 2014). There are three forms of time sampling including partial interval sampling, whole interval sampling, and momentary time sampling. In partial interval sampling, an occurrence is recorded if the behavior takes place at any point of the interval. In whole interval sampling, an occurrence is recorded if the behavior lasts the whole interval. In momentary time sampling, an occurrence is recorded if the behavior takes a place at the end of the interval (Mayer and Sulzer-Azaroff 2013).
2- Event recording: this technique is used in applied behavior analysis studies to detect and record the number of times a behavior of interest occurs using a variety of devices, such as wrist counters, pocket counters, hand tally digital counters, etc. (Cooper et al. 2014).

Both techniques were utilized in this study to conduct behavior observation. Each form of time sampling has its own inherent problems, such as over- or underestimation of safety behavior occurrence (Alvero et al. 2008). Such problems can make it difficult for researchers to decide on which form of time sampling to use. However, this is not an issue in this study because the study design cancelled procedural bias by the comparison of behavior prior and after the intervention. In other words, any procedural bias introduced in observations before the use of toolbox would be introduced in observations after the use of toolbox since the same procedures were used to collect all behavior observations. Whole interval sampling was used because it provides a conservative estimate of safety behavior (Taylor et al. 2012). Observation intervals were 30 seconds long to reduce the observer bias that may stem from long attention spans. Behavior observations were recorded using event recording procedures where observers record the number of safe and unsafe behavior during each observation session.

6.5.2.3 Observation procedures

Two observation sessions were conducted every week for 12 weeks. Each observation session lasted for 60 minutes and was divided to 60 observation intervals. During each interval, observers record safety behavior for 30 seconds and rest for 30 seconds. While the selection of observation day was done based on the availability of highway maintenance work, the session starting time was randomly selected. To reduce any bias that could be introduced by supervisory presence, observers were instructed to reduce the supervisory interaction with workers when possible. In addition, to allow workers to adjust for the observers' presence, observations were not recorded for the first two weeks of the study and for the first 30 minutes after arrival of every observation day. The maintenance work activities that were targeted in the observation sessions are the ones included in the toolbox. Observation sessions took place in different locations of the district based on the availability and distribution of maintenance work during the implementation period. In addition, the locations of observation sessions were selected in a way that ensured inclusion for different maintenance crews and different maintenance operations.

Once the time and location of the observation session were determined, the observer utilized event recording techniques to record safety behavior. Each observation session was divided into four equal 15 minutes sub sessions. Each sub session was focused on one maintenance worker who perform, when possible, a different work task from the workers observed in the remaining three sub sessions. This session division ensured more coverage of different work activities within each maintenance operation. It also ensured observing wide portion of participants, which led to a better representation of maintenance workers of district X. The selection of subjects was random with no repetition for the same subject to reduce dependency between observations. It is worth noting that one of the recommendations to use event recording is when the behavior of interest has discrete beginning and end points in order for observers to record it within the observation interval (Cooper et al. 2014). In this study, when the behavior of interest lasted longer than the observation interval, it was marked as "safe" if the subject followed the recommended safety practices and "unsafe" if the subject violated any of the practices. The reason of marking behavior as "unsafe" even if the target followed all the safe practices and violated only one is that work incidents can occur for one violation or a series of violations. If the targeted subject was not engaged in any work task during the observation interval, the observation was marked as “nonoccurrence” since no response class was detected.

6.5.3 Data reliability precautions

It is important to ensure data reliability in behavior analysis due to the bias associated with behavior observations that may hinder the validity of research. Bias in behavior data mostly comes from two sources including measurement procedures and observers (Taylor et al. 2012). Measurement procedures can introduce different types of bias including self-reporting bias, classification bias, and misclassification bias. Self-reporting bias, which stems from subjects reluctance to report unsafe behavior (Lyu et al. 2018), is not a concern in this study since self-reporting was not used in data collection. Misclassification bias refers to the difference between the estimated duration of behavior by measurement procedures and the actual duration. Classification bias is the degree to which measurement procedures tend to over- or underestimate the cumulative duration of behavior (Taylor et al. 2012). Both biases are major concerns when the main interest of the study is to obtain an estimate of behavioral occurrence through temporal units, such as duration. In this study, both biases are not concerning for two reasons: 1) behavior was not obtained through temporal units; and 2) any bias introduced was accounted for by comparison since the same bias will be counted in observations prior and after safety talks. The main concern in this study was the observer bias that could stem from observers misclassifying safe as unsafe or observers’ tendency to record a desired behavior and overlook undesired behaviors. Two precautions were considered to reduce such biases. To reduce behaviors misclassification, observers used the toolbox to define most behaviors of interest prior to conducting the observations. Having clear definitions of behaviors helped to reduce the ambiguity that might be presented when classifying behaviors during the observation sessions. To reduce observer bias and ensure data reliability, another precaution was considered by deploying two observers for 32 percent of observation sessions to independently observe the same behavior of the subject from the same position. Then the Interobserver Agreement (IOA) “The degree to which two or more independent observers report the same observed values after measuring the same events" (Cooper et al. 2014) was counted for 32 percent of the data. The purpose of deploying two observers was to determine Exact-Count-Per-Interval IOA and provide an objective indicator of data reliability.

6.6 Data analysis

Behavior data in this study were analyzed using SAS software, version 9.4. Copyright © 2019. SAS Institute Inc., Cary, NC, USA. Logistic regression model with mixed effects was fitted with behavior change as the response variable and the intervention (toolbox use) and the maintenance operation as predictors. A post-hoc examination of the interaction effect between the intervention and operations was included in the model. Data analyzed included overall 1500 observation for 100 subjects within 11 maintenance crew in 7 maintenance operations throughout 25 observation session. Intervention input was collected using the implementation fieldnotes while the rest of the data was collected through the behavior observation sessions. For privacy and confidentiality purposes, crews are given numbers instead of names in data analysis and the following sections.

6.7 Results

A major goal in the design of behavior evaluation was to include a high potion of the maintenance crews and operations to cover a representative sample of maintenance workers in the behavior observation sessions. However, due to the limited implementation time and the availability of specific work operations during the implementation period, 11 out of 16 maintenance crews and 7 out of 10 maintenance operations were covered in the behavioral observation sessions. Table (6.1) shows the statistics of behavior observations categorized by toolbox use within each maintenance operation. As shown in the table, subjects in 4 out of the seven maintenance operations were observed before and after the use of toolbox. However, although subjects engaged in "concrete repair and bridge maintenance" and "equipment maintenance" operations were observed several times, they did not use toolbox talks in both operations. I addition, subjects engaged in "litter and debris removal" were observed only after using the toolbox. It is worth noting that subjects were not observed in three maintenance operations including “snow removal”, “signs inventory and replacement”, and “guardrail maintenance”. It is also important to mention here that 80% of the observations covered subjects in the four maintenance operations that were covered prior and after using the toolbox. Some maintenance operations, such as “Road and shoulder repairs”, were observed more than other operations due to the availability of this operation throughout the implementation period.

Table 6.1 Behavior observations by toolbox use and maintenance operation

Operation	**Observations by toolbox use** Frequency Percent		
	No	Yes	**Total**
Concrete repair and bridge maintenance	180 12	0 0	180 12
Equipment maintenance	60 4	0 0	60 4
Litter & debris removal	0 0	60 4	60 4
Mowing	120 8	60 4	180 12
Pipe/drain cleaning and replacement	180 12	180 12	360 32
Road and shoulder repairs	240 16	240 16	480 32
Tree and brush trimming	120 8	60 4	180 12
Total	900 60	600 40	1500 100

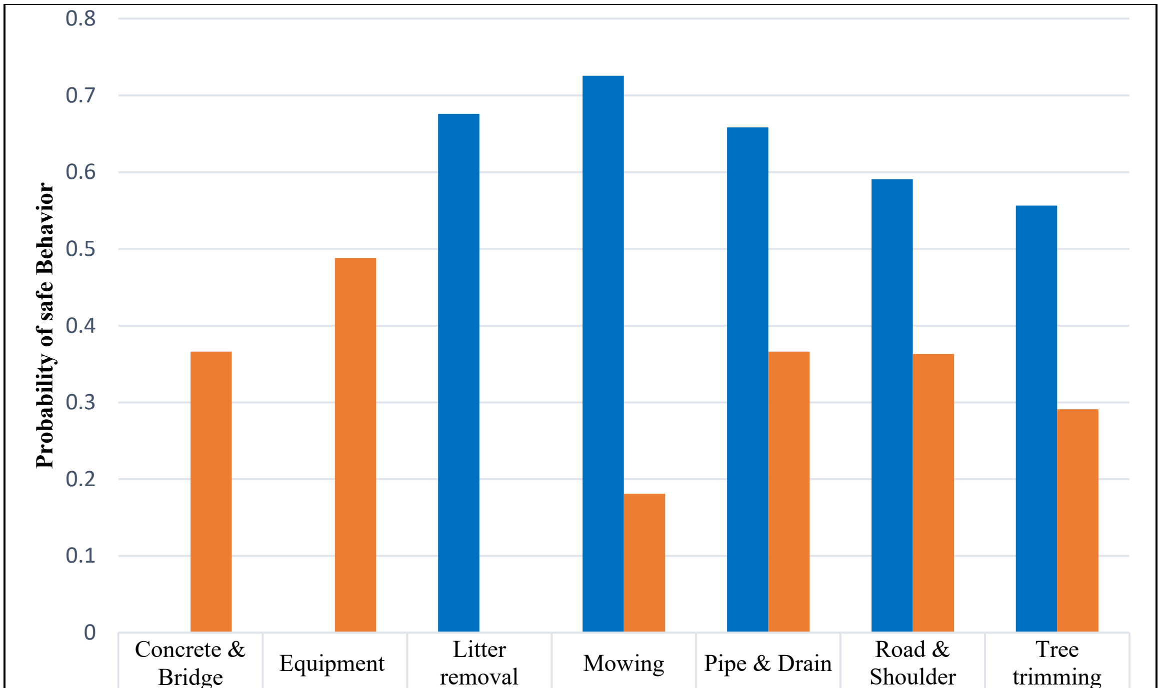
Table (6.2) shows the statistics of behavior observations of maintenance crews in district X categorized by the toolbox use and the observed safety behavior. Of the total 1500 observations, behavior occurrence was not observed in 268 intervals. The majority of crews were observed either two or three times. Crew 1 was observed 4 times and crew 8 and 9 were observed one time. The variation in observations per crew was due to the availability of maintenance work during the pilot implementation. The IOA for data included was calculated using the Exact-Count-Per-Interval IOA formula. The IOA between the two observers was 93%, which indicates a high reliability level of the behavior observations data.

Table 6.2 Behavior observations by maintenance crew and toolbox use

Crew	**Observation**	**Toolbox Use**		**Behavior**		
		Yes	**No**	**Safe**	**Unsafe**	**Non**
1	240	120	120	101	94	45
2	120	120	0	57	32	31
3	120	60	60	48	51	21
4	180	0	180	55	95	30
5	180	120	60	76	77	27
6	180	0	180	53	80	47
7	120	60	60	46	69	5
8	60	0	60	16	40	4
9	60	60	0	29	19	12
10	120	0	120	38	67	15
11	120	60	60	38	51	31
Total	1500	600	900	557	675	268

The results of statistical analysis show that toolbox use (safety talks) has significant effects (F=52.94, P <.0001) on participants safety behavior. On average, there seems to be a positive effect for pre-task safety talks on the probability of subjects' safe behavior. With 0.05 significance level, no significant effect was detected for maintenance operation on participants safety behavior. However, there results show a significant (F=2.69, P=0.0452) interaction effect between the toolbox use and the maintenance operation on participants safety behavior.

To gain a better understanding beyond the overall average effect of toolbox use on participants behavior, data were analyzed to examine the effect of safety talks on participants behavior within each maintenance operation. The results show that the positive effects of toolbox use on the average probability of safe behavior varied among different maintenance operations as shown in figure (6.2). The results show that subjects engaged in the mowing operation experienced the highest behavior change compared to those who were engaged in the other three operations that were observed prior and after the delivery of safety talks. With the available data, it was not possible to detect participants behavior change in the rest of operations because subjects were either not using the toolbox during the implementation time, as is the case in "concrete and bridge maintenance", or they were observed only once, as is the case in "equipment maintenance" and "litter and debris removal" operations.



	Concrete & Bridge	Equipment	Litter removal	Mowing	Pipe & Drain	Road & Shoulder	Tree trimming
Yes	0	0	0.676	0.7255	0.6582	0.5907	0.5564
No	0.3662	0.4881	0	0.181	0.3661	0.3631	0.2909

Figure 6.2 Behavior change by maintenance operations

6.8 Discussion

The purpose of conducting a safety behavior evaluation in this study was to examine the effects, if any, of pre-task safety toolbox talks on safety behavior change among highway maintenance crews. Although the pre-task toolbox talks were not designed to directly address workers safety behavior, the results of behavior change evaluation showed that conducting pre-task safety talks results in a significant change in safety behavior of highway maintenance crews. Although the toolbox talks were not implemented as intended in terms of frequency and fidelity, the introduction of relevant safety knowledge to highway maintenance crews proved to be associated with improved safe behavior and reduction in unsafe behavior. The improvement in workers safety behavior was witnessed across four maintenance operations for all the crews who participated in the pre-task safety talks. The highest behavior change was detected in the "Mowing" operation. There are two possible explanations for this magnitude of change in safety behavior of crews in the "Mowing" operation. The first explanation is associated with the frequency of toolbox talks. The pilot implementation took place in what the highway maintenance supervisors referred to as “the mowing season”. In this time of the year and due to the fast growth of grass, highway maintenance crews are engaged in mowing operations more than any other maintenance operations. Practicing this operation more often during the implementation time period means that safety talks were given frequently in mowing operations. This was evident by the implementation data. The implementation fieldnote showed that safety talks tailored to mowing were the most frequent talks given during the implementation period. In addition, the results of process evaluation in chapter 5 showed that the completeness (dose-delivered) of safety talks in mowing was 100% in all crews except two. As a results, the high frequency and complete delivery of safety talks might result in higher adoption of safe behavior and higher reduction in unsafe behavior. Although characteristics of toolbox talks, such as timing and frequency, have not been addressed in the literature (Eggerth et al. 2018), this explanation is consistent with what has been reported in two studies (Harrington et al. 2009; Olson et al. 2016). Olson et al. (2016) stated that “frequent safety-related communication is associated with higher levels of safe behavior and conditions and higher perceived safety climate”. Harrington et al. (2009) stated that improved quality and frequency of tailgate safety talks would result in a safer work environment. However, neither of the studies provided an evidence to support their statements. The second possible explanation of the higher magnitude of change in maintenance crews behavior within the mowing operation is associated with the approach adopted to observe safety behaviors. In mowing operation, workers behaviors do not change as frequent as their behaviors in other operations. For example, a worker could continue mowing the side of the road for miles, which means he/she would be engaged in the same behavior for a long time. Therefore, if the worker was engaged in a safe behavior, the majority of the observation intervals would be marked as safe and vice versa. Consequently, the behavior observation methods used combined with the unique nature of the mowing operation might result in a higher magnitude of change in behavior data.

Although construction companies recognize the value of safety and health training and education, most contractors, especially in small size companies, do not invest in safety training due to the lack of affordable short training programs (Harrington et al. 2009). The results of this study suggest that there is a promising opportunity for the industry to use toolbox talks as a cost effective intervention to train construction workers. This finding is consistent with what has been reported by (Harrington et al. 2009). In addition, as the increasing evidence in construction safety research has shown that unsafe behavior is responsible for the majority of work-related incidents and injuries, companies have been increasingly seeking safety management interventions that focusses on safety behavior. The results of this study suggest that task-specific toolbox talks can be utilized to improve safety behavior among workers.

6.9 Conclusion

The significant amount of resources and efforts dedicated for safety and health training combined with the outcomes realized from training programs made the effectiveness of these programs a focal point in the research arena. Several studies investigated the effectiveness of safety and health training programs. Researchers proposed different evaluation models to evaluate the effectiveness of training. However, one of the frequently missed components in empirical evaluation studies is the evaluation of behavior change. Most evaluation studies are limited to evaluating the short-term immediate outcomes, such as reaction and knowledge gain. It is important to evaluate the behavior change to examine the transfer of safety training and ensure that training is reflected on the workplace.

In this phase of the study, we evaluated the effectiveness of pre-task toolbox talks on the safety behavior of highway maintenance crews. Utilizing time sampling and event recording techniques to observe safety behavior, we examined behavior change among highway crews before and after the introduction of the task-specific toolbox talks. The results showed that toolbox talks have a significant positive effect on safety behavior of highway maintenance crew.

To the best of the researcher knowledge, this study represents the first try to evaluate the effectiveness of toolbox talks on safety behavior of highway maintenance workers. The results of the study suggest that toolbox talks can offer an effective solution to improve safety performance in the highway sector.

7 CONCLUSION

The aging transportation system in the United States and the high cost to build new roads and bridges to replace the existing system increase the demand to maintain the existing system. This in turn increases the workload on highway maintenance crews. Today, highway maintenance workers performed variety of work operations including roadways maintenance, bridges maintenance, landscaping, snow removal, guardrail maintenance, debris removal, etc. As a result, highway maintenance crews work in risky work environment with hazardous characteristics, such as the close proximity to speeding traffic, the extreme weather conditions, and the movement of large amount of materials and equipment. In addition, there is a lack of safety resources tailored to this sector of the construction industry. Most of the available safety programs, research, standards , and regulations are directed toward the general construction industry leaving the highway maintenance sector with insufficient attention.

This dissertation discusses the design, implementation, and evaluation of pre-task toolbox talks that were developed to improve safety awareness among highway maintenance crews in the state of Kentucky. This study consists of two main parts: (1) The design part that presents the process and procedures used to develop the toolbox; and (2) The evaluation part which presents the reaction and knowledge gain evaluation, the implementation evaluation, and the behavior change evaluation. Following is a summary of the findings and contributions of this study:

- **Chapter 2: a task specific toolbox was developed to address frequent hazards in highway maintenance work and provide safety guidance to prepare for pre-task safety talks.** In this chapter, ten years safety records of KYTC highway maintenance crews were analyzed to identify trends. Frequent incidents and hazards were identified within ten highway maintenance operations. Safety guidance was developed to control the risk associated with the identified hazards. The final product of the design phase is a safety toolbox intervention that is used by supervisors to prepare for task-specific pre-task safety talks. This study represents the first try to produce safety toolbox tailored to the highway maintenance sector. In addition to addressing the lack of research tailored to the safety of workers in this unique sector of the construction industry, this study provides DOTs with a cost effective approach to develop data driven safety intervention and improve safety awareness among highway maintenance crews. The development of safety toolbox in the design phase highlights the critical role for safety data reporting and archiving.

- **Chapter 4: Introducing relevant safety knowledge in the form of pre-task safety talks improved safety awareness among highway maintenance crews.** The purpose of this chapter is to evaluate the effectiveness of the pre-task safety talks on workers reaction and safety awareness. The results show that task-specific safety talks delivered prior to or at the beginning of the workday significantly improved workers safety knowledge by 22%, incidents identification skills by 23%, hazards identification skills by 23%, and prevention control identification skills by 21.5%. In addition, preparing and conducting pre-task safety talks improved supervisors and workers knowledge of the frequent incidents and causes of incidents within each maintenance operation. Moreover, significant improvement was realized in workers knowledge of prevention controls. The results suggest that data driven safety toolbox is an effective intervention to improve safety awareness among highway maintenance crews.
- **Chapter 5: The formative evaluation of the toolbox talks revealed that using narratives and photographic demonstration can improve the presentation of safety briefings and increase workers engagement. It was also found that work environmental factors can limit the implementation and effectiveness of toolbox talks.** The purpose of conducting formative evaluation is to evaluate the processes and procedures used to implement the toolbox safety talks. After examining the recruitment procedures, the reach and delivery of the safety talks, the quality of implementation, participant satisfaction, and the implementation context, we were able to identify the shortcomings of the toolbox, the underlying environmental barriers that impedes the implementation and effectiveness of toolbox talks, and the potential areas to improve the toolbox effectiveness. Environmental factors including shortage of man power, heavy workload, and lack

of time were found to be the most frequent barriers to conduct pre-task safety talks. In addition, the formative evaluation results showed that narratives of previous work incidents could increase the talks personal relevance to workers, which in turn increases workers engagement in safety talks. In addition, the results showed that including photographic demonstration of safety practices help to smooth the delivery of safety talks.

- **Chapter 6: Highway maintenance workers are 33.24 percent more likely to engage in safe behaviors if the pre-task safety talk toolbox is utilized.** In this chapter, we evaluated the change in safety behavior among highway maintenance crews who participated in the pilot implementation of toolbox talks. The analysis of three months behavior observations revealed that the pre-task safety toolbox talks significantly increased safe behavior and reduced unsafe behavior among highway maintenance crews. The results also suggest that increased frequency of safety talks lead to a higher improvement in workers safety behavior. The results of safety behavior evaluation showed that using task-specific toolbox talks is an effective way to improve safety behavior among highway maintenance workers. In addition, the association between toolbox talks and improved safe behavior suggest that toolbox talks offer a cost-effective solution to improve safety performance in the highway maintenance sector.

To the best of the researcher knowledge, this study represents the first empirical study conducted to address the occupational safety and health of highway maintenance crews. The main contributions of the study include:

1- Developing a data driven safety intervention to improve safety performance of highway maintenance crews;
2- Providing a framework to use lagging measures to design and develop proactive safety interventions;
3- Highlighting the need to address the occupational safety and health of an underserved audience of the construction workforce;

4- Addressing the gap found in the literature by conducting a comprehensive effectiveness evaluation of a common safety intervention in the construction industry;
5- Evaluating the effects of toolbox talks on safety behavior among highway maintenance crew; and
6- Offering a cost-effective solution to improve safety awareness and behavior among maintenance workers.

The safety toolbox developed in this study provides an effective solution to improve safety awareness and safety behavior of highway maintenance crews. The results of the study showed that the toolbox content was not only reflected on workers safety knowledge, but also transferred to the workplace and was reflected as an improved safe behavior. This indicates that an improved safety performance can be achieved by using task specific safety toolbox talks. However, introducing safety interventions, such as the toolbox developed in this study, may not lead to an improved safety performance if workers do not have the motivation to actively participate in the toolbox talks. The results of reaction assessment in this study showed that significant portion of workers lack the motivation to continue using the toolbox. This indicates a poor attitude towards safety and could be an indication of a poor safety culture. Therefore, it is important for construction organization to investigate safety culture prior to introducing safety interventions. Investing resources to improve safety culture is recommended before introducing safety interventions since workers may not practice the latter if they have poor attitude towards safety.

Beside the contributions, this study has some limitations. The data used to design the toolbox included safety records of KYTC highway maintenance employees between 2005 and 2015. This resulted in partial coverage (10 of out of 17) for the maintenance operations. Therefore, the toolbox safety talks cannot be generalized to other operations or outside the context of KYTC highway maintenance work context. It is recommended to design toolbox talks based on a larger range of data. The other limitation of this study is the potential supervisory interaction effects that could bias the behavior observations. Although several precautions were taken to reduce the supervisory interaction, the presence of observers in the workplace could bias the behavior data. Therefore, it is recommended to evaluate safety behavior change using behavior observations collected by recording videos of maintenance workers without the presence of observers. Finally, although the evaluation of reaction, knowledge gain, implementation, and behavior change provide a good indication of the effectiveness of the toolbox talks, these results have to be verified by safety records. Therefore, evaluating the impact of toolbox talks on safety performance using recordable incidents data is recommended.

This study raises many questions about the safety of highway maintenance workers. An important aspect to investigate in future research is the current state of safety culture within the highway construction and maintenance sector. No study was found in the literature to investigate the status of safety culture among highway construction and maintenance crews. The lack of motivation to participate in safety initiatives couples with the relatively poor safety performance in this sector could be attributed to a poor safety culture. Another aspect that requires investigation in future research is the effectiveness of general OSHA construction training, such as the OSHA 10-hour Construction Outreach Training course, in improving safety performance of highway maintenance crews. The uniqueness of work tasks and hazards resent in highway maintenance suggests that a general construction safety training may not be as efficient in the highway maintenance sector as it is in the general construction industry. Finally, an important issue to be investigated in future research is the lack of safety resources tailored to the highway maintenance crews. The finding in this study suggest that the available safety resources for highway construction and maintenance crews are heavily focused on the traffic-related accidents. However, limited amount of resources are dedicated for the occupational side of safety of highway maintenance crews.

APPENDECIES

Appendix A. Evaluation Questionnaires

This appendix presents samples of the questions used in reaction, knowledge, and implementation evaluations.

A.1. Supervisors baseline knowledge evaluation questions

Baseline safety knowledge questionnaire

Confidentiality: your answers to the questions in this interview will be anonymous and will never be linked to you personally.

Part I

In this part, there are 6 images of highway maintenance work tasks with a brief description of each task. Any of these tasks can cause a work incident that may result in an injury or damage. We would like you to identify what could go wrong in each task, why it may happen, and what can be done to prevent the harm.

Answering procedures:

1- On each photo, circle the area where you see a potential incident that could occur.
2- Under each photo, you have a table of three columns where you can describe the possible incident in the left column, the cause of incident in the middle column, and what can be done to prevent the incident in the right column.
3- In the left column there is a box that looks like this

1	2	3	4	5

In this box you can rate how frequently the incident could occur as shown below:

1	2	3	4	5
Never	Rare	Sometimes	Very often	Always

4- If you see more than one possible incident in one photo, you can number each area you circle on the photo. See the example in the next page.

Please, feel free to ask questions about anything in this interview.

In case you need further information about this interview, feel free to contact (________).

Thank you for your participation.

In this photo, the maintenance crew are trying to install the new guardrail.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

In this photo, the workers in this photo are trying to pull brush to haul it from highway.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

In this photo, workers are doing concrete work repair under bridge in high wind day.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

Part II

Section I

When an incident happens in KYTC maintenance work, how frequently is it due to one of the causes listed in Table 1?

Rate each cause in Table 1 based on their frequency to cause a maintenance work incident. Use the rating scale of 1 to 5 as explained below.

1	2	3	4	5
Never	Rare	Sometimes	Very often	always

Table 1

Incidents causes	**Frequency**
a) Contact with Stationary or sharp objects	
b) Animals or insects attack	
c) Pulling or pushing heavy items (tree branches, etc.)	
d) Lifting heavy items	
e) Falling or flying objects	
f) Vehicular accidents	
g) Work tools and equipment	
h) Foreign matter (body) in the eye	
i) Chemicals contact	
j) Falling from Different level	
k) Exposure to extreme temperature or contact with hot objects	
l) Fall on ice or wet floor	

Section II

Based on the scale of 1 to 4 shown below, rate the following statements shown in Table 2.

The scale

1	2	3	4
Strongly disagree	Disagree	Agree	Strongly agree

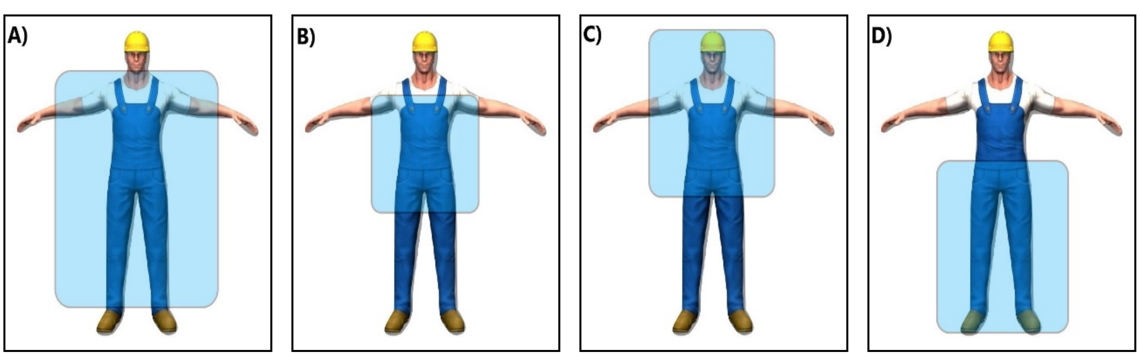
Table 2

Statement	**Rate**
7. New employees learn quickly that they are expected to follow good health and safety practices.	
8. Employees are told when they do not follow good safety practices.	
9. Workers and management work together to ensure the safest possible conditions.	
10. There are no major shortcuts taken when worker health and safety are at stake.	
11. The health and safety of workers is a high priority with management where I work.	
12. I feel free to report safety problems where I work.	

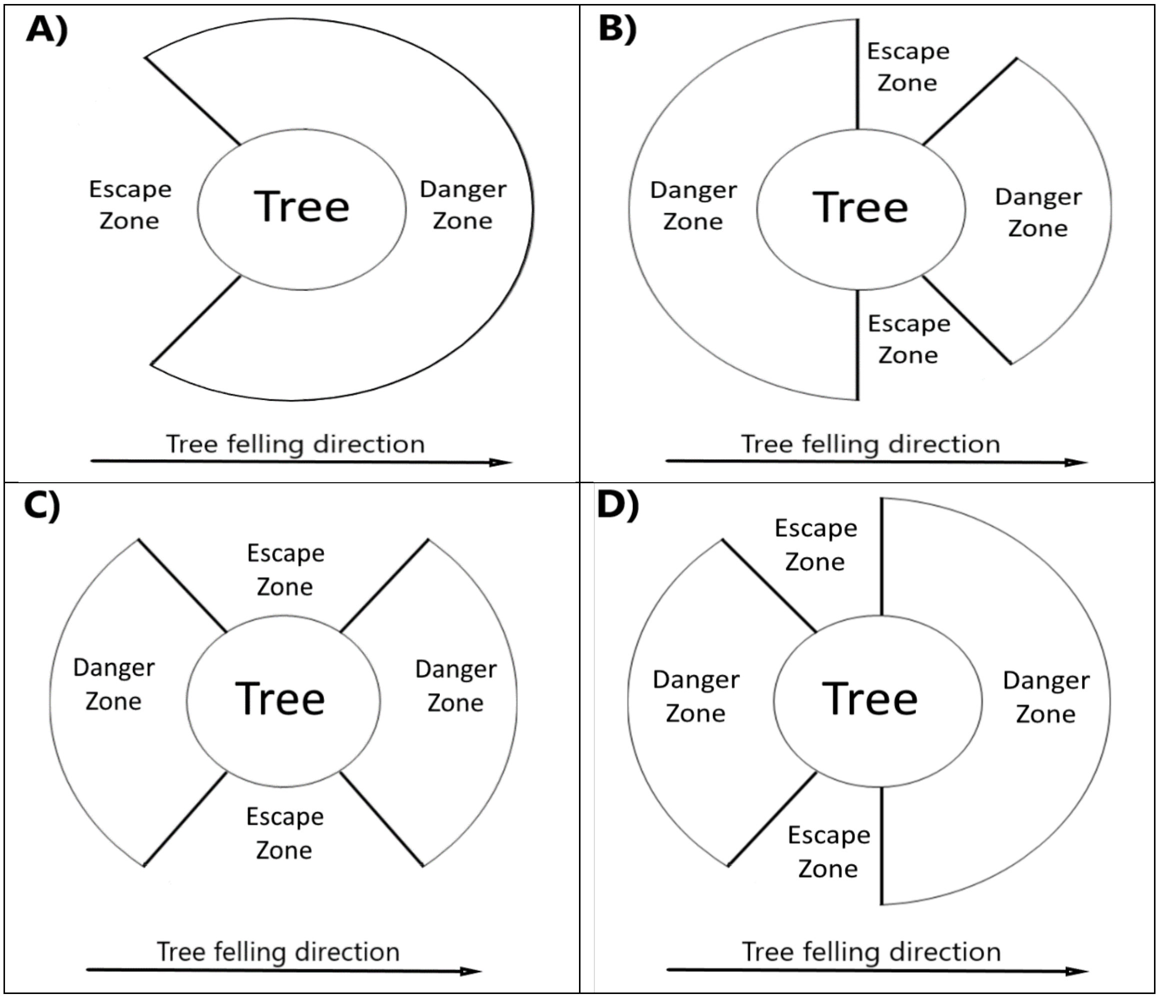
Part III

Circle one answer (letter) for each question.

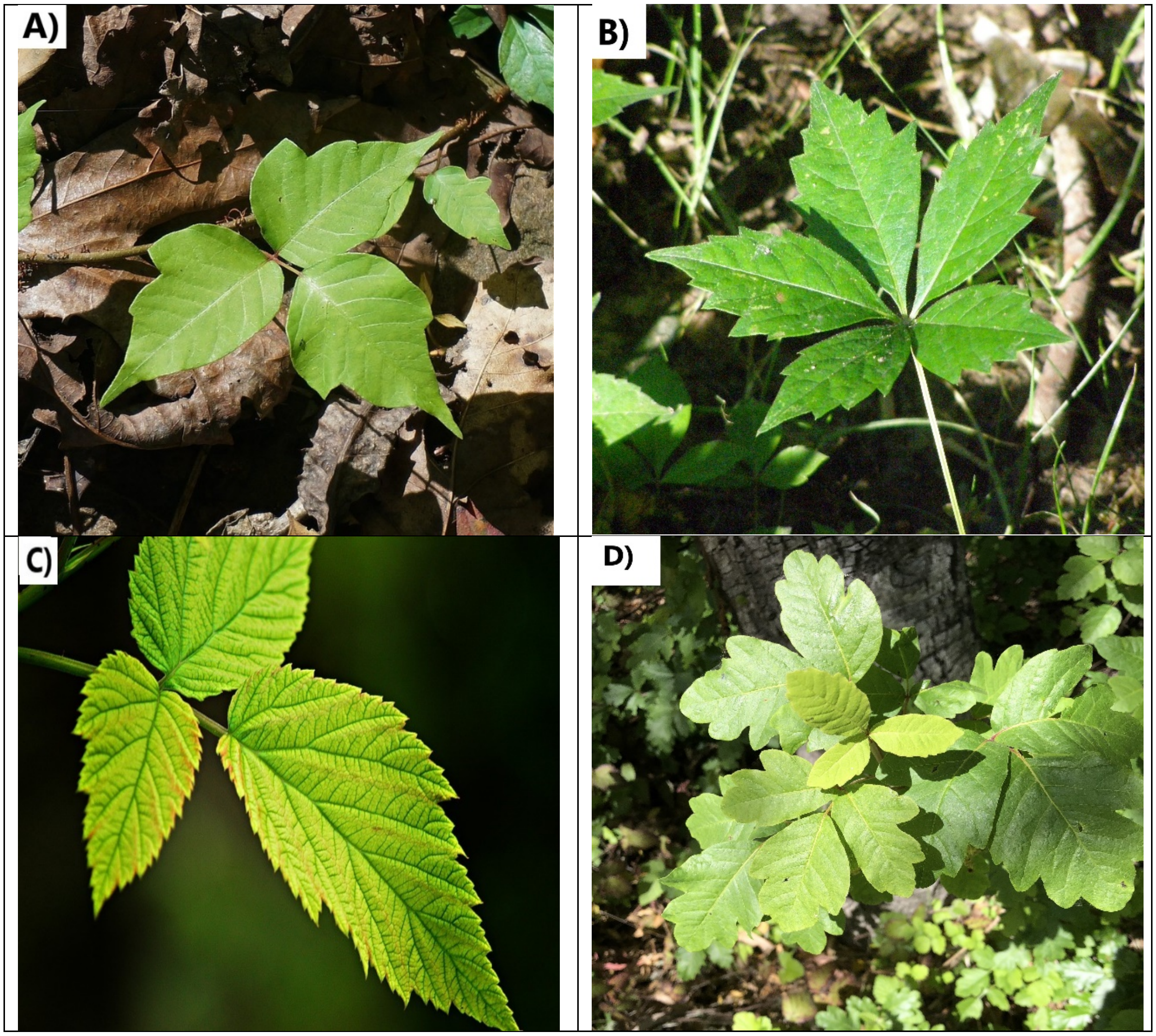
1- Which of the following shadowed areas represents the power zone?



2- Which of the following sketches should tree trimmers follow when cutting a tree?



3- Which of the following plants is poison Ivy?



4- Which of the following is the most frequent cause of incidents claimed by KYTC highway maintenance workers?

A) Lifting	B) Falling from different levels
C) Flying objects	D) Hand tools and equipment

5- Which of the following is the most frequent injury claimed by KYTC highway maintenance workers?

A) Strained by	B) Fall or slip
C) Cut, puncture, or scrape	D) Struck by

6- When falling a tree, no one except the feller should be within:

A) One tree length of the falling tree	B) Two tree lengths of the falling tree
C) Three tree lengths of the falling tree	D) Four tree lengths of the falling tree

----

Part IV

1) What are the most frequent work incidents you notice in maintenance work?
2) What reasons do you think led to such incidents?
3) What safety practices do you use to avoid such incidents?
4) What are the safety practices to avoid back injuries caused by lifting heavy items?
5) When climbing in and out of work vehicles and equipment, what technique can be used to avoid falling, tripping, and sliding incidents?
6) Are there any safety issues in your work that are frequent and have not been addressed by KYTC current safety practices?

A.2. Workers baseline knowledge evaluation questions

Hazard Identification Questionnaire

Confidentiality: your answers to the questions in this survey will be anonymous and will never be linked to you personally.

This survey consists of two parts (A & B). Please, answer all the questions and return the survey in the envelope to your supervisor.

In case you have any question about this survey, feel free to contact _________________.

Part A

Table 1 below has two columns. Read each statement in the left column.
In the right column:
Write **1** if you **strongly disagree** with the statement;
Write **2** if you **disagree** with the statement;
Write **3** if you **agree** with the statement;
Write **4** if you **strongly agree** with the statement.

Table 1

Statement	**Rate**
13. New employees learn quickly that they are expected to follow good health and safety practices.	
14. Employees are told when they do not follow good safety practices.	
15. Workers and management work together to ensure the safest possible conditions.	
16. There are no major shortcuts taken when worker health and safety are at stake.	
17. The health and safety of workers is a high priority with management where I work.	
18. I feel free to report safety problems where I work.	

Part B

The following pages have different images of highway maintenance work tasks with brief description of each task. Each of these tasks can cause a work incident that may result in an injury or damage. We would like you to identify what could go wrong in each task, why it may happen, and what can be done to prevent the harm.

Answering procedures:

1- On each photo, circle the area where you see a potential incident that could occur.
2- Under each photo, you have a table of three columns where you can describe the possible incident in the left column, the cause of incident in the middle column, and what can be done to prevent the incident in the right column.
3- In the left column there is a box that looks like this

1	2	3	4	5

In this box you can rate how frequently the incident could occur as shown below:

1	2	3	4	5
Never	Rare	Sometimes	Very often	Always

4- If you see more than one possible incident in one photo, you can number each area you circle on the photo.

In this photo, the maintenance crew are trying to install the new guardrail.

Incident	Cause	Prevention
1 | 2 | 3 | 4 | 5		
1 | 2 | 3 | 4 | 5		
1 | 2 | 3 | 4 | 5		
1 | 2 | 3 | 4 | 5		

In this photo, the workers in this photo are trying to pull brush to haul it from highway.

Incident	Cause	Prevention
1 | 2 | 3 | 4 | 5		
1 | 2 | 3 | 4 | 5		
1 | 2 | 3 | 4 | 5		
1 | 2 | 3 | 4 | 5		

In this photo, workers are doing concrete work repair under bridge in high wind day.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

In this photo, workers are replacing old guardrail with new one.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

In this photo, workers are trying to install a concrete pipe.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

The worker here is trying to lift the new traffic light to his coworker on the aerial lift.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

The worker on the aerial lift is trying to install new traffic sign in high wind day.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

In this photo, the operator is checking the level of salt left in the spreader.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

A.3. Supervisors post-use reaction and knowledge evaluation questions

Post-use safety knowledge questionnaire

Confidentiality: your answers to the questions in this interview will be anonymous and will never be linked to you personally.

Part I

In this part, there are 6 images of highway maintenance work tasks with a brief description of each task. Any of these tasks can cause a work incident that may result in an injury or damage. We would like you to identify what could go wrong in each task, why it may happen, and what can be done to prevent the harm.

Answering procedures:

1- On each photo, circle the area where you see a potential incident that could occur.
2- Under each photo, you have a table of three columns where you can describe the possible incident in the left column, the cause of incident in the middle column, and what can be done to prevent the incident in the right column.
3- In the left column there is a box that looks like this

1	2	3	4	5

In this box you can rate how frequently the incident could occur as shown below:

1	2	3	4	5
Never	Rare	Sometimes	Very often	Always

4- If you see more than one possible incident in one photo, you can number each area you circle on the photo. See the example in the next page.

Please, feel free to ask questions about anything in this interview.

In case you need further information about this interview, feel free to contact (________).

Thank you for your participation.

In this photo, the maintenance crew are trying to install the new guardrail.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

In this photo, the workers in this photo are trying to pull brush to haul it from highway.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

In this photo, workers are doing concrete work repair under bridge in high wind day.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

Part II

When an incident happens in KYTC maintenance work, how frequently is it due to one of the causes listed in Table 1?

Rate each cause in Table 1 based on their frequency to cause a maintenance work incident. Use the rating scale of 1 to 5 as explained below.

1	2	3	4	5
Never	Rare	Sometimes	Very often	always

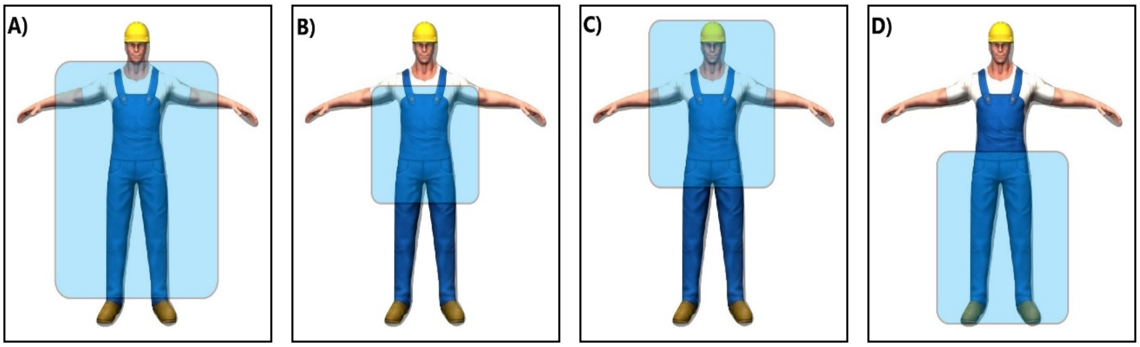
Table 1

Incidents causes	**Frequency**
m) Contact with Stationary or sharp objects	
n) Animals or insects attack	
o) Pulling or pushing heavy items (tree branches, etc.)	
p) Lifting heavy items	
q) Falling or flying objects	
r) Vehicular accidents	
s) Work tools and equipment	
t) Foreign matter (body) in the eye	
u) Chemicals contact	
v) Falling from Different level	
w) Exposure to extreme temperature or contact with hot objects	
x) Fall on ice or wet floor	

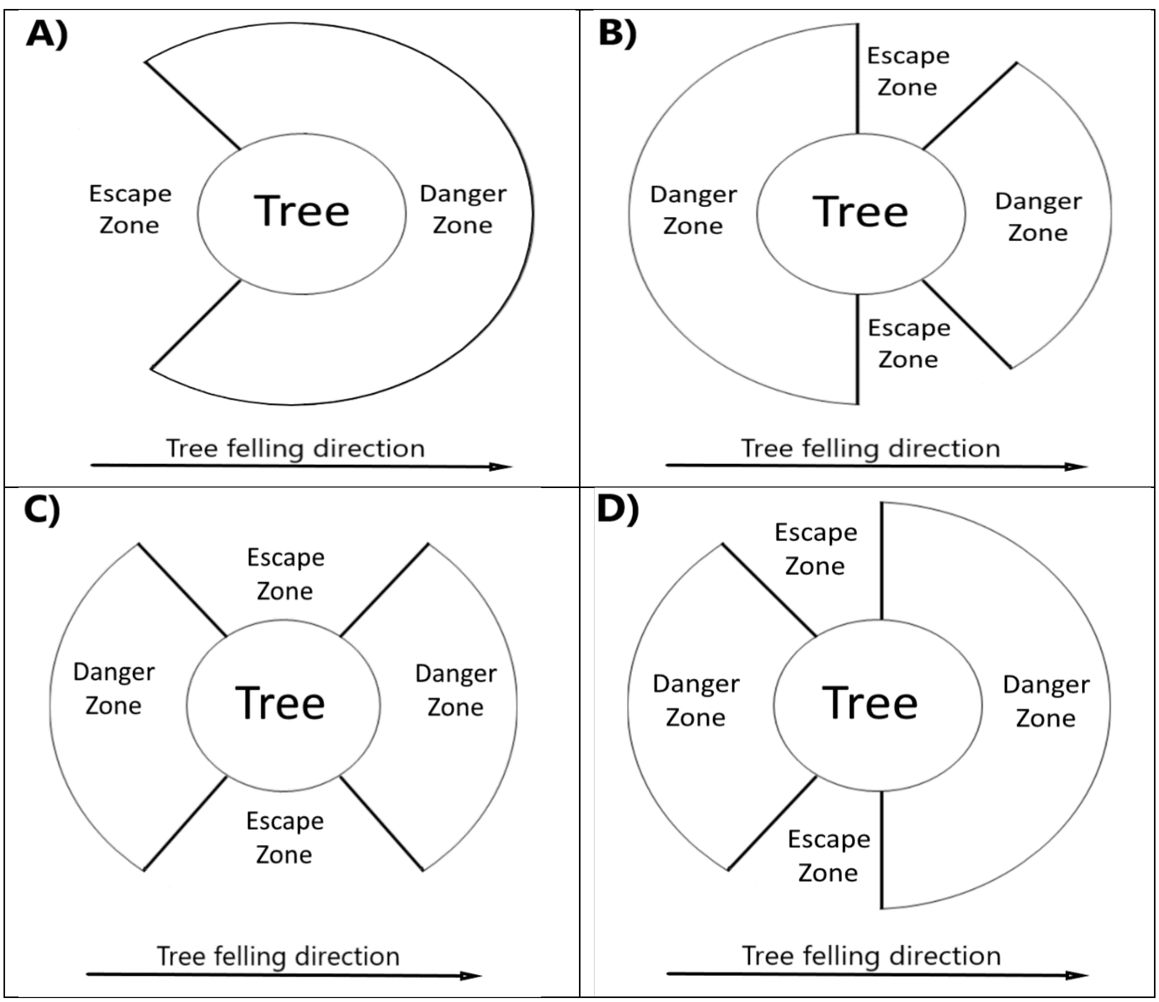
Part III

Circle one answer (letter) for each question.

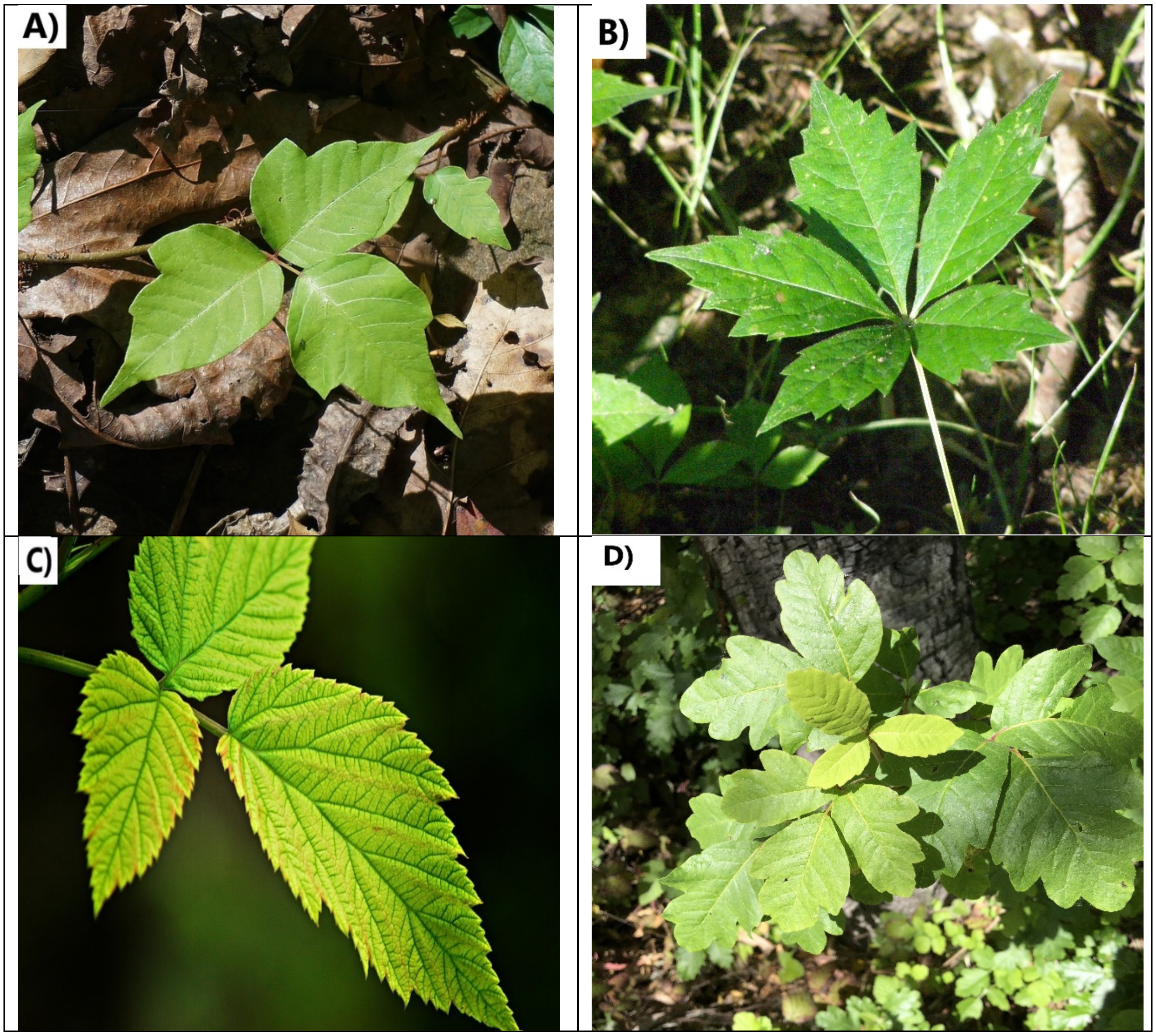
1- Which of the following shadowed areas represents the power zone?



2- Which of the following sketches should tree trimmers follow when cutting a tree?



3- Which of the following plants is poison Ivy?



4- Which of the following is the most frequent cause of incidents claimed by KYTC highway maintenance workers?

E) Lifting	F) Falling from different levels
G) Flying objects	H) Hand tools and equipment

5- Which of the following is the most frequent injury claimed by KYTC highway maintenance workers?

E) Strained by	F) Fall or slip
G) Cut, puncture, or scrape	H) Struck by

6- When falling a tree, no one except the feller should be within:

E) One tree length of the falling tree	F) Two tree lengths of the falling tree
G) Three tree lengths of the falling tree	H) Four tree lengths of the falling tree

----

Part IV: Rating the toolbox

Circle only one answer for each of the following six questions

1- Which format of the toolbox was practical and easier to use and understand?

A) Excel toolbox	B) Binder (hard copy)

2- Overall, how would you rate the toolbox?

A) Poor	B) Fair	C) Good	D) Very good	E) Excellent

3- How well the toolbox was in addressing common work safety hazards?

0 1 2 3 4 5 6 7 8 9 10

4- Would like to continue using the toolbox?

A) Yes	B) No

5- Do you think the toolbox need improvement, such as including more practices, more examples, more hazards, changing the layout, etc.?

A) Yes	B) No

If yes, briefly describe:_ _

6- Is using the toolbox more of a hindrance or a help to you being able to do your work well?

A) Hindrance	B) Help

A.4. Workers post-use reaction and knowledge evaluation questions

Hazard Identification Questionnaire

Confidentiality: your answers to the questions in this survey will be anonymous and will never be linked to you personally.

This survey consists of two parts (A & B). Please, answer all the questions and return the survey in the envelope to your supervisor.

In case you have any question about this survey, feel free to contact at (_______________).

Part A

Circle only one answer for each question in this part.

1- How helpful were the safety talks to you in the following areas?

	Not helpful	Somewhat helpful	Very helpful
a- Recognizing work safety hazards	**1**	**2**	**3**
b- Identifying hazards causes	**1**	**2**	**3**
c- Knowing what to do to avoid work incidents	**1**	**2**	**3**
d- Get the job done safely	**1**	**2**	**3**

2- Would you like safety talks to continue on weekly basis?	**Yes**	**No**
3- In the last three months, did you ask or was asked questions about safety during the safety talks?	**Yes**	**No**
4- In the last three months, has your supervisor asked you to demonstrate any safety practice during the safety talk?	**Yes**	**No**

5- On average, how long does the safety talk last?

A) Less than 10 minutes	**B)** About 15 minutes	**C)** About 20 minutes	**D)** More than 30 minutes

6- In the last three months, how often did your supervisor give a safety talk?

A) Never	**B)** Once a month	**C)** Once a week	**D)** Twice a week	**E)** Every day

7- Overall, how would you rate the safety talks?

0 1 2 3 4 5 6 7 8 9 10

Part B

The following pages have different images of highway maintenance work tasks with brief description of each task. Each of these tasks can cause a work incident that may result in an injury or damage. We would like you to identify what could go wrong in each task, why it may happen, and what can be done to prevent the harm.

Answering procedures:

5- On each photo, circle the area where you see a potential incident that could occur.
6- Under each photo, you have a table of three columns where you can describe the possible incident in the left column, the cause of incident in the middle column, and what can be done to prevent the incident in the right column.
7- In the left column there is a box that looks like this

1	2	3	4	5

In this box you can rate how frequently the incident could occur as shown below:

1	2	3	4	5
Never	Rare	Sometimes	Very often	Always

8- If you see more than one possible incident in one photo, you can number each area you circle on the photo.

In this photo, the maintenance crew are trying to install the new guardrail.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

In this photo, the workers in this photo are trying to pull brush to haul it from highway.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

In this photo, workers are doing concrete work repair under bridge in high wind day.

Incident	Cause	Prevention
1 | 2 | 3 | 4 | 5		
1 | 2 | 3 | 4 | 5		
1 | 2 | 3 | 4 | 5		
1 | 2 | 3 | 4 | 5		

In this photo, workers are replacing old guardrail with new one.

Incident	Cause	Prevention
1 | 2 | 3 | 4 | 5		
1 | 2 | 3 | 4 | 5		
1 | 2 | 3 | 4 | 5		

In this photo, workers are trying to install a concrete pipe.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

The worker here is trying to lift the new traffic light to his coworker on the aerial lift.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

The worker on the aerial lift is trying to install new traffic sign in high wind day.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

In this photo, the operator is checking the level of salt left in the spreader.

Incident	Cause	Prevention
1 2 3 4 5		
1 2 3 4 5		
1 2 3 4 5		

A.5. Supervisors post-use interview questions

1- Have you used the toolbox to deliver a pre-task safety talk ?

   If Yes, go to question 4

2- Did you have the chance to go through the toolbox or read some if it?
   - A- If Yes, do you think the toolbox is relevant to highway maintenance and address the common safety issues? Go to question 3
   - B- If No, go to question 3.

3- Was there any reason that prevented you from using the toolbox?
4- How would you rate the toolbox in helping you and your crew to get the job done safely?
5- How relevant is the toolbox content to the daily maintenance work you perform?
6- Did you find any weakness in the toolbox content or format?
7- What barriers prevented or hindered you from using the toolbox and conducting safety talks?
8- Do you have any suggestion to improve the toolbox and the quality of safety talks?

Appendix B. Statistical Analysis Codes and Outputs

This appendix shows the SAS code used in and the output of the statistical analysis of evaluation data.

B.1. SAS code for logistic regression analysis of safety knowledge data

```
proc import out=Work.kdata
Datafile="File path"
DBMS= xlsx; run;
proc glimmix data = kdata ;
class crew subject operation intervention ;
model hidentified/htotal = operation|intervention / dist=bin;
random subject(crew);
lsmeans operation*intervention / slice = operation ilink;
ods output lsmeans = cell_means; run;
proc glimmix data = kdata ;
class crew subject operation intervention ;
model cidentified/ctotal = operation|intervention / dist=bin;
random subject(crew);
lsmeans operation*intervention / slice = operation ilink;
ods output lsmeans = cell_means; run;
proc glimmix data = kdata;
class crew subject operation intervention ;
model pidentified/ptotal = operation|intervention / dist=bin;
lsmeans operation*intervention / slice = operation ilink;
ods output lsmeans = cell_means; run;
proc glimmix data = kdata ; class crew subject operation intervention ;
model Score/Total = operation|intervention / dist=bin;
random subject(crew);
lsmeans operation*intervention / slice = operation ilink;
ods output lsmeans = cell_means; run;
```

B.2. SAS code for logistic regression analysis of safety behavior data

```
proc import out=Work.Behaviordata
Datafile="File path"
DBMS= xlsx;
run;
proc glimmix data = Behaviordata;
where Behavior ^= .;
class Intervention Subject Crew Operation Date;
model Behavior = Intervention Operation Intervention*Operation / dist = bin link = logit
;
random subject(crew date);
lsmeans intervention intervention*operation / diff ilink;
ods output lsmeans = cell_means;
run;
proc sgplot data = cell_means; where operation ^= .; series x = operation y = Mu / group
= intervention; run;
proc freq data = Behaviordata; table operation*intervention; run;
proc sgplot data = cell_means; where operation ^= .; scatter x = operation y = mu /
markerattrs = (symbol=circlefilled) group = intervention;
series x = operation y = Mu / group = intervention lineattrs = (thickness=1) ; run;
```

B.3. Logistic regression analysis outputs of the safety knowledge assessments

The SAS System

The GLIMMIX Procedure

Model Information	
Data Set	WORK.KDATA
Response Variable (Events)	Incident Identified
Response Variable (Trials)	Incidents Total
Response Distribution	Binomial
Link Function	Logit
Variance Function	Default
Variance Matrix	Not blocked
Estimation Technique	Residual PL
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
Crew	13	1 2 3 4 5 6 7 8 9 10 11 12 13
Subject	10	1 2 3 4 5 6 7 8 9 10
Operation	10	1 2 3 4 5 6 7 8 9 10
Intervention	2	0 1

Number of Observations Read	2664
Number of Observations Used	2458
Number of Events	2240
Number of Trials	4381

Dimensions	
G-side Cov. Parameters	1
Columns in X	30
Columns in Z	89
Subjects (Blocks in V)	1
Max Obs per Subject	2458

Optimization Information	
Optimization Technique	Dual Quasi-Newton
Parameters in Optimization	1
Lower Boundaries	1
Upper Boundaries	0
Fixed Effects	Profiled
Starting From	Data

Iteration History					
Iteration	**Restarts**	**Subiterations**	**Objective Function**	**Change**	**Max Gradient**
0	**0**	**5**	9435.6686121	2.00000000	0.000032
1	**0**	**3**	9704.6101601	0.47686478	0.000605
2	**0**	**2**	9824.2146751	0.06293049	0.000073
3	**0**	**2**	9848.3701561	0.00148056	8.387E-8
4	**0**	**2**	9849.3459262	0.00002041	6.167E-9
5	**0**	**1**	9849.349009	0.00000032	3.628E-6
6	**0**	**0**	9849.3490318	0.00000000	2.88E-6

Convergence criterion (PCONV=1.11022E-8) satisfied.

Fit Statistics	
-2 Res Log Pseudo-Likelihood	9849.35
Generalized Chi-Square	1989.51
Gener. Chi-Square / DF	0.82

Covariance Parameter Estimates		
Cov Parm	Estimate	Standard Error
Subject(Crew)	0.1668	0.04326

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Operation	9	2353	24.06	<.0001
Intervention	1	2353	71.62	<.0001
Operation*Intervention	6	2353	3.67	0.0012

Operation*Intervention Least Squares Means								
Operation	Intervention	Estimate	Standard Error	DF	t Value	Pr > |t|	Mean	Standard Error Mean
1	0	-0.05594	0.1072	2353	-0.52	0.6017	0.4860	0.02677
2	0	-0.5364	0.1301	2353	-4.12	<.0001	0.3690	0.03030
2	1	0.3190	0.2242	2353	1.42	0.1548	0.5791	0.05464
3	0	-0.5554	0.08483	2353	-6.55	<.0001	0.3646	0.01965
4	0	-0.1097	0.1819	2353	-0.60	0.5464	0.4726	0.04533

Operation*Intervention Least Squares Means								
Operation	**Intervention**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Mean**	**Standard Error Mean**
4	1	2.4033	1.0696	2353	2.25	0.0247	0.9171	0.08134
5	0	1.0461	0.1680	2353	6.23	<.0001	0.7400	0.03232
5	1	3.3105	0.5929	2353	5.58	<.0001	0.9648	0.02014
6	0	0.1431	0.1254	2353	1.14	0.2540	0.5357	0.03118
6	1	2.3051	0.2411	2353	9.56	<.0001	0.9093	0.01988
7	0	-0.4588	0.1262	2353	-3.64	0.0003	0.3873	0.02995
7	1	1.1201	0.1731	2353	6.47	<.0001	0.7540	0.03211
8	0	-0.09252	0.1029	2353	-0.90	0.3688	0.4769	0.02568
8	1	0.6965	0.2568	2353	2.71	0.0067	0.6674	0.05701
9	0	3.5665	0.5105	2353	6.99	<.0001	0.9725	0.01364
10	0	-1.0260	0.1204	2353	-8.52	<.0001	0.2639	0.02339
10	1	0.3935	0.1755	2353	2.24	0.0251	0.5971	0.04223

Tests of Effect Slices for Operation*Intervention Sliced By Operation				
Operation	**Num DF**	**Den DF**	**F Value**	**Pr > F**
1	0	.	.	.
2	1	2353	11.44	0.0007
3	0	.	.	.
4	1	2353	5.38	0.0205
5	1	2353	13.62	0.0002
6	1	2353	66.64	<.0001
7	1	2353	59.03	<.0001
8	1	2353	8.49	0.0036
9	0	.	.	.
10	1	2353	47.89	<.0001

The SAS System

The GLIMMIX Procedure

Model Information	
Data Set	WORK.KDATA
Response Variable (Events)	Causes Identified
Response Variable (Trials)	Causes Total
Response Distribution	Binomial
Link Function	Logit
Variance Function	Default
Variance Matrix	Not blocked
Estimation Technique	Residual PL
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
Crew	13	1 2 3 4 5 6 7 8 9 10 11 12 13
Subject	10	1 2 3 4 5 6 7 8 9 10
Operation	10	1 2 3 4 5 6 7 8 9 10
Intervention	2	0 1

Number of Observations Read	2664
Number of Observations Used	2456
Number of Events	1812
Number of Trials	4770

Dimensions	
G-side Cov. Parameters	1
Columns in X	30
Columns in Z	89
Subjects (Blocks in V)	1
Max Obs per Subject	2456

Optimization Information	
Optimization Technique	Dual Quasi-Newton
Parameters in Optimization	1
Lower Boundaries	1
Upper Boundaries	0
Fixed Effects	Profiled
Starting From	Data

Iteration History					
Iteration	**Restarts**	**Subiterations**	**Objective Function**	**Change**	**Max Gradient**
0	**0**	**4**	9647.8135996	1.01033806	0.000223
1	**0**	**3**	9727.5691977	0.02541540	0.000034
2	**0**	**2**	9734.4011979	0.00069273	7.598E-8
3	**0**	**1**	9734.5054877	0.00001195	1.73E-7
4	**0**	**1**	9734.506965	0.00000098	0.000119
5	**0**	**1**	9734.5070858	0.00000079	3.129E-7
6	**0**	**0**	9734.5069884	0.00000000	1.425E-6

Convergence criterion (PCONV=1.11022E-8) satisfied.

Fit Statistics	
-2 Res Log Pseudo-Likelihood	9734.51
Generalized Chi-Square	2301.67
Gener. Chi-Square / DF	0.94

Covariance Parameter Estimates		
Cov Parm	**Estimate**	**Standard Error**
Subject(Crew)	0.2665	0.06013

Type III Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Operation	9	2351	21.65	<.0001
Intervention	1	2351	105.21	<.0001
Operation*Intervention	6	2351	4.88	<.0001

Operation*Intervention Least Squares Means								
Operation	Intervention	Estimate	Standard Error	DF	t Value	Pr > |t|	Mean	Standard Error Mean
1	0	-1.0889	0.1244	2351	-8.75	<.0001	0.2518	0.02344
2	0	-1.5023	0.1421	2351	-10.57	<.0001	0.1821	0.02116
2	1	-0.2381	0.1961	2351	-1.21	0.2248	0.4408	0.04833
3	0	-0.6318	0.09798	2351	-6.45	<.0001	0.3471	0.02220
4	0	-0.2621	0.1880	2351	-1.39	0.1633	0.4348	0.04619
4	1	1.6008	0.8108	2351	1.97	0.0485	0.8321	0.1133
5	0	-0.3662	0.1323	2351	-2.77	0.0057	0.4095	0.03199
5	1	1.7397	0.2689	2351	6.47	<.0001	0.8506	0.03417
6	0	-1.3578	0.1304	2351	-10.41	<.0001	0.2046	0.02122
6	1	0.5433	0.1316	2351	4.13	<.0001	0.6326	0.03058
7	0	-1.0998	0.1443	2351	-7.62	<.0001	0.2498	0.02704
7	1	0.4035	0.1593	2351	2.53	0.0114	0.5995	0.03824
8	0	-0.3023	0.1100	2351	-2.75	0.0060	0.4250	0.02689
8	1	0.1069	0.2486	2351	0.43	0.6672	0.5267	0.06198
9	0	1.0891	0.2053	2351	5.30	<.0001	0.7482	0.03869

Operation*Intervention Least Squares Means								
Operation	Intervention	Estimate	Standard Error	DF	t Value	Pr > |t|	Mean	Standard Error Mean
10	0	-1.3491	0.1338	2351	-10.08	<.0001	0.2060	0.02189
10	1	0.07657	0.1778	2351	0.43	0.6668	0.5191	0.04439

Tests of Effect Slices for Operation*Intervention Sliced By Operation				
Operation	Num DF	Den DF	F Value	Pr > F
1	0	.	.	.
2	1	2351	30.07	<.0001
3	0	.	.	.
4	1	2351	5.04	0.0248
5	1	2351	52.56	<.0001
6	1	2351	127.40	<.0001
7	1	2351	56.17	<.0001
8	1	2351	2.45	0.1179
9	0	.	.	.
10	1	2351	46.11	<.0001

The SAS System

The GLIMMIX Procedure

Model Information	
Data Set	WORK.KDATA
Response Variable (Events)	Prevention Identified
Response Variable (Trials)	Prevention Total
Response Distribution	Binomial
Link Function	Logit

Model Information	
Variance Function	Default
Variance Matrix	Diagonal
Estimation Technique	Maximum Likelihood
Degrees of Freedom Method	Residual

Class Level Information		
Class	**Levels**	**Values**
Crew	13	1 2 3 4 5 6 7 8 9 10 11 12 13
Subject	10	1 2 3 4 5 6 7 8 9 10
Operation	10	1 2 3 4 5 6 7 8 9 10
Intervention	2	0 1

Number of Observations Read	2664
Number of Observations Used	2462
Number of Events	1842
Number of Trials	5578

Dimensions	
Columns in X	30
Columns in Z	0
Subjects (Blocks in V)	1
Max Obs per Subject	2462

Optimization Information	
Optimization Technique	Newton-Raphson
Parameters in Optimization	17
Lower Boundaries	0

Optimization Information	
Upper Boundaries	0
Fixed Effects	Not Profiled

Iteration History					
Iteration	Restarts	Evaluations	Objective Function	Change	Max Gradient
0	**0**	4	2069.0267726	.	47.10199
1	**0**	3	2065.2474384	3.77933422	1.76685
2	**0**	3	2065.2312735	0.01616490	0.009541
3	**0**	3	2065.2312726	0.00000094	6.156E-7

Convergence criterion (GCONV=1E-8) satisfied.

Fit Statistics	
-2 Log Likelihood	4130.46
AIC (smaller is better)	4164.46
AICC (smaller is better)	4164.71
BIC (smaller is better)	4263.21
CAIC (smaller is better)	4280.21
HQIC (smaller is better)	4200.34
Pearson Chi-Square	2188.66
Pearson Chi-Square / DF	0.90

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Operation	9	2445	27.14	<.0001
Intervention	1	2445	207.76	<.0001
Operation*Intervention	6	2445	5.56	<.0001

Operation*Intervention Least Squares Means								
Operation	Intervention	Estimate	Standard Error	DF	t Value	Pr > |t|	Mean	Standard Error Mean
1	0	-1.4232	0.1048	2445	-13.58	<.0001	0.1942	0.01640
2	0	-1.9076	0.1229	2445	-15.52	<.0001	0.1293	0.01383
2	1	-0.4055	0.1521	2445	-2.66	0.0077	0.4000	0.03651
3	0	-0.5749	0.07891	2445	-7.29	<.0001	0.3601	0.01818
4	0	-0.7566	0.1323	2445	-5.72	<.0001	0.3194	0.02875
4	1	0.5390	0.4756	2445	1.13	0.2572	0.6316	0.1107
5	0	-0.3478	0.1168	2445	-2.98	0.0029	0.4139	0.02834
5	1	1.9859	0.2850	2445	6.97	<.0001	0.8793	0.03025
6	0	-1.0199	0.09823	2445	-10.38	<.0001	0.2650	0.01914
6	1	0.5232	0.1052	2445	4.98	<.0001	0.6279	0.02457
7	0	-2.2336	0.1921	2445	-11.63	<.0001	0.09677	0.01679
7	1	-0.1679	0.1409	2445	-1.19	0.2335	0.4581	0.03497
8	0	-0.3210	0.08291	2445	-3.87	0.0001	0.4204	0.02020
8	1	0.1900	0.2061	2445	0.92	0.3566	0.5474	0.05107
9	0	-2.1893	0.2818	2445	-7.77	<.0001	0.1007	0.02553

Operation*Intervention Least Squares Means								
Operation	Intervention	Estimate	Standard Error	DF	t Value	Pr > |t|	Mean	Standard Error Mean
10	0	-1.1638	0.1151	2445	-10.11	<.0001	0.2380	0.02088
10	1	0.2113	0.1631	2445	1.30	0.1953	0.5526	0.04033

Tests of Effect Slices for Operation*Intervention Sliced By Operation				
Operation	Num DF	Den DF	F Value	Pr > F
1	0	.	.	.
2	1	2445	58.98	<.0001
3	0	.	.	.
4	1	2445	6.89	0.0087
5	1	2445	57.40	<.0001
6	1	2445	114.99	<.0001
7	1	2445	75.19	<.0001
8	1	2445	5.29	0.0215
9	0	.	.	.
10	1	2445	47.43	<.0001

The SAS System

The GLIMMIX Procedure

Model Information	
Data Set	WORK.KDATA
Response Variable (Events)	Score
Response Variable (Trials)	Total
Response Distribution	Binomial

Model Information	
Link Function	Logit
Variance Function	Default
Variance Matrix	Not blocked
Estimation Technique	Residual PL
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
Crew	13	1 2 3 4 5 6 7 8 9 10 11 12 13
Subject	10	1 2 3 4 5 6 7 8 9 10
Operation	10	1 2 3 4 5 6 7 8 9 10
Intervention	2	0 1

Number of Observations Read	2664
Number of Observations Used	2459
Number of Events	5863
Number of Trials	14721

Dimensions	
G-side Cov. Parameters	1
Columns in X	30
Columns in Z	89
Subjects (Blocks in V)	1
Max Obs per Subject	2459

Optimization Information	
Optimization Technique	Dual Quasi-Newton
Parameters in Optimization	1
Lower Boundaries	1

Optimization Information	
Upper Boundaries	0
Fixed Effects	Profiled
Starting From	Data

Iteration History					
Iteration	**Restarts**	**Subiterations**	**Objective Function**	**Change**	**Max Gradient**
0	**0**	**5**	8041.5624605	2.00000000	0.000255
1	**0**	**3**	8339.1755749	0.11869572	0.000955
2	**0**	**2**	8364.2871664	0.00109135	2.686E-7
3	**0**	**2**	8364.546188	0.00001122	2.899E-9
4	**0**	**1**	8364.5471249	0.00000060	0.000135
5	**0**	**1**	8364.5471738	0.00000057	7.598E-6
6	**0**	**0**	8364.5471273	0.00000000	6.898E-6

Convergence criterion (PCONV=1.11022E-8) satisfied.

Fit Statistics	
-2 Res Log Pseudo-Likelihood	8364.55
Generalized Chi-Square	3777.99
Gener. Chi-Square / DF	1.55

Covariance Parameter Estimates		
Cov Parm	**Estimate**	**Standard Error**
Subject(Crew)	0.2334	0.04351

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Operation	9	2354	51.73	<.0001
Intervention	1	2354	373.94	<.0001
Operation*Intervention	6	2354	10.80	<.0001

Operation*Intervention Least Squares Means								
Operation	Intervention	Estimate	Standard Error	DF	t Value	Pr > |t|	Mean	Standard Error Mean
1	0	-0.8994	0.07801	2354	-11.53	<.0001	0.2892	0.01604
2	0	-1.4073	0.08797	2354	-16.00	<.0001	0.1967	0.01390
2	1	-0.2736	0.1173	2354	-2.33	0.0198	0.4320	0.02879
3	0	-0.6298	0.06854	2354	-9.19	<.0001	0.3476	0.01554
4	0	-0.5027	0.1051	2354	-4.78	<.0001	0.3769	0.02469
4	1	1.1361	0.3683	2354	3.08	0.0021	0.7570	0.06777
5	0	-0.04284	0.08897	2354	-0.48	0.6302	0.4893	0.02223
5	1	2.1975	0.1969	2354	11.16	<.0001	0.9000	0.01772
6	0	-0.8370	0.08074	2354	-10.37	<.0001	0.3022	0.01702
6	1	0.7792	0.08977	2354	8.68	<.0001	0.6855	0.01935
7	0	-1.1686	0.09335	2354	-12.52	<.0001	0.2371	0.01689
7	1	0.3646	0.1001	2354	3.64	0.0003	0.5902	0.02422

Operation*Intervention Least Squares Means								
Operation	**Intervention**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Mean**	**Standard Error Mean**
8	0	-0.2827	0.07371	2354	-3.83	0.0001	0.4298	0.01806
8	1	0.2446	0.1458	2354	1.68	0.0935	0.5608	0.03590
9	0	0.4199	0.1147	2354	3.66	0.0003	0.6035	0.02745
10	0	-1.2277	0.08528	2354	-14.40	<.0001	0.2266	0.01494
10	1	0.2049	0.1109	2354	1.85	0.0648	0.5510	0.02743

Tests of Effect Slices for Operation*Intervention Sliced By Operation				
Operation	**Num DF**	**Den DF**	**F Value**	**Pr > F**
1	0	.	.	.
2	1	2354	78.14	<.0001
3	0	.	.	.
4	1	2354	18.91	<.0001
5	1	2354	120.52	<.0001
6	1	2354	279.87	<.0001
7	1	2354	174.24	<.0001
8	1	2354	12.86	0.0003
9	0	.	.	.
10	1	2354	141.28	<.0001

B.4. Logistic regression analysis outputs of the behavior change evaluation

The SAS System

The GLIMMIX Procedure

Model Information	
Data Set	WORK.BEHAVIORDATA
Response Variable	Behavior
Response Distribution	Binomial
Link Function	Logit
Variance Function	Default
Variance Matrix	Not blocked
Estimation Technique	Residual PL
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
Intervention	2	0 1
Subject	4	1 2 3 4
Crew	11	1 2 3 4 5 6 7 8 9 10 11
Operation	7	1 2 3 4 5 6 7
Date	25	A1 A2 A3 A4 A5 A6 A7 A8 J1 J2 O1 O2 O3 O4 O5 O6 O7 S1 S2 S3 S4 S5 S6 S7 S8

Number of Observations Read	1232
Number of Observations Used	1232

Dimensions	
G-side Cov. Parameters	1
Columns in X	21
Columns in Z	100
Subjects (Blocks in V)	1
Max Obs per Subject	1232

Optimization Information	
Optimization Technique	Dual Quasi-Newton
Parameters in Optimization	1
Lower Boundaries	1
Upper Boundaries	0
Fixed Effects	Profiled
Starting From	Data

Iteration History

Iteration	Restarts	Subiterations	Objective Function	Change	Max Gradient
0	0	2	5426.3203079	0.32835806	3.929E-6
1	0	2	5370.2615899	0.03800829	0.001588
2	0	2	5369.5106109	0.00058461	0.000011
3	0	1	5369.4902428	0.00001690	2.619E-8
4	0	1	5369.4894971	0.00000180	0.000073
5	0	1	5369.4894174	0.00000346	0.00014
6	0	1	5369.4895704	0.00000219	5.891E-7
7	0	0	5369.4894738	0.00000000	5.259E-6

Convergence criterion (PCONV=1.11022E-8) satisfied.

Fit Statistics	
-2 Res Log Pseudo-Likelihood	5369.49
Generalized Chi-Square	1174.33
Gener. Chi-Square / DF	0.96

Covariance Parameter Estimates		
Cov Parm	**Estimate**	**Standard Error**
Subject(Crew*Date)	0.2001	0.08129

Type III Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Intervention	1	1132	52.94	<.0001
Operation	6	1132	1.27	0.2697
Intervention*Operation	3	1132	2.69	0.0452

Intervention*Operation Least Squares Means								
Intervention	**Operation**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Mean**	**Standard Error Mean**
0	1	-0.5485	0.2137	1132	-2.57	0.0104	0.3662	0.04961
0	2	-0.04754	0.3642	1132	-0.13	0.8962	0.4881	0.09101
0	4	-1.5098	0.2931	1132	-5.15	<.0001	0.1810	0.04345
0	5	-0.5491	0.2121	1132	-2.59	0.0098	0.3661	0.04923
0	6	-0.5621	0.1856	1132	-3.03	0.0025	0.3631	0.04292
0	7	-0.8911	0.2911	1132	-3.06	0.0023	0.2909	0.06003

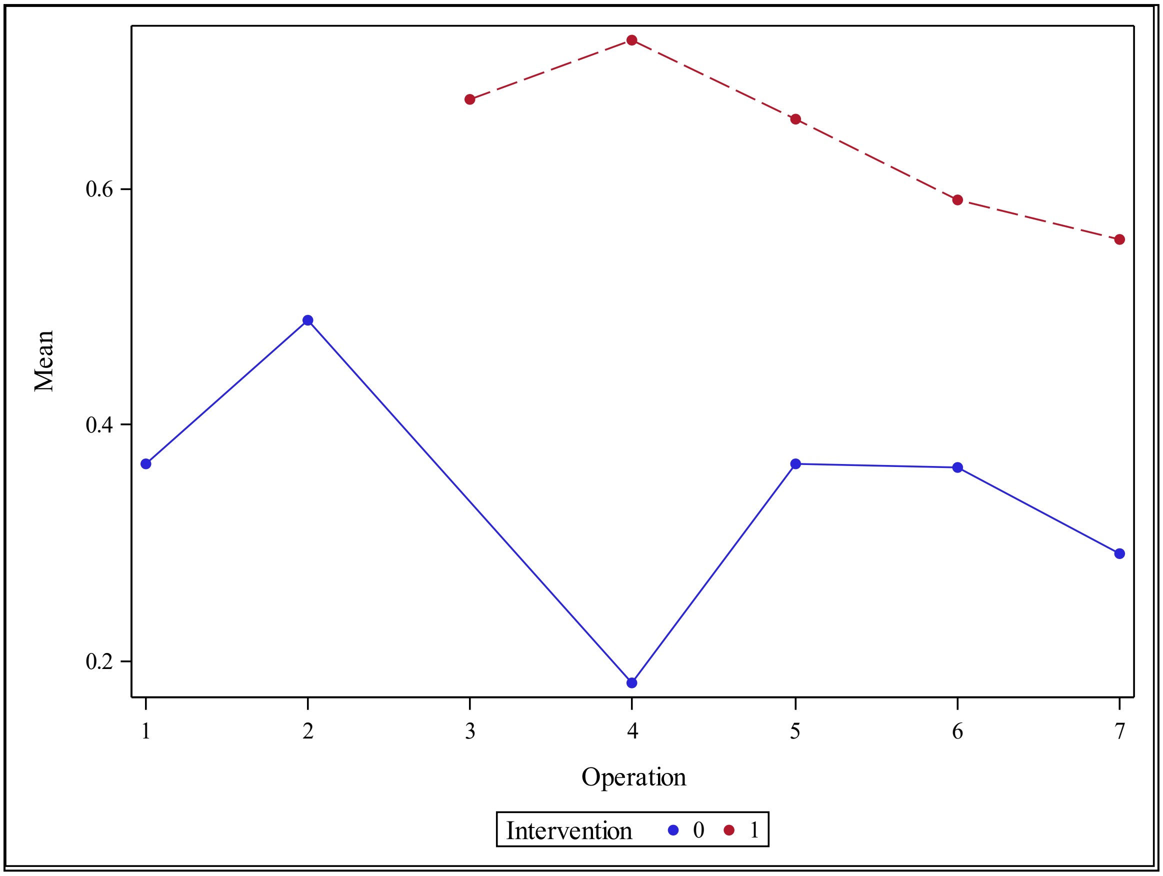
Intervention*Operation Least Squares Means								
Intervention	Operation	Estimate	Standard Error	DF	t Value	Pr > |t|	Mean	Standard Error Mean
1	3	0.7354	0.4073	1132	1.81	0.0713	0.6760	0.08922
1	4	0.9721	0.3857	1132	2.52	0.0119	0.7255	0.07681
1	5	0.6551	0.2175	1132	3.01	0.0027	0.6582	0.04893
1	6	0.3669	0.1840	1132	1.99	0.0464	0.5907	0.04448
1	7	0.2266	0.3752	1132	0.60	0.5460	0.5564	0.09262

Differences of Intervention*Operation Least Squares Means								
Intervention	Operation	Intervention	Operation	Estimate	Standard Error	DF	t Value	Pr > |t|
0	1	0	2	-0.5010	0.4223	1132	-1.19	0.2358
0	1	0	4	0.9613	0.3628	1132	2.65	0.0082
0	1	0	5	0.000623	0.3011	1132	0.00	0.9983
0	1	0	6	0.01364	0.2831	1132	0.05	0.9616
0	1	0	7	0.3426	0.3611	1132	0.95	0.3429
0	1	1	3	-1.2839	0.4600	1132	-2.79	0.0053
0	1	1	4	-1.5206	0.4410	1132	-3.45	0.0006
0	1	1	5	-1.2036	0.3049	1132	-3.95	<.0001
0	1	1	6	-0.9154	0.2820	1132	-3.25	0.0012
0	1	1	7	-0.7751	0.4318	1132	-1.79	0.0729
0	2	0	4	1.4622	0.4676	1132	3.13	0.0018
0	2	0	5	0.5016	0.4215	1132	1.19	0.2343
0	2	0	6	0.5146	0.4088	1132	1.26	0.2084
0	2	0	7	0.8436	0.4662	1132	1.81	0.0707

Differences of Intervention*Operation Least Squares Means								
Intervention	Operation	Intervention	Operation	Estimate	Standard Error	DF	t Value	Pr > |t|
0	2	1	3	-0.7830	0.5464	1132	-1.43	0.1522
0	2	1	4	-1.0196	0.5305	1132	-1.92	0.0549
0	2	1	5	-0.7026	0.4242	1132	-1.66	0.0979
0	2	1	6	-0.4144	0.4081	1132	-1.02	0.3101
0	2	1	7	-0.2742	0.5230	1132	-0.52	0.6002
0	4	0	5	-0.9606	0.3619	1132	-2.65	0.0080
0	4	0	6	-0.9476	0.3470	1132	-2.73	0.0064
0	4	0	7	-0.6186	0.4131	1132	-1.50	0.1345
0	4	1	3	-2.2452	0.5019	1132	-4.47	<.0001
0	4	1	4	-2.4819	0.4845	1132	-5.12	<.0001
0	4	1	5	-2.1648	0.3650	1132	-5.93	<.0001
0	4	1	6	-1.8766	0.3461	1132	-5.42	<.0001
0	4	1	7	-1.7364	0.4762	1132	-3.65	0.0003
0	5	0	6	0.01301	0.2819	1132	0.05	0.9632
0	5	0	7	0.3420	0.3602	1132	0.95	0.3425
0	5	1	3	-1.2845	0.4593	1132	-2.80	0.0052
0	5	1	4	-1.5212	0.4402	1132	-3.46	0.0006
0	5	1	5	-1.2042	0.3038	1132	-3.96	<.0001
0	5	1	6	-0.9160	0.2808	1132	-3.26	0.0011
0	5	1	7	-0.7758	0.4311	1132	-1.80	0.0722
0	6	0	7	0.3290	0.3452	1132	0.95	0.3408
0	6	1	3	-1.2976	0.4476	1132	-2.90	0.0038
0	6	1	4	-1.5342	0.4280	1132	-3.58	0.0004
0	6	1	5	-1.2172	0.2859	1132	-4.26	<.0001
0	6	1	6	-0.9290	0.2613	1132	-3.55	0.0004
0	6	1	7	-0.7888	0.4186	1132	-1.88	0.0598
0	7	1	3	-1.6266	0.5006	1132	-3.25	0.0012

Differences of Intervention*Operation Least Squares Means								
Intervention	**Operation**	**Intervention**	**Operation**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
0	7	1	4	-1.8632	0.4832	1132	-3.86	0.0001
0	7	1	5	-1.5462	0.3633	1132	-4.26	<.0001
0	7	1	6	-1.2580	0.3443	1132	-3.65	0.0003
0	7	1	7	-1.1178	0.4749	1132	-2.35	0.0188
1	3	1	4	-0.2367	0.5610	1132	-0.42	0.6732
1	3	1	5	0.08033	0.4618	1132	0.17	0.8619
1	3	1	6	0.3685	0.4470	1132	0.82	0.4098
1	3	1	7	0.5088	0.5538	1132	0.92	0.3585
1	4	1	5	0.3170	0.4428	1132	0.72	0.4742
1	4	1	6	0.6052	0.4273	1132	1.42	0.1570
1	4	1	7	0.7455	0.5381	1132	1.39	0.1662
1	5	1	6	0.2882	0.2848	1132	1.01	0.3119
1	5	1	7	0.4284	0.4337	1132	0.99	0.3234
1	6	1	7	0.1402	0.4179	1132	0.34	0.7372

Table of Operation by Intervention			
Operation(Operation)	**Intervention(Intervention)**		
Frequency Percent Row Pct Col Pct	**0**	**1**	**Total**
1	180 12.00 100.00 20.00	0 0.00 0.00 0.00	180 12.00
2	60 4.00 100.00 6.67	0 0.00 0.00 0.00	60 4.00
3	0 0.00 0.00 0.00	60 4.00 100.00 10.00	60 4.00
4	120 8.00 66.67 13.33	60 4.00 33.33 10.00	180 12.00
5	180 12.00 50.00 20.00	180 12.00 50.00 30.00	360 24.00
6	240 16.00 50.00 26.67	240 16.00 50.00 40.00	480 32.00
7	120 8.00 66.67 13.33	60 4.00 33.33 10.00	180 12.00
Total	900 60.00	600 40.00	1500 100.00



0.6
0.4
0.2
Mean
1
2
3
4
5
6
7
Operation
Intervention 0 1

Appendix C. IRB research protocol approval

University of Kentucky | Office of Research Integrity
IRB, RDRC

EXEMPTION CERTIFICATION

IRB Number: 44600

TO: Zamaan Al-shabbani Civil Engineering
PI phone #: 8594202361

PI email: zamaan_bc@uky.edu

FROM: Chairperson/Vice Chairperson
Non Medical
Institutional Review Board (IRB)
SUBJECT: Approval for Exemption Certification
DATE: 8/8/2018

On 8/8/2018, it was determined that your project entitled "*Improving safety performance of highway maintenance crews through pre-task safety toolbox talks*" meets federal criteria to qualify as an exempt study.

Because the study has been certified as exempt, you will not be required to complete continuation or final review reports. However, it is your responsibility to notify the IRB prior to making any changes to the study. Please note that changes made to an exempt protocol may disqualify it from exempt status and may require an expedited or full review.

The Office of Research Integrity will hold your exemption application for six years. Before the end of the sixth year, you will be notified that your file will be closed and the application destroyed. If your project is still ongoing, you will need to contact the Office of Research Integrity upon receipt of that letter and follow the instructions for completing a new exemption application. It is, therefore, important that you keep your address current with the Office of Research Integrity.

For information describing investigator responsibilities after obtaining IRB approval, download and read the document "PI Guidance to Responsibilities, Qualifications, Records and Documentation of Human Subjects Research" available in the online Office of Research Integrity's IRB Survival Handbook. Additional information regarding IRB review, federal regulations, and institutional policies may be found through ORI's web site. If you have questions, need additional information, or would like a paper copy of the above mentioned document, contact the Office of Research Integrity at 859-257-9428.

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Journal Papers

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Presentations

- Towards improving safety performance of transportation maintenance workers through a pre-task safety talk. Presented at the Construction Research Congress (CRC), New Orleans, LA, April 2018.
- Preparation and presentation of safety refreshers and pre-task safety briefings. Presented at the Kentucky Transportation Cabinet (KYTC), Lexington, KY, July 2018.
- Improving safety awareness of Kentucky maintenance employees through pre-task safety talks. Presented at the Department of Civil Engineering/ University of Kentucky. November 2018.