MULTI-PHASE EMPIRICAL INVESTIGATION AND PATH MODELING OF CONSTRUCTION WORKERS’ USE OF PERSONAL FALL ARREST SYSTEMS

DISSERTATION
Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate School
of The Ohio State University

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* * * * *
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2008

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ABSTRACT

Personal Fall Arrest Systems (PFAS) are required use by the Occupational Safety and Health Administration for construction employees who work at heights above six feet. However, the literature indicates that current levels of usage of PFAS are not adequate to reduce the number of fall-related injuries. To date, there are no published models describing PFAS usage and factors affecting that usage. Therefore, the objective of this research was to propose and develop a model that presents the main factors affecting PFAS use, including their interactions, in order to improve the understanding of factors that affect PFAS use. In the long term, such knowledge may help to increase PFAS use among construction workers.

Survey, interviews and participatory workshops were applied in the first three phases of this study to supplement the published literature in assisting us to analyze current usage of PFAS among construction workers and views of PFAS from construction workers and other stakeholders in the construction industry. Analysis of data from all these sources led to the development of a preliminary model of PFAS, and selection of the effect of training on PFAS use, in a longitudinal study to test the model.

The Technology Acceptance Model, with modifications from models of health and safety behavior, formed the bases for the preliminary model of PFAS use. In order to investigate the effectiveness of fall protection training in affecting one’s usage intention
and actual behavior of PFAS use, a survey was conducted among PFAS users who attended fall protection training courses. More importantly, two research questions were answered in this phase of the study: what are the significant drivers of PFAS use; and what are the correlations between the factors.

This study provided a theoretical and empirical foundation for understanding the factors contributing to construction workers’ PFAS use. A path model of PFAS use was developed and validated for the first time. The developed model explained 40% of the variance accounting for usage intentions. Perceived Value, Perceived Ease of Use, Subjective Norm and Supervisory Enforcement were determined to be positive drivers of usage intentions. Additionally, the results from this study also showed that fall protection training is effective in improving influence from Perceived value, Perceived Ease of Use and Subjective Norm to one’s usage intention of PFAS.

The anticipated benefit of this study is an improved understanding of PFAS use, which, in turn, may lead to intervention research that targets the factors that have been identified as affecting PFAS use.
Dedicated to my parents
ACKNOWLEDGMENTS

I would like express my deepest gratitude to my adviser, Dr. Carolyn Sommerich who has patiently guided me through this dissertation. She continually gave me support and encouragement throughout my graduate program. Without her, this dissertation will not be complete.

I wish to thank all of the members of my advisory committee for their thoughtful advice and willingness to share their expertise to aid in my research study. Dr. Elizabeth Sanders helped me for my preparation and data analysis of participatory workshops. Dr. Steven Lavender helped me during the construction of the research thoughts and preparation for the survey in this study.

I would like to express my special thanks to the individuals, businesses and organizations who voluntarily participated in this research. Without their support and willingness to participate none of this would have been possible. Their time and effort is much appreciated and will be remembered.

I also thank my colleagues, lab-mates and my statistics consultant for their willingness to help and their patience to my endless queries.

Finally, I would like to thank my husband, Naveen, who has been absolutely supportive, patient and encouraging throughout the progress of my academic program.
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CHAPTER 1

INTRODUCTION

A personal fall arrest system (PFAS) is a type of personal protective equipment used to either arrest a user in the event of a fall or to prevent the user from falling (only when used as a fall restraining device). PFAS is a multiple-component system, which consists of, but is not limited to, an anchorage, connectors and a body harness. It is an Occupational Safety and Health Administration (OSHA) requirement to use one of the three types of fall protection equipment, including guardrail systems, safety net systems and personal fall arrest systems, whenever an employee works on a surface 6 feet or above a lower level, with an unprotected edge.

There are some studies suggesting that proper use of PFAS should reduce number of fall-related injuries (Johnson, Singh & Young, 1998; Kines, 2002; Suruda, 1995). Some articles revealed that use of PFAS is not adequate when it is needed and required. Many researchers attempted to explain the reasons of inadequate PFAS use in the construction industry (Cattledge, et al. 1996b; Chi et al., 2005; Huang & Hinze, 2003). However, relatively few researchers systematically studied the factors that contribute to inadequate PFAS use. Therefore, in this study, a model of PFAS use is proposed for the

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first time to explain the factors that affect PFAS use, and the interactions between the factors.

Prior studies have developed various models explaining factors influencing workers’ self-protective behavior. Becker (1974) proposed the Health Belief Model (HBM) to explain the drivers of self-protective behavior. The drivers in HBM include perception of susceptibility, severity and barriers. In the Health Promotion Model (HPM) which was developed by Pender (1986), the factors that contribute to the use of hearing protection include perceived control of health, definition of health, health status, self-efficacy, benefits and barriers. Karasek and Theorell (1990) took organizational and social factors into consideration when developing a job demands-control-support (DCS) model to study workers’ health-related behavior. McGovern (2000) categorized the factors affecting Personal Protective Equipment (PPE) compliance of universal precautions into personal traits, work-related factors and organizational factors.

However, there are serious knowledge gaps existing in the literature of behavior models and factors affecting PFAS use. None of the models have been applied to study construction workers’ PFAS use. Little research has been done to provide evidence that the factors included in above models contribute to PFAS use. Therefore, reviewing the literature concerning factors affecting specifically on PFAS use, with integration of factors explained in the models of health and safety behavior, was the first step taken in this study to fulfill the research void.

Although prior studies on PFAS use provided suggestions and assumptions of how to improve its usage, many of them were made exclusively from researchers’ perceptions. For an instance, it was suggested in some studies that a more comfortable
PFAS design would increase use behavior (Haslam, Hide & Gibb, 2005; Hinze, Huang & McGlothlin, 2002; Sa, 2005). In order to construct an explicit and thorough model of PFAS use, perspectives from actual users of PFAS—construction workers, as well as other stakeholders in the construction industry—are needed to be collected in the first three phases of this study.

During Phase One, a preliminary survey was distributed to commercial construction workers whose jobs required using PFAS on a regular basis. The preliminary survey was a pilot effort to identify factors affecting PFAS usage from workers’ perspectives.

In Phase Two, interviews were conducted with involvement of supervisors, safety managers, OSHA officers and architects, to collect opinions on PFAS use, in the view of other stakeholders within the construction industry. Findings from the first two phases were consistent with the literature. However, workers and supervisors had different opinions on the reasons that contributed to non-use of PFAS.

In Phase Three, two small group interviews, in the form of participatory workshops, were organized to gather information on how to improve PFAS use. Construction workers, supervisors and safety managers were asked to work together during the workshops and express their ideas as a team. At the end of this phase, information collected from phases one to three was analyzed and discussed. The factors in the model were either reinforced, or requested for further investigation in the last phase of the study. In addition, it was a practical choice to select fall protection training as a factor to be tested in phase four for its effectiveness in the model.
As the last phase of this study, Phase Four finalized and validated the model of PFAS use. The preliminary model of PFAS use was integrated with a modified Technology Acceptance Model (TAM), which is a commonly used model in many studies to evaluate the effectiveness of education and training on decision-making concerning use of new technology (Hu, Clark & Ma, 2003; Venkatesh and Davis, 2000). In order to investigate the effectiveness of fall protection training in affecting one’s usage intention and actual behavior of PFAS use, a survey was conducted among PFAS users who attended fall protection training courses. More importantly, two research questions were answered in this phase: what are the significant drivers of PFAS use; and what are the correlations between the factors.

A review of literature is provided in the next chapter. The four phases of the study are included in Chapter 3, 4, 5 and 6. The conclusion of this study and suggestions for future research are presented in the final chapter.
CHAPTER 2

BACKGROUND & LITERATURE REVIEW

2.1. Construction Industry Injury Statistics

The construction industry has been recognized as one of the most hazardous industries worldwide and falls from heights have always been a major cause of both fatal and non-fatal injuries in construction operations (Chi et al., 2005). In a study of construction accidents that occurred between 1985 and 1989, it was discovered that falls accounted for 33% of the construction worker fatalities (Hinze, 1997; Hinze et al., 2002). The rate has been consistent for many years after that. Data from January 1990 through October 2001 included a total 7,543 OSHA-investigated accidents, among which falls accounted for 34.6% of the fatalities, on an average of about 360 fatalities per year (Hinze et al., 2002; Huang & Hinze, 2003).

Falls are also the second most frequent cause of non-fatal injuries resulting in days away from work, according to The Construction Chart Book (CPWR, 2008). In 2005, falls caused 36,360 non-fatal injuries, accounting for 23% of the total (CPWR, 2008). Therefore, preventing and protecting workers from falls is necessary to reduce fatal and nonfatal injuries in the construction industry.

There is a variety of fall-prevention and fall-protection equipment that can be applied on construction sites to either prevent workers from falling or mitigate the
consequences after falls (Chi et al., 2005), such as guardrails, safety nets, warning lines and Personal Fall Arrest Systems (PFAS). Duncan and Bennett (1991) stated that both fall-prevention and fall-protection equipment is useful in terms of reducing the rate or severity of fall-related injuries. Many researchers (Johnson, Singh & Young, 1998; Kines, 2002; Suruda, 1995) identified that PFAS is the most feasible, economical and promising among fall protection equipment and proper usage of PFAS should prevent injuries and fatalities caused by falls. In 1996, a new safety regulation was announced by the Occupational Safety and Health Administration (OSHA), which suggested several methods to control fall hazards (OSHA, 2006). The most notable revision of the OSHA regulations was as follows:

1926.502(d): Personal Fall Arrest System: Effective January 1, 1998, body belts are not acceptable as part of a personal fall arrest system. Body harnesses were mandated for PFAS to provide protection to workers.

However, the literature appears to show that usage of PFAS is poor in the construction industry. Approximately 30-50% of fall-related fatal and non-fatal injuries occurred either when PFAS was not in place or PFAS was not used properly (Cattledge, et al. 1996b; Chi et al., 2005), even after its use was mandated by the new fall protection regulations (Huang & Hinze, 2003). In light of these reports, a better understanding of the links between PFAS use, regulations and fall-related injury statistics is needed.

To study fall-related injuries in the construction industry, it was important to retrieve data from a database that contained the information of fall accidents. The most comprehensive repository for data on American workplace injuries and illnesses is the United States Bureau of Labor Statistics (BLS). Reviewing the most recent BLS data,
Among 5100 fatal injuries in private industry in 2005, construction had the highest percentage (at 22.9%, 1186) over other industries (Figure 2.1).

![Figure 2.1: Fatal injuries by private industry section, 2005 (BLS, 2007)](image)

Among all fatal accidents that occurred in the construction industry, BLS categorizes them by types of accidents. They are (1) Transportation incidents, (2) Assaults and violent acts, (3) Contact with objects and equipment, (4) Falls, (5) Exposure to harmful substances or environments, (6) Fire and explosions. Figure 2.2 indicates that falls account for the highest percentage at 33.22% (n= 394). This percentage is similar to those reported previously in the literature (Hinze, 1997; Hinze et al., 2002), demonstrating that work-related falls continue to be a leading cause of death in the private construction industry.
Figure 2.2: Event or exposure leading to fatal construction accidents, 2005 (BLS, 2007)

Figure 2.3 shows a comparison of the year to year numbers of fatal work injuries in construction during 1992-2005. The trend does not appear to show a significant decrease over time.

Figure 2.3: Number of fatal injuries in construction, 1992-2005 (BLS, 2007)
Figure 2.4: Number of fatalities from construction falls, 1994-2005 (BLS, 2007)

Figure 2.5: Falls as a percentage of all construction fatalities, 1994-2005 (BLS, 2007)
The number of fatalities from construction falls from 1994 through 2005 is shown in Figure 2.4. In spite of the great efforts being contributed towards a safe working environment in the construction industry, the number of fatalities remains consistent. Figure 2.5 indicates that, over the last twelve years, fall accidents have accounted for between 32% and 36% of all construction fatalities.

Figure 2.6 shows the rate of fatal injuries due to construction falls from year 1994 to year 2005. There was a slight downturn in the rate of fatal falls for two years after PFAS went into effect in 1998. In 2004, there was an uptick in the number of construction fatalities and falls as a percentage of all construction fatalities. In order to examine whether there is a statistically significant decrease in fall-fatalities rate after 1998, a t-test was applied and the results showed the significance exists (p=0.0037). However, no clear trends of decrease in either number of fatalities or portion of fall-fatalities over all construction fatalities were observed with respect to revisions of OSHA regulations. Having now examined the link between OSHA regulation and fall-related

![Figure 2.6: Fatality rate from construction falls per 100,000 workers, 1994-2005 (BLS, 2007)](image-url)
injuries, we next review the research literature on construction falls and use of fall protection equipment, especially PFAS use in the construction industry.

2.2. Literature Review

2.2.1. Relation between PFAS use and fall-related injury rate

The relation between usage of PFAS and rate of fall-related fatal and non-fatal injuries in construction has become a popular research topic in the last decade. Several publications addressed this specific area. Cattledge et al. (1996b) studied 182 fall-related, non-fatal injuries in the construction industry during 1991, prior to the PFAS regulation, which took effect in 1998; and they indicated that most of the fall-related fatalities could have been prevented with proper usage of PFAS. They also discovered that percentage of Personal Protective Equipment (PPE\(^2\)) usage increased with the increase of the height of the building, to the maximum of 55%, which was still low.

Janicak (1998) studied 428 construction fall-related fatalities and he determined that 35% of them were due to lack of fall protection and 6.4% of the fatalities occurred because the fall protection was not attached. Johnson, et al. (1998) examined fall protection equipment and determined that PFAS and its variants are one of the most promising methods to reduce injury rates. Kines (2002) researched construction workers’ falls through roofs. In 5 of 20 fatal and non-fatal injuries he studied, the workers did not use passive personal fall protective equipment (PFAS, safety nets, etc.). The results indicated that fatal injuries mostly occurred when PFAS was not used. Chi et al. (2005)

\(^2\) For research conducted before 1998, when PFAS was not emphasized by OSHA as mandated fall protection equipment, PPE referring to body belts and lifeline, appeared in most of the literature instead of PFAS.
conducted their study among 621 fatal falls in the construction industry between 1994 and 1997. They found that fall-related fatalities from building girders or other structural steel were mainly associated with improper use of PFAS. They suggested that PFAS should be used to mitigate the consequences of falls. Huang and Hinze (2003) studied a total of 2741 OSHA-investigated fall-related injuries in construction from January 1990 to October 2001 and 30% of the injuries occurred when PPE was used improperly or safety equipment was removed. This percentage has not changed significantly after new OSHA fall protection regulations took effect in 1998.

These researchers, and others, not only sought to better understand the relationship between falls and use of fall protection equipment, but also the factors that affect the use of fall protection equipment, specially PFAS. The links between PFAS use and factors affecting that use are also essential elements in understanding the relationship between PFAS use and fall-related injuries.

2.2.2. Understanding PPE, specifically PFAS usage

Various researchers have tried to understand why PFAS was not used on jobsites when it was needed and required. For example, Cattledge et al. (1996a) explained this as: (1) workers think it was not needed, or their companies did not provide them with PFAS, (2) PFAS itself was difficult to use, or (3) the work environment was not adequate to accommodate the safety devices, for example, the anchorage point was not in place. Sa (2005) discovered that most roofers who did not use PFAS reported that they thought it decreased productivity and that fall protection equipment made them uncomfortable. Janiack (1998) and Johnson et al. (1998) believed that lack of proper fall-protection
training and company’s enforcement of and compliance with fall-protection regulations are main causes of fall-related injuries.

There have been many models intended to explain the individual, social and organizational factors affecting an individual’s protective behavior. Becker (1974) developed the Health Belief Model, which explained the determinants of self-protective behavior. The determinants include the perception of susceptibility (personal vulnerability), severity (possibility of getting sick or injured), benefits and barriers of taking action (outcome expectancy), and self-efficacy (Becker, 1974; Cummings et al., 1980; Geer, Anna & Curbow, 2007; Janz and Becker, 1984). Geer et al. (2007) further applied the model to the investigation of workplace dermal exposure and they discovered that an increase in PPE self-efficacy related to an increase in precautionary behavior. For instance, “I am confident I can use PPE to protect myself and my supervisor makes sure I am provided with proper fitting PPE” could be used as an indicator of a person’s protective behavior. Pender (1986) proposed the Health Promotion Model (HPM) to discuss the prevention, early detection and protection of illness among nurses. Lusk (1997) adopted the HPM model to study the construction workers’ use of hearing protection. His study revealed that workers’ perceived value of use (benefits of using hearing protection), barriers to use, and self-efficacy significantly contributed to their use of hearing protection.

Extending the factors into an organizational and social level, Karasek and Theorell (1990) developed the job demands-control-support (DCS) model, focusing on how the changes in work organization influence workers’ health-related behavior. On the basis of the DCS model, Torp, Grogaard and Moen (2005) studied the social and
organizational factors associated with workers’ use of hearing protective devices. Their study revealed that the use of PPE was highly correlated with social support and health and safety related management support. McGovern (2000) studied the factors affecting general compliance and PPE compliance of universal precautions among health care workers and they categorized the factors into personal traits, work-related factors and organizational factors. Personal traits include demographics, job characteristics, knowledge and perceptions and confidence; work-related factors include cognitive demands, job ambiguity, workload and work-related stress; and organizational factors consisting of safety climate, PPE availability, and PPE training (McGovern, 2000). Their studies discovered that workers’ perception of a strong safety climate within an organization and PPE training are associated with PPE compliance. Workers who perceived strong safety climate and had some type of PPE training were more likely to be compliant with PPE.

In general, model construction can be an important exercise in developing and refining our understanding of a problem. As described above, the models of behavior have helped researchers to understand the main factors that influence self-protective behavior. In those cases, the goal of model development was not only to understand these relationships but to provide this knowledge to be able to affect behavior, thereby reducing injuries.

To date, there are no published models describing PFAS usage and factors affecting that usage. Given that PFAS use does appear to be related to the reduction in the rate of fall-related injuries and fatalities, developing such a model should lead to a better understanding of factors that drive or inhibit PFAS use. Therefore, the objective of this
In the following section we will review the literature concerning factors affecting PFAS specifically, in order to identify factors that should be included in the model of PFAS usage. We will also examine the factors that other models of health and safety behavior have identified as important, but that might not have been specifically mentioned as factors influencing PFAS use to this point. For purposes of this review, the factors have been classified into six categories: individual, organizational, regulatory, environmental, PFAS, and task-related factors.

2.2.2.1. Individual factors

Individual factors reported to influence PFAS use include age, gender, unionized or non-unionized workers, self-efficacy, risk perception, experiences related to the job, job and safety training, worker’s attitude and safety concern.

Age. Age is discovered to be an important factor that relates to occupational falls. An inverted U-shaped relationship between age and accident rate was proposed in many articles. The following polynomial regression (Figure 2.7) shows the inverted U-shape figure derived from data in Chi et al., 2005. From this figure, we observe that about one-half of the fatal accidents occurred to workers between 25 and 44 years old (51.4%).
Huang and Hinze (2003) reported a similar trend between age and fall-related accidents as the above distribution. They speculated the reason why young workers (<25 years old) experienced fewer accidents may be because they are more alert and flexible. Kines (2002) studied fall-related injuries occurring to male construction workers, in both the severity of the injuries and the location of the falls. He found that, when categorized by severity, the rates of serious-injury falls increase with the age (increasing among the workers aged 20 to 59); the majority of the falls (75%) occurred in workers aged 35 to 54. However, when characterized by location, he discovered that for falls from roofs, the relationship between age and injury rate was reversed. Young roofers are more likely to be involved in injuries due to falls from roofs. Little information was found on how age affects PFAS usage, such as which group of population has higher percentage of PFAS usage, younger workers or older workers.

**Gender.** The effect of gender has been addressed in several research articles. However, since the construction industry is a male-dominated industry, most of the research and analysis only referred to male employees due to the limited data sample of
female employees. Some articles found that female workers had far less risk of fatal falls than male workers (Cattledge et al., 1996a). Derr, Frost & Chen (2005) speculated that it may be because either female workers paid more attention at work than male workers or they were more concentrated on less risk-involved jobs. In contrast to these results, Chi et al. (2005) indicated that female workers are more likely to be involved in fall-related fatalities due to improper and inadequate usage of fall protection. They assumed that female workers might not have been adequately informed of safety concerns within the company. However, the case reports of work-related fatal falls which Chi et al. (2005) analyzed were from Taiwan. The speculations of gender effects might not be applicable in the U. S. construction population. Sa (2005) surveyed 129 roofers in the Midwest and he discovered that most female employees used fall protection on construction sites; for those who did not use it, the primary reason seems to be either they were isolated on the jobsites or they were not able to communicate with other workers on how to use PFAS.

**Unionization.** Ringen, Seegal & Englund (1995) stated that approximately 25% of construction workers in the U.S. are unionized. Derr et al. (2001) discovered that union workers had a higher risk of fatal falls than non-union workers, through studying OSHA’s database from 1990-1999. However, we can not speculate about the reasons for this association. There is no other evidence found in this area.

**Self-efficacy.** Many articles revealed that self-efficacy is an important factor affecting PPE use. Bandura (1977) defined self-efficacy as “the conviction that one can successfully execute the behavior required to produce the outcomes”. DeJoy (1986) explained self-efficacy theory as “a person is more likely to engage in a particular behavior if that person believes that he or she is capable of performing the requisite
behavior”. Sinclair, Gershon, Murphy & Goldenhar (1996) further defined self-efficacy in the context of health and safety as “one’s expectations of coping successfully with the health threat”. Torp et al. (2005) stated that good safety climate within a company will promote workers’ self-efficacy and thereby an increase in self-efficacy. The relationship between self-efficacy and PFAS still needs to be investigated.

**Risk perception.** Risk perception, defined as “one’s perception about his/her susceptibility to various ailments and disease” was considered as an indicator of self-protective behavior in many articles. (Bermudaz, 1999; Rimal, 2001; van der Pligt, 1996). van der Plight (1996) stated that it is understandable that one is capable of perceiving the risk and such perception influences the person to take appropriate actions to prevent or reduce the risk. Weinstein, Sandman and Robbers (1990) revealed a positive correlation between risk perception and protective behaviors, while another study found a negative correlation (Bermudaz, 1999). Rimal (2001) reviewed the literature on how risk perception influences one’s health behavior, and he explained the contradiction of results as the difference in health domains under investigation. To date, there has not been any study on how risk perception affects construction worker’s protective behavior.

**Other individual factors.** Several studies indicated that workers’ experience, attitude, knowledge and fall-protection training received might directly impact proper usage of PFAS (Hale, 1984; Sa, 2005). Hale (1984) reviewed the relationship between experience and accidents, and concluded that inexperienced workers are more likely to suffer accidents than more experienced workers. In the survey that Sa (2005) conducted in the roofing industry, it was found that 45% of the residential roofers have less than 5 years of experiences. This may partially explain why accident rates in residential roofing
industry are higher than other trades within the construction industry. DeJoy, Murphy & Gershon (1995) studied the factors influencing universal precautions (UP) among nurses and they discovered that those who are more knowledgeable about UP would assign higher scores to UP in terms of preventing occupational exposure to blood-borne pathogens. Thus, they are the ones more likely to use PPE correctly. Burke et al. (2002) proposed a model of general safety performance and discovered that depth of knowledge and skill of PPE use was positively associated with safety performance. However, the information on actual PPE usage was not collected during their study. Moreover, training, especially safety training, has been discussed in many studies. DeJoy (1986) stated that safety training is the most popular strategy in influencing workers’ self-protective behavior. Robins and Klitzman (1988) created an ecological model of worksite disease prevention, by suggesting that a successful training program within an organization would influence the knowledge, attitude, and health and safety behavior of both workers and managers. Detailed illustration of the role of training in terms of affecting PFAS usage will be presented in the next section: organizational factors.

2.2.2.2. Organizational factors

Various articles mentioned how an organization is responsible for improving inadequate PFAS usage. Janiack (1998) suggested that a company’s enforcement of the use of fall protection systems, safety training, as well as inspection and testing of protection systems are all necessary for proper use of PFAS. Huang and Hinze (2003) suggested that adequate provision of PFAS and training workers to use PFAS correctly are necessary to improve worker safety. In this review, organizational factors are
categorized into: compliance, enforcement, safety equipment availability, communication and safety initiatives, including safety committee, safety meeting and safety training.

**Compliance.** Johnson et al. (1998) and Sa (2005) used survey and interview methods to study how construction companies complied with OSHA fall protection regulations. Sa (2005) discovered a large number of residential roofers did not comply with fall protection regulations. Johnson et al. (1998) found that some construction workers and supervisors considered the new OSHA fall protection regulations under Subpart M difficult for them to understand and implement. Therefore, the authors believe it is important to examine a company’s compliance history and its ability to implement the regulations. In addition, they also proposed that OSHA should reduce the complexity of regulations in order to improve a company’s compliance with fall protection regulations. Both articles agreed that compliance with OSHA regulations is a very important factor with regard to PFAS usage.

**Enforcement.** When discussing the reasons why construction workers complied with OSHA fall protection regulations, both Johnson et al. (1998) and Sa (2005) discovered that requirement for employment is one of the major factors. Sa (2005) further investigated the relationship between a company’s enforcement of roofers’ use of fall protection equipment and roofers’ fall accidents experience and a significant correlation was discovered (r=-0.21, p=0.05 for residential roofers and r=-0.33, p=0.01 for commercial roofers). He also discovered a strongly positive relationship between a company’s enforcement and actual use of fall protection systems (r=0.56, p=0.001 for residential roofers and r=0.66, p=0.001 for commercial roofers). The results indicated

that a company’s enforcement was significantly related to the use of fall protection systems and having fewer fall-related accidents.

**Safety equipment availability.** Availability of fall protection equipment is one of the organizational factors that directly related to worker’s PFAS use. DeJoy et al. (1995) studied the factors influencing adherence to universal precautions among nurses and they indicated that availability of PPE significantly correlated with a company’s safety climate. It was also recommended that a company should provide workers with a variety of PPE options and choices. Companies should foresee that the costs they invest in safety equipment will eventually improve their safety performance. However, there has not been any research on how safety equipment availability is associated with actual usage of the equipment.

**Communication.** Communication was mentioned only in a limited number of studies of PFAS use. Some studies found that poor communication did increase the risk of construction accidents. The study by Sa (2005) showed that lack of communication with other workers is the major reason why female workers do not use PFAS on jobsites. Sa (2005) also discovered that many Hispanic roofers he interviewed had difficulties reading and writing in English. They were not aware of fall-protection regulations and their use of PFAS was not enforced by their managers. He did not further reveal the reason for lack of enforcement in this case, but this type of unsafe situation could be considered, at least partly, a result of poor communication within work teams. Although these studies indicated that female and Hispanic workers are two sub-groups of construction workers having difficulties due to communication problems, there are no statistical data to indicate how communication contributes to PFAS usage. In addition, in
the study of self-protective behavior in the workplace, DeJoy (1986) stated that a good communication system between workers and management is an indicator of a successful safety program.

**Safety initiatives.** Effective safety initiatives are reflectors of strong management support. Torp et al. (2005) conducted research on factors that influence use of PPE and they discovered a significantly positive correlation between management support and use of PPE. Safety initiatives include a company’s written safety policy, safety committee, safety training, regularly scheduled safety meetings and other effort or money that a company has spent or invested in order to improve its safety performance. Hoonakker, Loushine & Carayon (2005) studied the effectiveness of a construction company’s safety initiatives by using Experienced Modification Rate (EMR) as an available source of information with regard to accidents and injuries. EMR is a widely used and accepted indicator of a company’s past safety performance by US employers (Hoonakker et al., 2005). Lower EMR indicates that fewer severe accidents had occurred than expected during the past years, which results in lower insurance costs. Therefore, a reduced EMR is considered a goal for companies seeking to improve their safety performance. The study by Hoonakker et al. (2005) showed that it took time for safety initiatives to take effect and for money that companies invested in safety to pay off. But eventually, safety performance, in the form of number of injuries at the participating companies, improved after three years.

**Safety training.** Safety training is an important form of safety initiative and it was suggested in many studies that safety training is necessary to reduce fall-related fatal and nonfatal injuries (Hsiao and Simeonov, 2001; Huang and Hinze, 2003; Johnson et al.,

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4 http://www-group.slac.stanford.edu/bsd/pur/images/forms/Mod.html
OSHA requires that in the construction industry, a company shall assure that each employee has been trained by a competent person in certain hazard-related areas. Robin and Klitzman (1988) suggested that a successful safety training program would influence both workers and managers’ health and safety behavior. Harvey (2001) conducted a survey in the nuclear industry to measure employees’ responses before and after a safety training program and his study indicated that proper safety training will change safety attitudes and safety culture within a company.

Some literature showed that fall protection training is inadequate in the construction industry. The Bureau of Labor Statistics conducted 20 surveys of workers’ injuries on the job from 1978 to 1990 and 75% of the surveyed workers who experienced injuries from falls from elevations did not receive training in fall protection (Cohen and Colligan, 1998). The study suggested that inadequate safety training may have contributed to the occurrences of injuries. However, other reports showed contradictory results. Cattledge et al. (1996b) found that among the 182 victims of fall-related non-fatal injuries, 63% received some type of fall protection training. 28% reported they had received training at least twice a year from the employer, while 12% received training once a year. Goldenhar (2001) developed a survey to study the health and safety training status in non-union construction contractors and discovered that 81% of the construction contractors did provide training.

Although as mentioned above, many studies have suggested that adequate fall protection training should reduce the number of fall-related accidents, there are only a few articles that have evaluated the effectiveness of safety training programs in the construction industry. Kinn, Khuder & Bisesi (2000) examined the effectiveness of safety

\[ 5 \text{ OSHA Regulations (Standard- 29 CFR) 1926.503} \]
education and training to reduce injuries in six plumbing and pipefitting companies. They found the workers who received safety training have lower injury rates compared with those who did not have safety training. They concluded that safety training was significantly associated with reducing injuries. Dong, Entzel & Men (2004) studied the effectiveness of safety and health training in reducing the number of work-related injuries among 8568 construction workers in Washington State. Their study revealed that the workers who received some type of safety and health training were 12% less likely to file a worker compensation claim than non-trained laborers, suggesting that training might be effective in reducing work-related injuries or reducing the severity of the injuries. However, there are also reports that concluded that safety training was not effective in preventing workplace accidents. Sa (2005) studied the relationship between fall protection training programs and falls from roofs among 129 roofers and the correlation was as low as -0.05 (p=0.70) for residential roofers and 0.07 (p=0.60) for commercial roofers. His results indicated that fall protection training program alone might not be enough to reduce fall-related accidents in the roofing industry. This finding was not surprising at all. Tracing back to a review article in the field of safety training from 1984 (Hale, 1984), it was indicated that “there were almost as many studies showing that job training had no effect on safety as studies showing a positive effect (Jonah, Dawson & Bragg, 1982)”. Therefore, it was suggested that post-training evaluation should be provided along with training programs and that the evaluation should be considered a necessary component in terms of conducting an effective training program (Read, 1996). McGovern (2000) conducted a survey to discover the factors affecting universal precautions compliance and their results showed that training on the use of PPE was
significantly associated with PPE compliance, by stating that “workers who had some
PPE training were 5.7 times more likely to be compliant with UP compared to workers
without any training”. There has not been any research specifically on the effectiveness
of training in PFAS use in terms of its influence on one’s intention to use PFAS.

There are two articles that specifically addressed fall-protection training programs
within the construction industry. One was aimed at scaffold fall safety; the study used
training seminars as an assist to safety posters and flyers (Saarela, 1989). Before-and-
after comparison was applied to evaluate the effectiveness of the training. A 39%
decrease in injuries was found in the department after the training. The other training
program used narrative simulations to address issues on prevention of fall-related
injuries. The performance of the program received a high rating from participants after
the training, but the effectiveness of preventing fall-injuries was not evaluated in the
study (Wojcik, Kidd and Parshall, 2003).

2.2.2.3. Regulatory factors

Regulatory factors include establishment and OSHA’s enforcement of fall-
protection regulations. For more than 15 years, OSHA has worked to revise fall
protection regulations. Most regulations, such as ‘29CFR Part 1926 Subpart M
1926.500d’, stipulate fall protection at different heights, dependent on the job activities.
OSHA also developed guidelines for fall protection training: 1926. 503 which are under
the new fall protection regulations 29 CFR Part 1926 Subpart M.

As the primary agency responsible for enforcement of workplace safety
regulations, the overall effect of OSHA has clearly been positive, reducing workplace
fatalities by 60% and occupational injury and illness rates by 40% since its creation in 1971 (Wallace, 2006). However, some studies showed that only having the regulations “on the book” might not be adequate in reducing the number of workplace injuries. Derr et al. (2001) studied the effect of OSHA fall protection regulations for construction (February 1995; 29CFR Part 1926 Subpart M) by calculating fatality rates from the database of OSHA’s Integrated Management Information System; they did not find significant effectiveness of the revised regulations. Huang and Hinze (2003) analyzed data of OSHA investigation reports before and after new fall protection regulations (1990-2001). They failed to find either a decrease in the number of falls on construction sites or a pattern of decrease. The authors speculated the result was due to inadequate training of construction workers.

There is one cross-sectional study that showed a positive impact of OSHA’s regulations. Nelson, Kaufman, Kalat & Silverstein (1997) studied the effectiveness of OSHA’s regulations by comparing workers’ compensation claim rates for falls between two groups of employers: one group of employers had been cited for violating falls standard, another group had never been cited. Results showed that the rate of workers’ compensation claims for fall injuries decreased after employers were cited for violating regulations. In other words, OSHA’s enforcement of fall-related regulations is effective in reducing work compensation claims when regulations are recognized and understood by companies.
2.2.2.4. Environmental factors

Work height. Work height, which is defined as “the distance from the work surface to the impact surface” (Janicak, 1998), is directly linked to the risk of falls and PFAS usage. It was found in several articles that severity of injuries from fall-accidents increases with increase of height of free-fall (Hsiao and Simeonov, 2001; Zimolong, 1985). However, some studies reported that most of the incidents occurred at relatively low elevations (< 30ft). Huang and Hinze (2003) studied 1018 fall accident investigation reports which included information on falling heights and reported the average height of facilities where falls happened was 37.4 ft; and more than 70% of the falls occurred below 30ft. They speculated that it might be the case that fall-prevention techniques and equipment are less likely to be implemented at the lower elevations. Janicak (1998) also reported that the average height of facilities where fall-related fatalities occurred was 41ft. It indicated that as an accident occurred at higher elevation, death was a more likely outcome.

Cattledge et al. (1996b) studied the relation between usage of PPE (safety belts) and work height when fall-accidents occurred. The results showed that the PPE usage increased with the increase in work height, and it increased dramatically when the work height was above 30 ft (to the maximum of 55%). There has not been any article that studied the statistical correlation between work height and PFAS use.

Weather. Suruda (1995) discovered that rain or high wind contributed to 11% of the 55 fall-related cases they studied. Huang and Hinze (2003) found that in winter and spring months (December to May), falls were a larger proportion of all accidents than in summer and autumn months (June to November); it was speculated that the cold weather
conditions might cause more falls than mild weather. They assumed that it might because floor conditions are more slippery and workers’ movements are slower in winter than in summer.

*Anchorage point.* Problems related to the installation of anchorage points were mentioned in a few fall-accident analysis articles. Cattledge et al. (1996b) and Chi, et al. (2005) found that lack of an anchorage point was the cause of some fall-related injuries. Huang and Hinze (2003) stated that sometimes accidents happened because workers were not able to find a place to tie off their body harness. Hecker and Gambatese (2003) suggested architects and engineers should consider providing anchorage points for PFAS. They believe anchorage points designed into the permanent structure for making connections to a lifeline and a harness could reduce fall hazard exposure. The problem associated with the lack of anchorage point could also be solved by improving the design of PFAS. Johnson et al. (1998) proposed an innovative PFAS variant by combing PFAS with a “Safe-T-Strap System”, which could be used as a temporary anchorage. Detailed information on this design will be provided in the next section: PFAS factors.

2.2.2.5. PFAS factors

A personal fall arrest system (PFAS) is described by OSHA as a “system including but not limited to an anchorage, connectors, and a body harness used to arrest an employee in a fall from a working level” (OSHA, 2006). PFAS is classified as a form of PPE. It is used to prevent employees from falling (used as restraining device) and to mitigate the consequence after falling (used as an arresting device). Figure 2.8 shows the major components of a PFAS.
PFAS design. Design (including fitting, comfortableness, easiness to put on and easiness to adjust) and cost of PFAS both interact with PFAS usage, but there is a negative correlation between these two. Some recent studies found the design of PFAS might constrain and interfere with workers’ movements (Haslam et al., 2005; Hinze et al., 2002). Sa’s surveys and interviews (Sa, 2005) discovered that PFAS made roofers feel uncomfortable and roofers felt that PFAS might reduce their productivity. However, no quantitative data was provided to demonstrate that PFAS use actually affects a worker’s productivity.

Cost of PFAS. Haslam et al. (2005) discovered that most construction companies purchase safety equipment (including PFAS) based on its price and performance, while durability may only be considered sometimes and easiness to use was not included in the purchasing factors. Haslam et al. (2005) also reported that there are improved designs available, but companies are generally not willing to purchase high-cost PPE. Overall,

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The personal protective equipment worn by the worker

C: Connecting Devices
The critical link which joins the Body Harness to the Anchorage / Anchorage Connector (e.g. shock-absorbing lanyard or retractable lifeline)

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6 Picture is from: http://www.nationalladder.com/miller-fall-protection/fall+protection+equipment.htm
easiness to use, comfortableness and cost of PFAS are the main factors that PFAS designers should consider in order to improve its usage in the construction industry.

One example of a harness with many attractive features is the “Edge Harness”. Features include quick-connect buckles and shoulder and legging padding. However, the price range of this harness is $220-$280, as much as four times the cost of some basic harnesses.

Another alternative to the traditional harness design has been proposed by Kohis and Shekar (2006). They integrated a safety harness into work overalls and developed a user-friendly safety harness system (Kohlis and Shekar, 2006). Mind-mapping focus groups were held in order to explore usage problems and opportunities for improvements. The new design was judged to be easier to put on, more comfortable and meet requirements of safety standards. However, it also costs substantially more (three to six times) than a basic harness, likely making it too expensive for many small and mid-sized construction companies.

**Sizing and fitting.** In terms of sizing schemes and fitting of the PFAS, the majority of commonly used products are designed with enough adjustability that they are categorized as one-size-fits all and some are categorized into four standard unisex sizes. Hsiao, Whitestone and Kau (2007) evaluated PFAS sizing schemes by three-dimensional torso scan in which 108 women and 108 men participated voluntarily. The results estimated that at least 24% of men and 31% of women would not be able to find a well-fitting PFAS based on their “body dimensions and the current sizing schemes”. Their study outcomes suggested an improved PFAS scheme system of two sizes for women and three sizes for men instead of one-size-fits all.
2.2.2.6. Tasks-related factors

Types of tasks. Cattledge et al. (1996b) listed the three most frequent tasks that victims were engaged in when fall-accidents occurred: tool using (24%), material handling (22.5%) and climbing or descending a ladder (10.4%). PFAS is not required while workers are performing the third task (climbing or descending a ladder); workers have to apply some type of fall protection when they perform material handling and use tools at elevations above 6ft. Hsiao and Simeonov (2001) stated that “there is sufficient experimental evidence that shows that material handling affects the control of balance through different mechanisms”. Although there are no articles explaining how tool use was connected to elevated fall-accident rates, since tool use is a type of physical exertion and it requires a person’s full attention, some research has shown that dividing attention can increase the probability of tripping and falling (Chen et al., 1996).

Suruda (1995) discovered that 9.4% of 288 fall-related accidents in the roofing industry were associated with steel-erection. Huang and Hinze (2003) stated some workers fell during steel erection operations because they had to disconnect PFAS temporarily in order to be able to move or change locations. Chi et al. (2005) further found that falls from building girders or other structural steel were mainly associated with improper use of PFAS.

Duration of the tasks. Duration of the task is a factor that has been neglected by most of the literature. None of them directly discussed the relation between the length of certain tasks and fall-accidents rate when performing the task. However, it was mentioned in several articles that some workers felt it was troublesome to tie off the harness for a short period of time and then unhook the lanyard again in order to change
locations or switch operations (Huang and Hinze, 2003; Sa, 2005). This finding suggested that PFAS usage might be low if the task is short.

2.2.3. Summary of the literature concerning factors affecting PFAS usage

Based on this literature review, the following cause-effect (fishbone) diagram (Figure 2.9) is presented to analyze and link the factors and sub-factors that appear to influence PFAS usage.

Figure 2.9: Cause-effect diagram of factors that might contribute to PFAS usage

While this review of the literature allows us to formulate this preliminary model, additional information which was not found in the literature, will help fill in some knowledge gaps and facilitate the formulation of a testable model of PFAS use.
2.3. Path modeling

Path analysis is a type of multiple regression analysis and it is often applied in the area of investigation of correlation and causation in causal models. As such, this technique was selected as a means through which to develop a statistically testable model of PFAS use from the preliminary cause-effect diagram (Figure 2.9).

Path analysis was first proposed by a geneticist, Sewall Wright to “measure the direct influence along each separate path in such a system and thus of finding the degree to which variation of a given effect is determined by each particular cause” (Wright, 1921). Path models were soon adopted by many scientists, and were used in a variety of fields, such as sociology, social sciences and economics (Duncan, 1966; Munro, 2005).

In the 1960s, path models were applied by researchers to investigate questions in the area of behavior science. Fishbein (1967) proposed the Behavioral Intention Model (Figure 2.10), which stated that focal behavior is a function of the intention of that behavior, and attitude toward the behavior and subjective norm are considered as two predictors of intention (Fishbein, 1967; Oliver and Berger, 1979).

![Behavioral Intention Model](image)

**Figure 2.10: Behavioral Intention Model (Fishbein, 1967; Oliver and Berger, 1979)**

Becker (1974) used path analysis to develop the Health Belief Model, in order to explain the determinants of self-protective behavior. The predictors of self-protective
behavior include the perception of susceptibility, severity, benefits and barriers of taking action and self-efficacy (Becker, 1974; Cummings et al., 1980; Geer et al., 2007; Janz and Becker, 1984). Lusk (1997) applied path analysis to investigate construction workers’ use of hearing protection. Figure 2.11 gives an example of how path modeling was used in his study. One-way arrows are used to connect each determining variable to each variable depending on it. The numerical values in the diagram are path coefficients, which are used to describe the correlations between the variables. As shown in the model, low perceived barriers of use of hearing protection (simplified as “barriers” in Figure 2.11) was found to be the strongest factor that directly impacts a construction worker’s hearing protection use (with path coefficient= -.36).

Figure 2.11: Standardized path model of construction workers’ use of hearing protection (Lusk, 1997)

In the current study, six categories of factors, a total of twenty-five sub-factors are considered as possible predictors of proper PFAS usage, as shown in Figure 2.9. Path analysis appears to be a suitable method to test and validate the model of PFAS use. In
the following phases of this study, we intend to develop and apply the model to answer the following questions:

1. Which factors are significantly strong predictors of PFAS usage?

2. What are the correlations between the factors?

Before we can answer these two questions, addressing some of the knowledge gaps regarding PFAS usage will be required.

2.4. Development and test of the Path Model

2.4.1. Knowledge gaps

The majority of the reviewed literature that studied the factors affecting PFAS use were based on OSHA accident investigation reports (Huang and Hinze, 2003; Janicak, 1998; Kines, 2002). However, some information, such as workers’ self-efficacy, risk-perception, a company’s compliance with safety regulations and whether an anchorage point was in place, could not be retrieved from these investigation reports. Furthermore, the targeted populations of the accident reports are construction workers who had experienced falls. The information on the workers who have not experienced fall-accidents also needs to be collected. Therefore, direct investigation methods, including surveys and interviews should be applied to help discover construction workers’ and supervisors’ opinions on the factors affecting PFAS use.

In terms of training, many studies suggested that safety training is important to reduce the number of fall-related injuries (Hsiao and Simeonov, 2001; Huang and Hinze, 2003; Johnson et al., 1998), but limited information was collected on construction workers’ fall protection training, for example, whether they have received training, length
of the training, and information on the lecturers. These overlooked factors could be significant in terms of affecting one’s PFAS use. It was also found in the literature that safety training is effective in influencing one’s self-protective behavior (DeJoy, 1986). However, none of the researchers specifically studied the effectiveness of training in affecting ones’ PFAS use behavior.

Although availability of Personal Safety Equipment was significantly correlated with a company’s safety climate (Dejoy et al., 1995), there were no articles that reported either how availability of PFAS affects its usage or how costs of PFAS influence safety managers’ decisions on selection of safety equipment. Information with regard to PFAS availability and its cost needs to be collected in this study to determine their relationships with PFAS usage.

Review of the literature also reported PFAS design to be an important factor in influencing its usage. Many studies revealed that some construction workers perceived un-comfortableness, difficulties to use and restrictiveness of movements when using PFAS (Haslam et al., 2005; Hinze et al., 2002; Sa, 2005). It was assumed that a more comfortable, easier to put on and easier to adjust PFAS would increase PFAS use among construction workers. However, the assumption was based on researchers’ perception. In order to obtain actual PFAS users’ opinions on their preferable PFAS design, participatory design workshops will be conducted to collect opinions and ideas on PFAS design from construction workers’ aspects.

Obviously, there are serious knowledge gaps existing in the literature review of PFAS use and the factors affecting PFAS use. In addition, as mentioned before, there was no published model explicitly describing PFAS use. This study has been planned as a
first attempt to address these gaps. A four-phase approach is proposed to develop, refine, test, validate and finalize the path model of PFAS use (Figure 2.12).

2.4.2. Four-phase approach

![Diagram of four-phase approach](image)

Figure 2.12: Four-phase approach of development and testing of the Path Model of PFAS use

2.4.2.1. Phase one: preliminary survey among construction workers

Surveys were used by Johnson et al. (1998) and Sa (2005) to discover the usage of fall protection equipment and related training programs from construction workers’ perspectives. However, both studies were limited to the roofing industry, which only accounts for a small section of the construction industry. Extending the scope of the survey to other sectors within the construction industry will occur in phase one. Also, safety training was not sufficiently addressed in either of these two prior studies.
Thus, the objectives of Phase One will be: (1) to gather information on PFAS use among a diverse sample of construction workers; (2) identify factors that correspond with PFAS use from worker’s perspectives; (3) characterize the nature of fall protection training experience, including delivery methods, lecturers and training length, within the sampled population.

2.4.2.2. Phase two: interviews of safety professionals

Torp et al. (2005) described the use of Personal Protective Equipment as a type of social and organizational behavior. This indicated that when investigating the factors affecting PFAS use, perspectives from other stakeholders within the construction industry, including management of the construction companies, safety professionals, designers and architects, should also be included before we draw overall conclusions.

Only one article (Johnson et al., 1998) reported managers’ opinions on reasons for construction workers’ compliance and noncompliance with fall protection regulations. However, this study did not provide many insights on fall protection training programs. Therefore, interviews are to be conducted in Phase Two to collect information on PFAS use, including training and other factors, in the view of the supervisors, safety managers and architects.

2.4.2.3. Phase three: participatory workshops

Among the articles on factors influencing self-protective behavior, there were only a few that mentioned differences in workers and managers’ perspectives. Johnson et al. (1998) discovered different reasons for workers’ compliance and noncompliance with
safety regulations between workers and managers’ perceptions. Geer et al. (2007) conducted a survey to study knowledge, attitudes, and perception (KAP) of workplace dermal hazards. The results from their survey showed that managers had lower scores than workers on the questions regarding workers’ training on dermal hazards. This indicated that workers were more confident than managers that they were well trained.

In the current study, different perceptions from construction workers and managers, with regard to factors influencing PFAS use, are expected after comparing the results from Phase One and Phase Two. Therefore, Phase Three will be needed to gain more comprehensive opinions from different stakeholders in the construction industry. Participatory workshops will facilitate gathering such information.

Participatory workshops are normally used as events to help users and other stakeholders communicate and share ideas, goals and outcomes generated from the workshops. In Phase Three, two participatory workshops with involvement of construction workers, supervisors and safety managers will be organized to allow for information gathering in a more open-ended and creative format than surveys and interviews in phase 1 and 2, respectively. The workshops will generate more ideas on how to improve PFAS use. Workers and managers will be working, creating and expressing their ideas as a team, instead of two separate groups.

At the end of Phase Three, data collected from the first three phases will be organized and analyzed to develop and refine the path model of PFAS use.
2.4.2.4. Phase four: finalize and validate the path model

As the last phase of this study, the objective of Phase Four is to finalize and validate a preliminary path model of PFAS use. Through the path model, we intend to seek answers to two questions mentioned earlier: Which factors are significantly strong predictors of PFAS usage; and what are the correlations between the factors. The results from this phase will help formulate and validate the path model of PFAS use.
CHAPTER 3

PRELIMINARY SURVEY

3.1. Background

The review of literature in Chapter Two indicated that proper PFAS use should reduce fall-related injury rate in the construction industry. It also proposed a cause-effect diagram with factors that might potentially contribute to PFAS usage. Since construction workers are actual users of PFAS, their perspectives on PFAS are important to understand.

Reviewing the previous studies, there are only two articles (Johnson et al., 1998; Sa, 2005) that studied the construction workers’ perspectives in fall protection equipment and related training programs. The 1998 study by Johnson et al. discovered that the current compliance of fall protection regulations was poor in the residential roofing companies in Hawaii and they suggested proper fall protection training and application of some innovative PFAS designs, such as a “Safe-T-Strap System” and a Roof Jack, would reduce fall-related injuries. However, they did not collect any information on the basis of workers’ experiences with fall protection training and their results did not show any correlation between training and PFAS use. Although the study by Sa (2005) discovered reasons for use and non-use of fall protection equipment in the roofing industry, there was only one question on that survey that addressed fall protection training. More
information on fall protection training needs to be collected. In addition, both studies were limited to the roofing industry, which only accounts for a small section of the construction industry. Extending the scope of the survey to various trades in the construction industry will be necessary in this study.

Therefore, a preliminary survey will be conducted in this phase of the study to 1) gather general information on PFAS use among construction workers; (2) identify the factors that correspond with PFAS use from worker’s perspectives; (3) characterize the nature of fall protection training experience, including delivery methods, instructors and training length, within the sampled population.

The primary focus of this chapter is to provide specific information on development of the questionnaire, recruitment of participants, procedures of conducting the survey, results and discussions on the results from the survey.

3.2. Questionnaire development

The survey was designed in six sections. Part of the questionnaire was adopted from Johnson’s workers’ survey (Johnson et al., 1998) and Sa’s first survey (Sa, 2005). The questionnaire in the current study started with questions about workers’ general demographic information, such as age, gender, work experience in the construction industry and the specific trade that they work in. The second section asked about workers’ working conditions. The purpose of this section was to discover whether PFAS are needed based on their general working heights. It was followed by the section “general information on falls”, which asked about workers’ experience with falls, whether there was any type of fall protection in place when accidents happened, and what
were the causes of the falls they experienced. The fourth part consisted of three questions on fall protection training: whether they had fall protection training, what were the delivery methods of the training they had, and what was the length of the most recent training session they took. The next section intended to discover whether workers use PFAS when needed, and what they like and what they dislike about PFAS. The objective of this section was to provide some ideas for changing workers’ usage behavior. The last section was an open-ended question asking additional comments or suggestions.

Most questions in this questionnaire were multiple-choice, which allowed the participants to place checkmarks on one or more of the applicable choices given under each question. Meanwhile, the option “other (please specify) _____” was given as the last choice of almost every question to give participants an open choice if none of the answers from the given list were appropriate. In addition, open-ended questions were used to collect information on workers’ years of experience, injury history and additional comments on PFAS use. A copy of the survey is provided in Appendix A (page 217).

3.3. Sample size calculation

Determining sample size in a survey study is a very important issue because a sample that is larger than necessary leads to waste of time, resources and manpower, while a sample that is too small produces results with low precision. Factors which are needed to be taken into consideration when deciding on the sample size are: the desired confidence level, the response rate expected and the resources available (Jolliffe, 1986).

One of the objectives of this preliminary survey is to discover what percentage of construction workers wear PFAS when needed. For any binary response question, the
most conservative response estimate is 50%. With an absolute error of ±5 percentage points, sample sizes are calculated based on different confidence levels (Table 3.1).

<table>
<thead>
<tr>
<th>Confidence Level</th>
<th>Calculated sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>99%</td>
<td>664</td>
</tr>
<tr>
<td>98%</td>
<td>542</td>
</tr>
<tr>
<td>95%</td>
<td>385</td>
</tr>
<tr>
<td>90%</td>
<td>271</td>
</tr>
<tr>
<td>80%</td>
<td>165</td>
</tr>
<tr>
<td>70%</td>
<td>108</td>
</tr>
</tbody>
</table>

Table 3.1: Calculated sample size based on different confidence levels

Table 3.1 shows that in order to achieve higher confidence level, a larger sample size is required. However, it is not feasible to recruit five or six hundred construction workers to participate in this survey. Due to limited resources and time for this survey, an 80% confidence level is selected. The sample size is 165 accordingly. Considering 60%-70% expected response rate, approximately 250 to 280 questionnaires are intended to be distributed for the current survey.

3.4. Pilot test of the questionnaire

In June 2007, the first draft of the questionnaire was pilot tested by six construction workers, including two roofers, two iron workers and two superintendents, who were working on major construction projects on campus. They were not asked to take the survey, but to look through the questionnaire thoroughly and report their feedback through informal discussions between researcher and participant. The purpose of pilot-testing is to screen poorly-worded questions and refine the overall quality of the questionnaire (Rea and Parker, 2005). Pilot-testing helped the researchers understand the participants’ perception of the questions and confirmed that the questionnaire contained appropriate terminology.
3.5. Survey procedures

There were several steps in the questionnaire distribution. First, researchers were introduced to the jobsites of different construction companies by individuals in the department of Environmental Health and Safety of The Ohio State University and some organizations in the construction industry, including The Associated General Contractors of America (AGC) and Builders Exchange (BX). During the first visit, researchers explained to the managers or superintendents on-site the purpose of this survey and how their industry could benefit from this study. Once they agreed to participate, a permission letter was signed by the person who was in charge of that specific site. A sample permission letter is provided in Appendix A (page 222). After the approval was achieved, researchers scheduled another visit to where they met the potential survey participants, reviewed IRB documents, and distributed questionnaires. Researchers were introduced to potential participants by their superintendents. However, superintendents were excluded from the area after the survey session started so that the confidentiality of personal information was maintained, including the decision to participate or to decline to participate in the study.

Researchers normally started out explaining the purpose of the study and reading the cover page of the questionnaire, which informed the workers that their participation would be anonymous and voluntary, and that they did not have to participate. Participants were also told that they could fill out the questionnaires after work or at work and bring them back to the researchers the next day. Sometimes the participants completed the questionnaires when researchers were present, while in most of the cases the researcher would make another visit to the jobsite to collect the completed questionnaires.
3.6 Response processing and statistical analysis

Through this preliminary survey, we intend to discover the correspondences and associations among workers’ age, gender, work experience (number of years in construction), highest working height, company’s provision of PFAS, fall experiences, fall protection training, concerns about not using PFAS and PFAS use.

The answers on PFAS usage were coded from 1-4, where 1= not at all, 2= rarely, 3= most of the time, and 4= always. The answers on the last multiple-choice question of the survey “Do you have any concerns about not wearing a harness when needed?” were coded from 1-4, where 1= no problem at all, 2= a minor problem, 3=a serious problem and 4= a very serious problem. Length of a respondent’s most recent training was categorized as: 1=less than 10 minutes, 2= 10-30 minutes, 3=30 minutes-1 hour, 4=1-10 hours, 5= more than 10 hours. Worker’s highest working height was coded as: 1=less than 6 feet, 2=7-10 feet, 3=11-15 feet, 4=16-20 feet, 5=21-25 feet, 6=more than 25 feet.

Since some variables are not continuous, the non-parametric method: Spearman’s correlation was used to examine relationships between two ordinal variables or one continuous and one ordinal variable. The ordinal variables include: highest working height, length of the most recent training received, concerns about not using PFAS, and PFAS use.

Among all variables, there are four binary responses, which include: whether workers had fall experiences, owns their own harness, received fall protection training or the company provided them with PFAS. When analyzing the relationships involving only one of these four variables, binary logistic regression was used to calculate whether these four variables are associated with other non-binary variables. Binary logistic regression
was also applied to calculate the association between whether respondents use PFAS because of a “personal safety concern” and their concerns about not using PFAS.

When determining the associations between two binary variables, Pearson’s Chi-square test of association was applied to calculate the relationships specifically among these four. Additionally, since “types of fall protection training” is a categorical variable, its relationship with other variables was examined by Chi-square test of association as well. Cut-off p-value is selected to be 0.05 for significance.

Minitab version 15 and SPSS version 15 statistical packages were used for data analysis in this chapter.

3.7 Results

3.7.1. General information about the participants

Between August 2007 and February 2008, approximately 280 questionnaires were distributed within 14 construction companies and organizations; 167 completed responses were collected. The response rate was 60%. The sample must be considered a convenience sample. The companies that participated in the survey were all commercial construction companies. This did not mean that residential construction was excluded from the study by design. Researchers contacted several residential construction companies, including two residential roofing companies from August-October, 2007. However, once researchers displayed the questionnaire to the company owners and explained to them the purpose of the study, they showed reluctance to participate by indicating workers’ unfixed work schedules and locations.
Among the 167 completed responses collected, 161 were from male construction workers and six were from female construction workers (3.6%). Because of the small sample size of female participants, it is not feasible to identify the associations between gender and PFAS use and other variables in this phase of the study.

The average age of participants was 37 years old (SD=10.8) and their average experience in the construction industry was 13 years (SD=9.7). Figures 3.1 and 3.2 show the distributions of participants’ age and work experience in the construction industry, respectively.

![Figure 3.1: Age distribution of the participants](image-url)

Figure 3.1: Age distribution of the participants
Figure 3.2: Distribution of participants’ years of experience in the construction industry

Figure 3.3 displays the distribution of participants’ types of work. Most respondents marked more than one type of work. “Electrician” was the most common type of work, marked by more than one third of respondents. This occurred because one of the companies we distributed questionnaires within was an electric company. By talking to their safety manager, most of their employees had experiences working on
heights and they were all required to use PFAS. This distribution does not represent the general distribution of all different trades in the construction industry and is a typical outcome of using a convenience sample in the survey.

When asked “What types of surface conditions are you commonly walking on?”, they were allowed to choose all the applicable answers. One hundred and twenty-two respondents chose “ground”; ninety-three selected “ladder”, seventy-eight of the answers were “scaffold” and 54 of them replied “roof”. A few respondents chose “other” and two of them added “tower cranes”, six of them mentioned “lift”, which includes scissor lift and bucket lift. In terms of “working heights”, the findings indicated that the majority of the respondents worked on a variety of heights, from ground to above 25 ft.

![Figure 3.4: Distribution of participants’ working heights](image)
3.7.2. General information on falls

The questions in section two were intended to gather information on workers’ experience with fall-related accidents. Fifty-seven respondents replied they had experienced falls on job-sites, which accounts for 34% of the sampled population. Twenty-four out of the 57 (42%) respondents answered that fall-related accidents they experienced were due to slip, trip and loss of balance. Twenty-three replied that some type of injury occurred as a consequence of the accident, such as fractures, cuts and sprains. Twenty-two out of 57 (38%) answered that there was no fall protection in place (including guardrails, PFAS or safety nets) when accidents happened. Six out of these 22 reported that when accidents occurred, they were not wearing PFAS in situations in which PFAS was required.

3.7.3. Training

There were three questions included in the section on “fall protection training”. The first question asked the participants whether they had ever received any type of fall protection training. Ninety-one percent of the respondents (n=152) answered “yes” while 9% (n=15) of the workers said they never had any training on fall protection. The ones who answered “yes” on the first question were asked to respond to two additional questions. The first inquired about the format of the training. The majority of the respondents (n=101) answered “tool box talk”, which is a safety talk conducted by the superintendents or safety managers on the job everyday or sometimes once a week. The general length of tool box talk varies from ten minutes to thirty minutes. Ninety-four respondents answered “video training” and 83 of them chose “lectures from supervisors”;
another 79 of the respondents replied that they had training from professional trainers. The second related question asked “how long was your most recent training”. The responses showed that the most common training length they had recently was 10-30 minutes, which accounts for 29% of all responses (Figure 3.5), and 10 -30 minutes is the length for a typical tool-box talk.

![Figure 3.5: Distribution of length of the participants’ most recent training (n=150)](image)

3.7.4. Personal Fall Arrest Systems

The questions in this section were designed to gather general information on PFAS usage among the participants, and identify their motivations for using and not using PFAS. The results from this section showed that most respondents worked for companies that provided their employees with PFAS (92%), while only 14 respondents (8%) reported that they were not supplied with a harness. When they were asked “Do you have your own harness?”, 72 of the answers were “yes” and 97 of the responses were “no”. This showed almost half (47%) of the respondents actually had a personal harness and they kept the harness as part of their own safety equipment. When the ones who did
not own a personal harness were asked about whether they would like one, fifty-three (55%) answered “yes”, thirty respondents (31%) said “no” and one respondent indicated that he did not care whether it was personalized or not.

The next question was relative to workers’ actual harness use. Sixty-three percent (n=103) of the workers said they always use a harness and another 27% (n=44) reported that they use it “most of the time”; only 10% (n= 16) of the respondents said they never use harness when it is needed or use a harness very rarely.

When asking about the reasons why they wear a harness, among the 147 workers who answered that they “always use PFAS when needed” or use it “most of time”, 112 of them (76%) indicated that they wear a harness because it is a requirement of employment; 109 (74%) answered that they use a harness due to their personal concern for safety; other reasons included “supervisory enforcement” (52%, n=76) and “peer pressure” (8%, n=12). One person added his own comment, which was “I can not perform work without it”. The respondents, who answered that they used a harness “very rarely” or “not at all”, were asked about why they did not use a harness. The most common responses were “they make me work slower than usual”, “they restrain my movement”, “difficult to find a tie-off point for it”, “they make me uncomfortable” and “nobody wears them on the jobsite”. One person commented that “it took too long to put it on”. Figure 3.6 and Figure 3.7 show the distributions of participants’ motivations for using and not using a harness.
Figure 3.6: Distribution of the reasons for using harness (n=147)

Figure 3.7: Distribution of the reasons for not using harness (n=16)
The next question asked all participants “What do you dislike the most about your harness?” For this question, they were also allowed to choose all applicable answers listed. Ninety-six of all 167 responses (57%) were “comfort level”; 30 of the participants chose “difficult to use”, which accounts for 18% of all responses; followed by the answer “everyone shares them in the company”, which was selected by 17 of the participants (10%); there were seven people who disliked the color of harness and three disliked the material. In addition, 11 participants added their own comments beside the selected answers, which included: lanyard as a tripping hazard (n=4), difficult and troublesome to work in (n=3), no front D-ring (n=1), restrain my motion (n=1), weight of the harness (n=1) and size of harness (n=1).

The last question in this section provided insights into the respondents’ attitude regarding PFAS usage by asking “Do you have any concerns about not wearing a harness when needed?” It was surprising to find out that more than half of the respondents (52%) selected “there is no problem at all” or “a minor problem”. Results were subsequently analyzed by sub-groups: one group being those who answered the reasons for their use of PFAS as “personal safety concern” and the other group, who did not select that option. This analysis showed that those who think their use of PFAS is a “personal safety concern” were more inclined to believe that not wearing a harness “is a very serious (or serious) problem”. Figure 3.8 and 3.9 show the two distributions of responses. The significance of the difference in answers from these two groups will be revealed in the session 3.7.6. “Correlation and other associations”.

7 “Your harness” does not necessarily mean the harness that was owned by the respondent. It could be understood as a harness the respondent was currently using or frequently used.
Figure 3.8: Distribution of participants’ concerns about not using a harness (n=102) (Group 1: the respondents who selected use of PFAS is “personal safety concern”)

Figure 3.9: Distribution of participants’ concerns about not using a harness (n=54) (Group 2: the respondents who did not select use of PFAS is “personal safety concern”)

42% 42%
3.7.5. Other comments

This section contained an open-ended question asking about participants’ other comments on PFAS. A total of 22 comments were received, which can be categorized into three groups as follows:

*I realized that usage of harness is important.* Under this category, there are comments such as “harness will save my life”, “fall protection is important, you don’t get a second chance”, “I want my workers to go home to their families everyday”, and “my harness saved my life when I fell from a scaffold 13 ft from the ground”.

*I do not like the design of the harness.* This category includes “harness should be designed so that it can be adjusted easily”, “make harness light-weight with good hook-offs”, “sometimes I trip over the lanyard”, and “the design should be more like a harness for rock climbing where the arrest is centered at the front of the body”.

*I have to use it because it is required when working on heights.* One mentioned “at my workplace, everyone has to put it on, so I put on my harness as well”; the other added “in my company, one would be fired if found not using a harness”.

3.7.6. Correlations and other associations

In this survey, it was intended to identify the relationships between the factors that might possibly correspond with workers’ actual PFAS use. The factors include: workers’ age, gender, working experience, working heights, fall experiences, company’s provision of PFAS and fall protection training received. In addition, the answer to the last multiple-choice question of the survey “Do you have any concerns about not wearing a harness when needed?” was considered as an indicator of a person’s safety concern,
which is also expected to relate with PFAS use and above factors. In addition, the correspondences among variables also need to be investigated. However, due to the fact that PFAS use is a requirement of employment for the majority of the respondents in this survey, the ability to test the correlations and associations might be limited by the nature of the sample.

As mentioned in section 3.6, three different statistical methods were applied to analyze the correspondences among variables. Table 3.2 and Table 3.3 display the results from Spearman’s correlation and binary logistic regression. The results from Chi-square test of association are not listed because no significant correspondence was discovered by this method.

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Work experience</th>
<th>Highest working height</th>
<th>Training length</th>
<th>PFAS use</th>
<th>Concern about not using PFAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFAS use</td>
<td>p</td>
<td>0.001**</td>
<td>0.170</td>
<td>0.271</td>
<td>&lt;0.001***</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>r</td>
<td>0.259</td>
<td>0.110</td>
<td>0.087</td>
<td>0.286</td>
<td>0.307</td>
</tr>
<tr>
<td>Concern about not using PFAS</td>
<td>p</td>
<td>0.012*</td>
<td>0.166</td>
<td>0.272</td>
<td>0.037</td>
<td>&lt;0.001***</td>
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<tr>
<td></td>
<td>r</td>
<td>0.207</td>
<td>0.113</td>
<td>-0.089</td>
<td>0.167*</td>
<td>0.307</td>
</tr>
</tbody>
</table>

Table 3.2: Results from Spearman’s correlation
(Note: * p<0.05; **p<0.01; ***p<0.001. r: Spearman’s correlation coefficient)

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Work experience</th>
<th>Highest working height</th>
<th>Training length</th>
<th>PFAS use</th>
<th>Concern about not using PFAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall experience</td>
<td>p</td>
<td>0.459</td>
<td>0.827</td>
<td>0.671</td>
<td>0.737</td>
<td>&lt;0.001***</td>
</tr>
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<td></td>
<td>odds-ratio</td>
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<td>1</td>
<td>0.96</td>
<td>0.97</td>
<td>0.42</td>
</tr>
<tr>
<td>Own harness</td>
<td>p</td>
<td>0.281</td>
<td>0.233</td>
<td>0.007**</td>
<td>0.463</td>
<td>0.760</td>
</tr>
<tr>
<td></td>
<td>odds-ratio</td>
<td>1.02</td>
<td>1.02</td>
<td>1.25</td>
<td>1.08</td>
<td>1.18</td>
</tr>
<tr>
<td>PFAS provision</td>
<td>p</td>
<td>0.036*</td>
<td>0.178</td>
<td>0.801</td>
<td>0.026*</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td></td>
<td>odds-ratio</td>
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<td>1.05</td>
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<tr>
<td>Training</td>
<td>p</td>
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<td>0.110</td>
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<td>odds-ratio</td>
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<td>0.97</td>
<td>0.94</td>
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<td>1.77</td>
</tr>
</tbody>
</table>

Table 3.3: Results from binary logistic regression
(Note: * p<0.05; **p<0.01; ***p<0.001)
Variables corresponding with PFAS use. It is shown in Table 3.2 that there was a significant positive correlation between age and frequency of PFAS use ($r=0.259$, $p=0.001$). A histogram graph was plotted (Figure 3.10) to present more details of the relationship. It shows that all respondents over 50 years of age reported using PFAS “most of the time” or “always” (n=20).

![Figure 3.10: Histogram of age vs. PFAS use](image)

A significantly negative correlation was discovered between PFAS use and fall experiences (odds-ratio=0.42, $p<0.001$). The result showed that those who had fall experiences were more likely to answer “do not use PFAS” or “use PFAS rarely”, as distributed in Table 3.4.
To further investigate, a binary logistic regression was applied to calculate the odds ratio of having experiences of falls with respect to PFAS usage. The results indicated that those who did not use a harness or rarely used a harness had a higher possibility to have experienced falls (Figure 3.11). It may be speculated that those who always wear PFAS might have stronger safety awareness than those who do not or rarely use PFAS, which makes them more careful on the jobsites and more aware of falling hazards.

![Figure 3.11: Likelihood of having experienced falls vs. participants’ PFAS usage](image-url)
There was a positive correlation between a company’s provision of PFAS and workers’ PFAS use (odds-ratio=4.01, p<0.001). This showed that if a company provided PFAS, their employees were more likely to use it frequently. Length of participants’ most recent training was also found to be significantly related with PFAS use (r=.286, p<0.001). This indicated that the longer their last training lasted, the higher chance that participants would answer “always use PFAS”.

Number of years of work experience, highest working heights, whether workers have their own PFAS, whether they received fall protection training and types of training were not found to be associated with PFAS use.

Meanwhile, the answers to the question “Do you have any concerns about not wearing a harness when needed?” was found to have a significant relationship with one’s PFAS use (odds-ratio=1.97, p=0.013). Those who believed not wearing PFAS was not a problem or minor problem were less likely to use PFAS than others.

Variables corresponded with “concerns about not using PFAS”. In addition, age, a company’s PFAS provisions, and training length are correspondent with one’s concerns about not using PFAS, similarly to their associations with PFAS use. Surprisingly, although whether a worker has received training was not discovered to be related to PFAS use, it was found significantly correlated with one’s concerns about not using PFAS. The result showed those who had received fall protection training had higher probabilities of believing not wearing a harness was a very serious or serious problem (odds-ratio=1.77, p=0.026). It was also discovered that the respondents who selected “personal safety concern” as a reason for their use of PFAS were more likely to consider
not wearing a harness a very serious or serious problem (odds ratio=1.69, p<0.001), which validated our speculation at the end of 3.7.5.

**Other associations.** It was also discovered from Table 3.3 that likelihood of harness ownership increased with increase in highest working height (odds-ratio=1.25, p=0.007). Figure 3.12 displays the increase in the likelihood of respondents’ owning their own harness with the increase in their highest working height. This indicated that if a worker realized that he/she had to work on/above 25ft, there was more than a 50% chance that he/she would choose to own a harness instead of using the universal one shared with other employees within the company.

![Figure 3.12: Likelihood of having an own harness vs. workers’ highest working height](image)

It was also found that whether or not a company provided employees with PFAS corresponded with the length of last training the employees received (odds-ratio=1.54, p=0.026) and their concerns about not using PFAS (odds-ratio=1.97, p=0.013). This
could be understood as follows: a company that supplies employees with adequate fall protection equipment is more likely to provide them with longer training sessions, which may increase the employees’ safety concern (‘concern’ as in recognition of importance).

There were no associations discovered among responses to these four questions: fall experience, whether workers had their own harness, received fall protection training or the company provided them with PFAS, by Pearson’s Chi-square test of association.

3.8. Discussion

For this study 167 completed surveys were collected from construction workers in and around Central Ohio. The objective of the survey was to examine current PFAS usage in the construction industry and identify reasons for use and non-use of PFAS from workers’ perspectives. There was also interest in looking for associations between PFAS design, fall-protection training, PFAS usage and fall-related accidents. Some findings from the survey corresponded to previous studies, while some showed contradictory results with other studies.

**PFAS usage.** This survey discovered that 63% of the respondents always use a harness and another 27% use a harness most of the time. This finding corresponds to what Sa (2005) discovered from his survey: the usage of fall protection devices is 98% among commercial roofers. Regarding lack of fall protection equipment in the current survey, 38% of the respondents who answered that they had experienced falls on the jobsite reported that there was no fall protection in place when accidents occurred. This percentage seems to be lower than the results from Cattledge et al (1996b). In that study
of 182 nonfatal fall-related injuries, the authors found usage of PFAS 10-55% of the time (meaning non-use 45-90% of the time).

A negative relationship was discovered from the current survey between fall experiences and PFAS use. It could be assumed that using PFAS might possibly influence ones’ safety behavior so that he or she will be more aware of falling hazard and has higher safety concern when working on heights, which reduces the possibility of falling. It could also be interpreted as the participants with fall experiences are more likely to answer “do not use PFAS” or “use PFAS rarely” (as shown on Figure 3.10), which is the opposite of what we always believe (fall experiences might motivate one to use PFAS more frequently). For future study, a key question stating “Did your use of PFAS affect (increase/ decrease) your fall experiences?” should be included in the questionnaire, in order to determine whether fall experiences actually affects safety behavior.

Reasons for use and non-use of PFAS. This survey examined the reasons why workers use and do not use PFAS. Table 3.1 and Table 3.2 compared the results from this survey with two previous studies (Johnson et al. 1998; Sa, 2005). As shown in Table 3.2, the rank of the reasons why the respondents used PFAS from the current survey were identical with what Sa (2005) discovered among commercial workers, while both Johnson et al. (1998) and Sa’ (2005)’s studies among residential workers showed the consistent results.
Table 3.5: Comparison of three studies with regard to the reasons why respondents used PFAS

It was found from the current survey that one of the main reasons why workers did not use PFAS was that the respondents believed that PFAS made them work slower than usual, in other words, it reduced their productivity. The same finding was discovered by Johnson et al. (1998) and Sa (2005). However, all results are from workers’ perception and none of the studies provided quantitative data to show how PFAS use affects workers’ productivity. “Uncomfortable” was listed in the results of all three studies as a reason for non-use of PFAS. This indicated a possibility of improvement in comfortableness of PFAS might increase PFAS use. In addition, the “restrictiveness of movement” and “difficult to find a tie-off point” were also considered important in affecting workers’ desire not to use PFAS.
---|---|---|---
(1) They make me work slower than usual (50%) | (1) Slows me down (54%) | (1) Uncomfortable (100%) | (1) They reduced the productivity (41%)
(2) They restrain my movement (50%) | (2) Uncomfortable (46%) | (2) Uncomfortable (41%) | (2) Uncomfortable (41%)
(3) Difficult to find a tie-off point (50%) | (3) Not a requirement of employment (26%) | (3) Peer pressure (6%) | (3) Peer pressure (6%)
(4) They make me uncomfortable (44%) | (4) Believe they will not fall (23%) | | |
(5) Nobody wears them on the jobsite (13%) | (5) Peer pressure (22%) | | |

Table 3.6: Comparison of three studies with regard to the reasons why respondents did not use PFAS

**PFAS design.** Previous studies indicated that easiness to use, comfortableness and cost of PFAS are important factors affecting PFAS usage in the construction industry (Johnson et al., 1998; Haslam et al. 2005). In this survey, the most frequent answers to what the respondents did not like about PFAS were “comfort level”, “difficult to use” and “everyone shares them in the company”. It was specially noticed that more than half of the respondents who did not own a personal harness responded that they would like to have their own harness. This indicated that providing a personal harness to each employee might be a solution for a company to encourage employees to use PFAS. However, to a company, providing each employee a personal harness may be more expensive than purchasing universal harnesses and allowing everyone to share them within the company. Haslam et al. (2005) raised the point that there are comfortable PFAS designs available, but companies may not be willing to purchase the higher-cost
equipment. Since supervisors and safety managers are the purchasers of PFAS, their perspectives with regard to PFAS design and its cost need to be understood. These are examined in the Phase Two of the current study.

**Fall protection training.** The Bureau of Labor Statistics conducted twenty surveys of workers’ injuries on the job from 1978 to 1990 and 75% of responding workers who experienced injuries from falls from elevations did not receive any fall protection training (Cohen and Colligan, 1998). However, Cattledge et al. (1996b) studied 182 fall-related non-fatal injuries, and discovered that 63% of the victims received some type of fall protection training. Sa (2005) discovered that 95% (55 out of 58) of the commercial roofers he surveyed had fall protection training program. The responses from the current survey showed that 91% of the respondents (n=152) had some type of fall protection training.

Although it was suggested in many studies that safety training is necessary to reduce fall-related fatal and nonfatal accidents (Hsiao and Simeonov, 2001; Huang and Hinze, 2003; Johnson et al., 1998), only one study (Sa, 2005) investigated the relationship between these two variables and no correlation was found (r= 0.07, p=0.60). The results from the current study also did not find a significant correlation between fall protection training and fall-related accidents (p=0.555).

It is thought that adequate fall protection training should influence PFAS usage (Johnson et al., 1998; Sa, 2005), but none of the studies discovered a significant correlation between fall protection training and PFAS usage. The current survey did not find any evidence to show that respondents who received fall protection training were more likely to use PFAS. However, it was discovered that those who received fall
protection training were more likely to answer that not wearing a harness is a very serious or serious problem (odds-ratio=1.77, p=0.026). This indicates that fall protection training might be influential in promoting one’s safety perception. In addition, positive relationships were discovered between PFAS usage, a company’s provision of PFAS, and the length of respondents’ most recent training, up to ten hours and above. The results indicated that if a company provided PFAS and professional training courses (normally only professional training courses lasted more than ten hours), the employees were more likely to use PFAS. This reflected that a company with a strong safety commitment may be influential in motivating workers to use PFAS.

In terms of training methods, the literature shows that safety and health training in the construction industry still remains in the format of a traditional lecture-centered program. Goldenhar (2001)’s survey discovered that common safety training methods among non-union construction companies are lectures, discussions and demonstrations (97%, n=45), followed by printed materials (94%) and videos (94%). Results from the current survey showed use of similar methods. The most frequently used methods among the respondents are tool box talk, video watching and training from professional trainers. Sixty-six percent (n=101) of the 152 responses had “tool box talk”, while 61% (n=94) answered “video training” and 52% (n=79) replied that they had training from professional trainers. There was no significant association discovered between the training methods and PFAS usage.

In order to further assess effects of fall protection training on PFAS usage, a comparison of workers’ usage behavior or intention to use PFAS before and after a fall protection training program will be explored in a later phase of this study.
**Other organizational factors.** It was discovered in a previous study that a company’s enforcement of fall protection regulations is significantly related to the use of PFAS and having fewer fall accidents (Sa, 2005). The current survey revealed that the requirement of employment is the top reason for workers to use PFAS, which accounts for 76% of the responses. The results from the current survey also showed that if a company provided employees with adequate fall protection equipment, the employees were more likely to use them. However, the current survey did not provide much information in depth of company’s actions and attitude towards PFAS use, such as the methods that companies applied to enforce employees to use PFAS, the personnel who enforced the regulations within the organization, and how the organizational factors weights in the PFAS use model. Such information will be studied in the subsequent phases of this study.

3.9. Limitations

The main limitation of the current survey is the use of a convenience sample, which consisted of only commercial construction workers, and from one geographic region. Additionally, the proportions of the trades we surveyed are different from the overall proportions within the construction industry. Use of a convenience sample indicated that workers who were not surveyed might behave differently than the workers in the convenience sample. This means that the results from the current survey may not apply to residential construction companies, nor do they generally represent commercial construction. It should be considered a pilot effort to begin to understand the use of PFAS from the perspective of commercial construction workers.
Although the number of completed surveys was slightly larger than the calculated sample size, the number of participating companies was only fourteen. All of the trades in the construction industry were not represented in this survey. The participating companies were sized from 20-500 employees. According to the latest statistical data published by National Institute for Occupational Safety and Health (NIOSH), there are a total of 52.6% of employees working for companies in this range within the construction industry in 2002 (CPWR, 2008). A larger sample size and responses from companies with fewer than twenty employees would be desirable in a future study. In addition, when determining sample size, an 80% confidence level was selected due to the infeasibility of collecting a larger number of responses. In future studies, a higher confidence level (90 or 95%) should be considered for higher precision of the results.

All responses to the questionnaire were self-reported. There are many factors that might affect the validity and reliability of the self-reported responses, which include respondents’ characteristics and wording of the questionnaire (Foley, Manuel & Vitolins, 2005). In this specific study, some questions were directly related to worker behavior. These might be considered sensitive questions to some of the participants, even though they were told the survey was confidential and voluntary. Ideally, the reliability of the survey could be assessed by repeating the survey to the same group of participants, and the validity of the survey could be examined by comparing their survey responses with other types of data, such as observations and medical records. However, due to limited time and manpower, researchers were not able to perform these assessments of reliability and validity of the survey.
3.10. Conclusion

The following conclusions were drawn from the preliminary survey:

Construction workers are at risks of fall hazard and PFAS usage is not adequate when needed. Thirty-four percent of the sample had experienced falls. Thirty-eight percent of the respondents who experienced fall-related accidents answered that there was no fall protection equipment in place when accidents occurred. It was also discovered that those who use PFAS more often are less likely to have had a fall experience. It could be speculated that use of PFAS might increase one’s safety awareness. The relationship between fall experience and PFAS use will be further investigated in the subsequent phases of this study.

The majority of the respondents to the survey chose to use PFAS when necessary. However, their motivations for using PFAS were varied. “Requirement of employment”, “Personal concern for safety” and “Supervisory enforcement” were found to be the top three reasons why they chose to use PFAS. It was also discovered that a company’s provision of adequate fall protection equipment strongly affects its employees’ PFAS use. These results implied that strong management commitment to safety appeared to motivate PFAS use.

Ninety-one percent of the sample had some type of fall protection training. Most common training methods are tool-box talk, video watching and training from professional trainers. It was discovered that fall protection training positively corresponded with one’s concerns of wearing a harness (answers to the last multi-choice question). In addition, it was found that length of participants’ most recent training was
significantly associated with their PFAS usage. The longer their most recent training lasted, the higher chance participants would “always use PFAS”.

The reasons that these construction workers do not like to wear PFAS include: they feel PFAS reduces their productivity, PFAS restrains their movement, sometimes it is difficult to find a tie-off point, everyone shares them in the company, and design of harness is uncomfortable. This could mean that improved PFAS designs might increase PFAS use.

Overall, Phase One: the preliminary survey gathered information on PFAS usage among a convenience sample of commercial construction workers and identified the reasons these workers use and do not use PFAS. Results from the survey indicated that improved PFAS design and length of fall protection training may affect PFAS usage. However, opinions on PFAS use from other stakeholders within the construction industry, including management of the construction companies, safety professionals and architects, should also be included in an examination of PFAS effectiveness. Therefore, interviews are to be conducted in Phase Two to collect information from other stakeholders.

More detailed information is also needed from the workers. Survey is only one method for gathering data and other methods, such as participatory workshops, will be used in Phase Three to gather more insights on the factors affecting PFAS usage from both workers and superintendents.

In addition, Phase One failed to provide insight on the relationship between fall
protection training and PFAS use, though the literature suggests there may be a linkage. This will be further investigated through other methods, to further develop and refine a path model of PFAS use, in subsequent phases of the study.
CHAPTER 4

INTERVIEWS

4.1. Introduction

The previous chapter illustrated how the preliminary survey was applied to gather information on construction workers’ PFAS use and to investigate the factors that might influence PFAS usage. The results revealed that there were multiple reasons why workers were reluctant to use PFAS although they understood the use was mandatory. However, the survey only provided insights on PFAS use from the workers’ perspectives. Several theoretical models have explained the use of Personal Protective Equipment as a type of social and organizational behavior (Torp et al., 2005). Karasek and Theorell (1990) discovered that organizational aspects of work could influence workers’ health and safety behavior. Therefore, besides obtaining information from individual users, perspectives from other stakeholders within the construction industry should also be included before we draw overall conclusions. Figure 4.1 listed all stakeholders in the construction industry.
Mior and Buchholz (1996) stated that the construction industry has a rigid hierarchy. On the top of the hierarchy, developers or investors decide to develop a new commercial or residential area. Then the architects and designers design a building which will meet the specifications of the developers. Then contractors and subcontractors typically bid on a job by responding to specifications with a dollar amount for which they can do the job. After the contract is signed, the work is assigned to workers who are at the bottom of the hierarchy (Mior and Buchholz, 1996). Although the tasks in the industry are divided, workers’ behavior is still influenced by other stakeholders who are listed on the top of the hierarchy, such as the management of the construction companies, safety personnel, designers and architects.

In order to build a comprehensive path model of PFAS use, interviews are needed to gather information from the above stakeholders, including supervisors’, safety professionals’, trainers’ and architects’ perspectives. Compared to a survey, an interview is more time consuming and less feasible for collecting information from larger numbers of people. However, an interview is open-ended, which allows participants to provide
more detailed answers for each question, so both methods can be implemented as data gathering tools (Foley et al., 2005).

4.2. The development of questions

Considering different perspectives among supervisors, safety professionals and architects, three sets of questions were specially designed for each profession. All three sets of questions started by asking the interviewees’ job title, job responsibilities, work history and experiences.

For supervisors, the rest of the questions were focusing on PFAS usage on their specific jobsites. For example, “Does your company provide employees with PFAS (harness)?” “What is the harness model that your company is using?” “Can you tell me about the fall protection training program in your company?” “Does your company have any rewards program to encourage safety behavior?”

For safety professionals, such as OSHA inspectors and investigators, their questions were designed to investigate the issues concerning inadequate PFAS usage based on their work experience. The questions included: “Among all the accidents you have investigated, what is the main factor that causes falls?” “Have you investigated any specific fall-related cases in which the victims were not wearing a harness?” “Have you conducted any type of safety training for construction employees?”

For architects, researchers intended to extend the research problem to the level of social behavior, by addressing questions related to the role of each important component of construction hierarchy. The questions included “How do you describe the teamwork between architects (designers), engineers and contractors?”, “Can you explain ‘safety through design’ from your perspective?”
There is one common question for the three sets of questions: “From your point of view, what might be the main reasons that workers do not wear a harness? Do you have any thoughts on how to increase current harness usage?” which allows participants to provide more relevant information. Three sets of questions can be found in the Appendix B (page 224).

4.3. Procedures

Potential participants were introduced to the researcher through the OSHA-OSU Safety Day conference which was held by the Department of Environmental Health and Safety of The Ohio State University with cooperation of OSHA Ohio office. The researcher then contacted potential participants through either email or phone to arrange for the interviews. A total of fourteen participants were contacted, including architects at OSU, safety managers, supervisors, OSHA investigators and safety consultants. Nine interviews were conducted from February to March, 2008. Participation rate was 65%.

A typical interview lasted from thirty minutes to an hour. Each interview started with the researcher explaining the purpose of this study and the informed consent process. Participants were requested to read the consent form and sign it once they agreed to participate. They were also notified that the entire interviewing process would be audio-recorded for future data analysis.
4.4. Results

4.4.1. Background information of the interviewees

A total of nine professionals were interviewed during a two-month period. Four of them were superintendents of construction companies, one was a safety manager and vice president for a commercial roofing company, two were OSHA officers (including one OSHA onsite consultant) and one was an architect. The majority of the interviewees had more than ten years of experience in the construction industry and had been through the evolvement of safety in the industry over last decade. Their background information is listed in Table 4.1.

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Job title</th>
<th>Specialty</th>
<th>Years in construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Safety consultant</td>
<td>Fall protection</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>OSHA safety compliance officer</td>
<td>Construction safety</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>OSHA safety compliance officer</td>
<td>Construction safety</td>
<td>21</td>
</tr>
<tr>
<td>4</td>
<td>Safety manager</td>
<td>Construction safety</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>Assistant superintendent and safety coordinator</td>
<td>Construction safety</td>
<td>1 1/2</td>
</tr>
<tr>
<td>6</td>
<td>Superintendent</td>
<td>Iron work, safety</td>
<td>23</td>
</tr>
<tr>
<td>7</td>
<td>Superintendent</td>
<td>General construction work</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>Superintendent</td>
<td>General construction work</td>
<td>18</td>
</tr>
<tr>
<td>9</td>
<td>Architect</td>
<td></td>
<td>16</td>
</tr>
</tbody>
</table>

Table 4.1: Background information of the interviewees

4.4.2. Interviews with superintendents and safety manager

*PFAS availability.* All superintendents and the safety manager that were interviewed indicated that their companies provide employees with PFAS. There are various models of harnesses applied in the industry. The most commonly used harness models are Miller traditional non-stretch full-body harnesses 650-850 (shown as Figure
4.2) and DBI-SALA basic harnesses Delta (shown as Figure 4.2.). The prices of these harnesses range from $60 to $120. The companies usually store PFAS in a company toolbox, when it is not used. All employees in the same company are allowed to share the company harnesses.

![Figure 4.2: Miller non-stretch full-body harness](http://www.millerfallprotection.com/fall-protection-products/body-wear/non-stretch-harnesses)

![Figure 4.3: DBI/SALA harness](http://www.jlindustrial.com)

However, the interviewees further mentioned that some workers, especially those who have to wear PFAS during a majority of their work time, preferred to have their own harness, because they feel the standard harness is uncomfortable and troublesome to adjust to their own size after others have used it. They either ask their employers to purchase a harness especially for their needs or they select and purchase their own harnesses. For example, one supervisor mentioned that there is one type of harness manufactured by DBI/SALA that is designed to fit the population with a waist of 54” or greater, several of his workers purchased this type of harness on their own. Interviewees also mentioned that most of the iron workers have their own harnesses, because they use them very frequently. A common harness model that a worker would purchase on his/her

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8 Picture is from: http://www.millerfallprotection.com/fall-protection-products/body-wear/non-stretch-harnesses

9 Picture is from: http://www.jlindustrial.com
own is DBI/SALA Exofit, which was shown in Figure 4.4. Two superintendents who have used the Exofit commented on this harness as “comfortable” and “light-weight”.

![Image of DBI/SALA Exofit harness](http://www.masonrymagazine.com)

Figure 4.4: DBI/SALA Exofit harness

**Key criteria of PFAS.** During our discussions on “key criteria to make PFAS acceptable”, “comfort” and “economical” were two criteria mentioned by most of the interviewees. Three superintendents stated that the reason they think the cost of PFAS is important is that they are the ones responsible for purchasing safety equipment in the company and they are given a certain amount for their safety budget every month. Therefore, cost of PFAS seems to be the most important criteria to the superintendents.

One commented in detail that the harnesses need to be more comfortable on the shoulders and back and another added that leg straps should have padding as well. Two superintendents mentioned “light-weight” and “ergonomically fit”. “Quicker-adjustment”, “user-friendly” and “do not restrain movement” were also considered factors that affect satisfaction with PFAS.

**Productivity impact.** When the researcher further asked “do you think usage of PFAS reduces workers’ productivity”, two of the superintendents thought that some

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10 Picture is from: http://www.masonrymagazine.com
workers might offer that as an excuse for not using PFAS. They believed reduction of productivity was the workers’ perception. However, they did not believe that projects had been delayed due to the requirement for workers to use PFAS. In contrast, the other three interviewees emphasized that pre-planning, such as setting up anchorage and selecting the correct fall protection equipment, did slow down the normal work pace, but they believe that use of PFAS is definitely worthwhile and beneficial when considering the consequences due to accidents.

**Fall protection training.** The next question was “Can you tell me about the fall protection training program in your company”. All superintendents and the safety manager that were interviewed were identified as the competent person on their job sites. A competent person is defined by OSHA (2008a) as a person “who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them”. It was also indicated that a competent person is responsible and capable of providing safety training on the job site (OSHA, 2008). Three of four superintendents interviewed regularly conduct safety training of new employees on the job sites. The formats of the first day fall protection are safety orientation and a safety talk, and most of training of new employees is one-to-one training. During the orientation, the superintendents go over all the topics listed on the training materials. For example, they would explain “100% 6-foot fall protection” to the new employees and ask whether they understood it. In some companies, the employees receive a certificate once they complete the training, indicating their eligibility for the job. Only one of the superintendents uses hands-on training method to teach new
employees. He demonstrates the proper way to put on a harness and attach the harness to a lifeline and an anchorage point. In addition, calculation of free-fall distance was covered in the training.

Two companies provide regular training courses to all employees; these are led by professional trainers. The formats of the training are various, depending each time on the trainer. The professional training courses are considered to be comprehensive and informative.

All superintendents and safety manager are responsible for retraining their employees. If an employee was found to behave unsafely on the jobsite, he/she would be retrained by the superintendent. In addition, weekly tool-box talks and monthly safety meeting are commonly applied in most construction sites to maintain employees’ safe behavior. Table 4.2 shows general information on the fall protection training for new employees, from interviewees who are numbered from 4 to 8 in table 4.1.

<table>
<thead>
<tr>
<th>Interviewee no. in table 4.1</th>
<th>Format</th>
<th>Length</th>
<th>Trainer</th>
<th>Number of trainer vs. trainees</th>
<th>Retrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Mandatory quarterly safety training</td>
<td>10 hours or above</td>
<td>Professional consultants</td>
<td>One to thirty</td>
<td>yes</td>
</tr>
<tr>
<td>5</td>
<td>Safety orientation</td>
<td>10-20 minutes</td>
<td>Superintendent</td>
<td>One to one or one to multiple</td>
<td>yes</td>
</tr>
<tr>
<td>6</td>
<td>Mandatory safety training at the beginning of the year</td>
<td>8 hours</td>
<td>Professional trainer</td>
<td>One to forty</td>
<td>yes</td>
</tr>
<tr>
<td>7</td>
<td>Safety orientation</td>
<td>10 minutes</td>
<td>Superintendent</td>
<td>One to one or one to multiple</td>
<td>yes</td>
</tr>
<tr>
<td>8</td>
<td>Safety orientation, equipment demonstration</td>
<td>20-30 minutes</td>
<td>Superintendent</td>
<td>One to one or one to multiple</td>
<td>yes</td>
</tr>
</tbody>
</table>

Table 4.2: General information of fall protection training for new employees from interviewee no.4-8 in table 4.1
When further asked “Do you have any ideas on how to improve fall protection training”, three interviewees preferred hands-on training. They indicated that trainers should not only demonstrate how PFAS should work, but also allow trainees to go through the process of putting on a harness, connecting it to a lanyard and finding an appropriate tie-off point. Only through this process, would the trainees understand that PFAS is not just the harness, but a multiple component system, consisting of a full body harness, a lanyard and an anchorage. One interviewee mentioned that his experience of falling with a harness on during a safety training session made him more aware of the force that would occur after a fall. He believed this type of demonstration would assist workers to realize how dangerous it would be working at heights without a PFAS. Two superintendents emphasized that all superintendents should be properly trained so that they have better safety knowledge, which makes them eligible to train others.

*Improvement on PFAS use.* When discussing methods of improving PFAS usage, four of five interviewees especially emphasized that safety training is important in terms of motivating employees to use PFAS appropriately. They also stated that a company’s enforcement of safety training and comprehensive safety policy are necessary for proper safety culture within the company. One superintendent suggested that a harness should be purchased based on every employee’s special needs and an employee’s name tag should be attached to it. He believed that personalized harnesses would highly encourage employees to use harnesses. Furthermore, it was also indicated that availability and accessibility of appropriate fall protection equipment was necessary for a company to motivate PFAS usage.
Incentives. The last question for superintendents and safety managers was “Are there any incentives or rewards in the company to encourage safe behavior?” Two of them replied “yes” to the question. One superintendent explained the “safety bonus” policy in this company: every employee would have a certain amount of safety bonus every month if they were working safely on jobsites; if a superintendent or a safety manager observed them behave unsafely, the penalty will be deducted from their bonus. The other superintendent reported a similar safety policy that his employer enforced. The company provided a safety bonus of $.50 every work hour and $.75 for every hour of overtime. Every employee would receive the safety bonus at the end of year if he/she was not involved in any kind of safety accidents throughout the year. They both believed that either a bonus or rewards system is a motivation for employees to work safely.

4.4.3. Interviews with OSHA officers and consultants

A total of three OSHA officers and consultants were interviewed. One of the OSHA officers is specialized in fall protection and she has conducted 730 inspections throughout her eight years with OSHA. Among these 730 inspections, 85% were related to fall protection.

Factors that cause fall-related injuries. Two OSHA officers were first asked “Among all the accidents you have investigated, what is the main factor that causes fall-related injuries”. They both replied that it was lack of fall protection, which includes not using PFAS, guardrails, safety nets or PFAS that was not tied-off. One further explained that during her investigations, she discovered that many employees were not trained on how to wear a harness and when to wear it. Improper usage of fall protection and lack of training were most commonly cited during OSHA accident investigations.
**Key criteria of PFAS.** The following question was “What do you think are the key criteria to make PFAS acceptable?” “Comfort”, “easiness to put on” and “light-weight” were the top three criteria they mentioned, which were very similar to the answers from the superintendents and workers. One addressed that she has seen workers use a one-piece harness, which integrated a safety harness into work overalls. She said the users highly complimented the product due to its easiness of use.

**Reasons for not using PFAS.** When the three professionals were asked “what might be the main reasons that workers do not wear a harness”, they all mentioned “they wanted to get the job done quickly” or “they were taking the shortcut by choosing not to use a harness in order to save time”. The answers implied that some workers perceived the existence of PFAS would either slow their work pace because it takes time to hook and unhook a harness, and they also believed a harness interferes with their work tasks. One OSHA consultant provided an alternative explanation, by stating that it might possibly be due to worker’s ignorance of safety regulations.

**Improvement of PFAS use.** When answering the question “how to improve PFAS use”, all three professionals suggested that strong enforcement and commitment from the management of the company should motivate safe behavior. One stated that “poor safety is due to poor management”. They further stated that a company should have a comprehensive safety program, regular safety meetings, strong enforcement of safety policy and constant training and retraining of their employees. They also believed that training plays an important role in hazard recognition and motivation; talking to employees and adequate training of employees would help them to understand the importance of the safety equipment and motivate them to wear PFAS.
Fall protection training. Two of the three interviewees have conducted professional construction safety training, such as OSHA 30 hour training. A variety of training methods were applied, such as PowerPoint presentation (mentioned as the most common training format), videos and hands-on training. They indicated that hands-on training is the most effective and informative training method from the feedback of the trainees. Through hands-on training, the trainees learn how to put on a harness, how to find an appropriate tie-off point, experience a fall with a harness on, and calculate the actual force that occurs due to falling. In addition, an informative presentation with OSHA statistics on accidents, pictures of scenarios, examples of accidents and case studies help workers to be more aware of safety hazards and motivate them to use fall protection equipment when necessary.

Training evaluation. Many evaluation methods were applied to examine the effectiveness of the training. One consultant typically distributed an open-book test after training, which consists of 35 questions. The trainees would first work on them individually, then discuss them within a group, and correct answers would be announced at the end of the training session. She believed post-test is beneficial for both trainees and trainers in terms of recognizing the influence of training. One interviewee mentioned that she experienced difficulties when communicating with non-native English speakers during inspection and accident investigation. She further stated that based on OSHA regulations, training should be conveyed in a language that non-English speaking employees could understand (OSHA, 2008b).
4.4.4. Interview with an architect

When describing the teamwork between architects, designers, engineers and contractors, the architect confirmed being in a construction hierarchy in which they work independently most of the time and there is a lack of communication between the groups. In the construction hierarchy shown in Figure 4.1, an architect’s responsibility is designing a building that meets the specifications of the owner or developer. Traditionally, architects and engineers are not responsible for informing contractors of hazards that might result from the design (Baxendale and Jones, 2000). Contactors and sub-contractors have always been considered the ones with sufficient knowledge and experience in tackling safety issues throughout the construction processes. Therefore, the hierarchy not only passes down the work to the construction workers, but also passes down the risks involved in the work (Baxendale and Jones, 2000). The architect further stated that some designers, architects and engineers have not had any type of safety training and they were not knowledgeable enough of the safety regulations. There have been cases where buildings were designed in ways that made it infeasible to apply any type of fall protection during construction and maintenance.

However, he stated that the architects and designers are currently going through a transition stage: integrating safety into design. At least one person in the team has to be knowledgeable and experienced in construction safety to avoid the potential risks involved during the construction process of the building. The team leader should recommend that the designers and architects take proper safety training to gain a basic knowledge of construction health and safety. Sometimes designers and contractors may even work together to develop the drawings at the early stage of the building process in
order to reduce the risks. “Safety through design” is a revolution not only aiming at architects and designers, but the entire population in the construction industry.

4.5. Discussion

The interviews provided a consistent picture of superintendents’ and safety professionals’ perception of current PFAS use and how to increase the use. Combing the results from the workers’ survey in the last Chapter, the following table lists reasons for not using PFAS, desired characteristics of a harness, desired characteristics of fall protection training and future improvements on PFAS usage from the perspectives of three different groups of construction industry stakeholders.

<table>
<thead>
<tr>
<th>Reasons for nonuse of PFAS</th>
<th>Workers’ perspectives</th>
<th>Superintendents and safety managers ‘perspectives</th>
<th>OSHA officers and consultants’ perspectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makes the users work slower than usual, restrains movement, difficult to find a tie-off point, uncomfortable</td>
<td>Uncomfortable, troublesome to put on and adjust, not enforced, slows down the job</td>
<td>Eagerness to get the job done quickly, troublesome to tie-off</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Desired factors of a harness</th>
<th>Comfort, easy to use, personalized</th>
<th>Comfort, cost, quick-adjustment, light-weight, personalized</th>
<th>Comfort, easiness to put on, light-weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desired factors of fall protection training</td>
<td>N/A</td>
<td>Hands-on training, experience fall with a harness on, proper training for trainers</td>
<td>Hands-on training, proper language for non-English speaking workers</td>
</tr>
</tbody>
</table>

| How to improve PFAS usage | N/A | Training, availability and accessibility, enforcement of policy | Safety program, safety meetings, enforcement of safety policy, training |

Table 4.3: Comparison of results from survey and interviews

Reasons for nonuse of PFAS. Johnson et al. (1998) studied the reasons for workers’ noncompliance of fall protection regulations from construction managers’
perspectives and they discovered that “slow down the job”, “uncomfortable design of PFAS” and “believe they will not fall”, “peer pressure” and “supervisor does not enforce” are the main reasons why workers choose not to use PFAS when required. This is consistent with the findings listed on Table 4.3, which shows that “uncomfortable”, “troublesome to use PFAS”, “slow down the job” and “PFAS use is not enforced” are mainly mentioned by the superintendents and safety managers interviewed. Among them, “troublesome to use PFAS” and the workers’ perception of use of PFAS might “slow them down” are also reinforced by OSHA officers and consultants interviewed.

Among the reasons listed above, only “uncomfortable design of PFAS” could be improved through change of PFAS design. The rest, such as workers’ perception of a properly tied-off PFAS use might “slow down work pace” and “restrict movement”, cannot be changed in the current situation. Although it might be the fact that PFAS use actually slows down the job (currently no quantitative data are provided to support this assumption), it was explained by some superintendents that additional time spent on using harness is considered necessary and beneficial to protect workers from accidents. Therefore, in order to encourage workers to use PFAS, management’s enforcement and proper training should be emphasized to influence workers’ use behavior.

**Improvement of PFAS use.** As mentioned above, during the investigation of why workers do not use PFAS, the majority of the interviewees believe that the commitment from management plays an important role in creating safety culture and preventing accidents. Management’s commitment to safety is reflected in adequate fall protection training, a comprehensive safety program and fall protection plan, regular safety meetings and strong enforcement of safety policy. During the interviews, fall protection
training was also emphasized by both superintendents and OSHA professionals because it is the most direct, feasible and economic method to encourage and motivate the usage of PFAS among workers. Furthermore, superintendents and the safety manager indicated that a safety bonus is a beneficial method to motivate safe behavior within the company.

**PFAS design.** “Uncomfortable design” of PFAS is mentioned in most research studies as one reason why workers do not use PFAS. These studies also mention that the improvements in PFAS design should make the system more comfortable for users (Johnson et al., 1998; Sa, 2005). The results of the interviews from the current study also showed that in terms of the factors that affect acceptability of a harness, comfort, easiness of use and light-weight were three criteria mentioned by the interviewees. In addition, superintendents indicated that a personalized harness might increase workers’ usage because they perceive it is more comfortable than the universal harness and it reduces the time to adjust the harness. Superintendents, normally the purchasers of safety equipment, mentioned costs of a harness as another factor affecting its usage. This implied that due to the limited safety budget of some construction companies, the company’s universal harness might be the most economic choice and not meet the special requirements of users. Each employee purchases his/her own harness could be considered the optimal solution for both the company and the user. However, whether workers believe purchasing their own harness is a good investment needs to be investigated in the subsequent phases of this study.

**Fall protection training.** As shown on the Table 4.3, fall protection training is viewed as a tool to encourage PFAS use among workers by superintendents and OSHA officers. In discussions on how to improve fall protection training, one of the findings
was that only a small portion of construction workers received their safety training on their first day of work. Most of the fall protection training for new employees was provided by either superintendents or safety managers on site, and the length of the training varied from ten to thirty minutes. Some companies provide annual or monthly mandatory group training presented by professional trainers. However, in the situation that an employee’s first day on job happened to be right after the mandatory group training, an additional training on the job site should also be provided by the superintendent. It can be suggested that companies should make comprehensive safety training a requirement for new employees.

It was mentioned by interviewees that hands-on training, including demonstration of safety equipment should be involved in fall protection training. OSHA professionals further remarked that proper training should be provided in a language that non-English speaking employees could understand.

*Safety through design.* The interview with the architect revealed the necessity of integrating safety concepts into every level of the construction hierarchy. The “safety through design” concept which was mentioned by the architect stated that only infiltrating adequate safety knowledge into the process of design and architecture would make fall protection integration feasible and realizable. Teamwork between designers, architects, engineers and contractors is necessary to create and maintain a safe and health workplace. Therefore, “safety through design” concept is considered a foundation of proper PFAS use.
4.6. Limitation

Due to limited time and manpower, only nine professionals were interviewed throughout a two-month period. All five superintendents and safety manager are working for commercial contractors and four of them are currently involved in OSU construction projects. OSU has its own safety regulations which are more comprehensive than OSHA regulations. This suggests that the interviewees might have higher safety concern and the companies they work for might have better safety culture than the average construction industry. Ideally, a combination of interviewees from residential and commercial construction companies would be a desirable sample selection. However, as mentioned in the previous chapter, the researcher failed to convince residential construction companies to participate in this study.

4.7. Conclusion

The following conclusions can be drawn from the interviews with the supervisors, safety professionals and architects: “PFAS use not enforced”, “the design is uncomfortable”, “troublesome to use PFAS”, “slow down the job” and “interferes with the tasks” were discovered to be the reasons for nonuse of PFAS, from the perspectives of the interviewees.

When asked how to improve current PFAS usage, fall protection training was suggested by the majority of the interviewees to motivate workers’ PFAS use behavior. However, three out of the five superintendents and safety managers interviewed answered that their companies offered fall protection training to new employees only through safety orientation or general talk, with a length of just 10-30 minutes. This showed a common
phenomenon that fall protection training for new employees is inadequate in some construction companies. It was suggested by the safety professionals during the interviews that more comprehensive safety training, such as OSHA 10 hour and OSHA 30 hour training are preferred for a better understanding of safety regulations, fall hazards and how to use PFAS correctly.

In addition, some organizational factors, such as company’s enforcement and incentives were mentioned by some safety professionals as important factors for influencing PFAS usage.

Comparing the results from the preliminary survey (Chapter 3) and these interviews, it was found that construction workers attribute non-use of PFAS to design issues, such as un-comfortableness and job-restrictiveness, while the managers and safety professionals tend to believe that fall protection training plays an important role in affecting PFAS use. This reveals some degree of misperception between various stakeholder groups, and importantly, between supplier and users of PFAS. Additional information on use and barriers to use will be sought through use of small group interviews, to explore some insights of PFAS design and training. The detailed information of small group interviews will be provided in the next chapter.
CHAPTER 5

PARTICIPATORY WORKSHOPS

5.1. Introduction

Table 4.3 in the last chapter demonstrated the results from both preliminary surveys and interviews (chapter 3 and 4). Through the surveys, the workers’ perspectives of current PFAS usage were discovered and the interviews focused professionals’, including superintendents, safety professionals, OSHA officers and architects’, opinions on inadequate usage of PFAS. From the results of the preliminary survey and interviews, it was discovered that PFAS design and fall protection training are both considered strong factors in terms of affecting PFAS use in the construction industry. It was also mentioned in the first two phases that company’s enforcement and the availability of anchorage points are thought to play important roles in PFAS usage.

However, the construction workers seem more inclined to attribute the reasons why they do not use PFAS when required to design problems, while the majority of safety managers and OSHA officers believed that fall protection training is a stronger predictor of PFAS usage than PFAS design. Some individual factors, such as risk perception and self-efficacy were not specifically addressed in the first two phases of data collection in this study.
Small group interviews provided means of examining a topic in more depth than may be possible in a survey or individual interviews. Participatory workshops are a form of small group interviews that include a portion of time spent imagining, designing and redesigning the topic of the interview, to meet the participants’ needs, wants and desires. Therefore, participatory workshops were seen as a valuable study tool for further study of PFAS design and training.

5.2. Background

Participatory workshops first started in Europe, during the Scandinavian workplace democracy movement and were considered to be “a set of theories, practices, and studies related to end users as full participants in activities” (Muller, 1993). Schuler (1993) further defined “participation” as “users and other stakeholders participated in the design process to ensure that the design outcomes fit the way people will actually use the product in their own lives”. Sanders (2002) described the participatory methodology as “a belief that all people have something to contribute to the design process and that they can be both articulate and creative when given appropriate tools with which to express themselves”. Participatory workshops are normally used as events to help users and other stakeholders communicate and share ideas, goals and outcomes.

Several studies have applied a participatory methodology in the construction industry to address safety and health issues in the workplace. Moir and Buhholz (1996) conducted two participatory activities: (1) intervention ideas, and (2) comparison of safety systems of two different contractors, in highway construction industry in Boston. The objective of the first activity was to gather feedback on intervention ideas and
generate new ideas, regarding ergonomics issues, from the various levels of the construction hierarchy. The first activity also helped promote the intervention ideas widely within the participants. The second activity explored both workers and management personnel’s perceptions of contractors’ safety culture, including norms, beliefs, behaviors, previous and current safety systems. However, the article did not present the results of the evaluation of these two activities. Vink (1997) applied a participatory approach in workplace redesign to reduce the physical workload and the perceived shoulder and back pain among 50 scaffolders. A checklist with a variety of improvements was completed by the scaffolders in order to identify the problems needed to be tackled in the redesign. The improvements were then selected, implemented and evaluated. However, only 26% of the participants of the first questionnaire (checklist) responded to the evaluation of the improvements after half a year. Although the scaffolders participated directly in the redesign process, the improvements in the checklist were generated by a steering group led by the management of the company. There was no direct communication between the steering group and scaffolders during the whole process. In a broader participatory point of view, this type of participatory approach was considered as “user-centered design” with “expert-mindset” (Sanders, 2006), which is not actually participatory in principle (i.e. involving the end-users). The same participatory approach was applied in a large installation company to reduce sick leave days caused by musculoskeletal workload (de Jong and Vink, 2002). The results showed that 138 devices were used among 7000 workers and eight out of nine units used at least one device. However, similar to Vink’s study in 1997, the selection of the
improvements was done by only safety professionals, management of the company and one external expert.

Participatory workshops were also applied in facilitating safety and health training in the construction industry. Baker, Stock & Szudy (1992) reported a training program designed to improve the quality of safety in the construction company. “Tailgate safety meetings” were conducted to assist construction workers identify potential hazards and develop solutions while participating. The participants of the safety meetings consisted of workers from different trades with a wide range of workers’ experiences. Participants’ reactions to the training program were positive. However, there was no comparison of workers’ behavior or attitude before or after training. Spielholz (2007) described participatory training sessions delivered to construction workers and safety professionals that utilized fatality narratives, description of incident narratives and pictures, and materials translated into languages prevalent within the working population. This format of training was evaluated to be effective through web-survey. However, it might not be the best tool for workers because only 14% of respondents of their web-survey were construction workers.

Although most studies listed above did not evaluate the effectiveness of the improvements suggested from the workshops, or encountered low response rate during the evaluation, participatory approach is considered a useful tool in exploring ideas and insights from the target population. The previous studies indicated that participatory methodology could be applicable and effective in the construction industry if it includes practices shown to be important in prior studies, including (1) Participants with enough experience and knowledge should be selected; (2) Participants should be fully immersed
in their experiences before the sessions; (3) The session materials should use prevalent terminologies within the participants’ trade (Spielholz, 2007). These practices were also adhered to in the current study.

5.3. Procedures

Two participatory workshops were conducted in spring, 2008. The objectives of the workshops were to generate ideas for improving PFAS usage, but with different focuses. Since the results from the first two phases of this study indicated that PFAS design and fall protection training are two strong factors affecting PFAS usage, the first workshop was specifically aimed at generating ideas for improvements in PFAS design, while the second was focused on fall protection training programs in the construction industry. Both workshops were planned to be approximately two-hours long, consisting of three session elements: sensitization, individual work and group work.

5.3.1. Participants of the workshops

One of the key characteristics of participatory workshops is that they include end-users in the design process. They are the ones who may have unique insights as to how to improve their work and their work life. They are treated as experts, because they have the most knowledge and experiences concerning what they do and how they work. Among two workshops in this study, the potential end-users were construction workers and superintendents who have experiences in using PFAS. The recruitment flyers (see Appendix C, page 231) were distributed to various construction sites and training centers
in Central Ohio. The flyer described the purpose of the study, the qualifications of participants, the incentives for participation and contact information of researchers.

A total of fifteen participants attended the two workshops, including ten construction workers, three superintendents and two safety personnel from three different contractors. The average age of the participants was 35 years old, and their years of experience in construction industry varied from 3 months to 23 years, with an average of 11.7 years.

5.3.2. Participatory workshop materials

Development of the research materials, for example, generative tools, is very important in participatory workshops. The purpose of the tools is to build an interface between researchers or designers and participants so that the participants are able to immerse themselves into thinking about their own experiences and expressing themselves with the tools provided to them during the workshop. Some examples of participatory tools include: scenarios, mock-ups and simulations of the work and technology; designed games, stories and generative tools. For example, the construction of a collage may be focused on thinking, mapping, feeling and story-telling activities. Sanders (2002) further described a workshop toolkit as “a scaffold that allows people to express their experiences and creativity”. Figure 5.1 demonstrates some typical types of generative tools, such as collaging toolkit, cognitive mapping toolkit and Velcro-modeling toolkit. The specific tools used in this study (sensitization workbook, timeline toolkit, and design toolkit) will be introduced while explaining the procedures of each session.
5.3.3. Sensitization

The sensitization phase of each of the two participatory workshops in this study involved the completion of a “workbook” tool by each workshop participant. Sleeswijk Visser et al. (2005) defined a workbook as “a booklet with open-ended, fun, friendly questions to answer and things to draw”. A week before the workshops, each participant was asked to complete a workbook and the completed workbook was to be submitted to the researchers at the beginning of workshops. The purpose of sensitization is to assist participants in recalling their experiences and feelings in order to help idea generation. If submitted prior to the workshop, they can also help researchers prepare for the workshops.

The first section of the workbook in this study asked the participants to describe themselves using questions, such as “What is your favorite TV show”, “What are your hobbies” and “For what reasons do you work in the construction industry”. The second section requested participants to record a log of their daily work life for one day and in the last section they were asked to address their concerns about PFAS design or training (depending on which workshop they participated in). In addition, the participants were given the opportunities to list their favorite PFAS design and even draw the design that
they would like to propose. Figure 5.2 shows a sample of a workbook page for the PFAS design workshop. On this page, a participant was asked to keep a log of a typical workday of his or her life. The workbooks for both design and training workshops can be found in Appendix C (page 232).

![Sample page of a workbook for participatory workshops](image)

Figure 5.2: Sample page of a workbook for participatory workshops

5.3.4. Individual sessions

In the forty-minute individual sessions, each participant was expected to complete a project individually in the first twenty minutes, then present the project to all participants and comment on the other participants’ projects in the next twenty minutes. The individual sessions for both workshops were designed the same: the participants were asked to make a timeline of their PFAS experiences, from their first day of using PFAS (or other fall protection equipment if PFAS was not applied in the industry when they started working) until the present. Each participant was given a large sheet of paper with a horizontal center-line across the middle. The center line was to be read as a
timeline, from past till now. Above the line, indicated “positive” perceptions and below the line, indicated “negative” perceptions. The degree of “positive” and “negative” increased with the increase of distance from the center-line. Pictures and words were distributed to participants to assist their immersion into their experiences and express their emotions, memories, and opinions regarding PFAS usage.

A total of 42 pictures and 60 words were selected and pilot tested to ensure the timeline toolkit was adequate and appropriate for participants to be able to express their PFAS experiences. The contents of the pictures and words covered their work tasks, job sites, accidents scenarios, fall protection equipment and some emotion-expressing pictures. The three-pages of pictures and words are shown as Figure 5.3.

Figure 5.3: Toolkits for the individual activities

The participants were asked to choose the pictures and words, which they felt best described their thoughts and feelings, then cut, place and tape them on the white paper. They were told they could use as many pictures and words as they felt made sense but they did not have to use all of them (Figure 5.4). They were also allowed to add handwritten comments on the white paper.
5.3.5. Group sessions

The objectives of the group sessions were to generate ideas on how to improve PFAS usage within each workshop. The participants were divided into two groups and each group was asked to complete a group project within thirty minutes. After the project was completed, one member of each group would present their results and share them with the other group. The group session fully utilized the experiences of participants and provided the participants an interface to present their thoughts to the researchers.

In the group session of PFAS design workshop, some 3D tools, such as foam shapes, straps, bubble wrap, pieces of cloth were distributed to each group to facilitate their creation of a PFAS prototype. Velcro, scissors and staplers were provided to shape and attach the pieces together. A picture of the design toolkit is shown in Figure 5.5. Figure 5.6 shows the design product of one of the groups.
Figure 5.5: Tools in the group session of the first participatory workshop

Figure 5.6: Pictures of participants in the group session of the first participatory workshop
In addition, there was an extra ten-minute session at the end of the PFAS design workshop. The participants were asked to respond to a poster with information and pictures of different training methods and discuss which methods they preferred. The purpose of this extra session was to gather information on their opinions related to fall protection training and help the researchers prepare for the second workshop. The timetable of all the procedures in the first workshop is provided in Table 5.1.

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
<th>Checklist for the facilitator</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 min</td>
<td>Introduction</td>
<td>Welcome everyone, explain the objectives of the study, goal and address that their experiences in using PFAS is highly appreciated</td>
</tr>
<tr>
<td>5 min</td>
<td>Warm up and Ice breaking</td>
<td>Introduction of the facilitator, researchers and participants, ask an ice-breaking question</td>
</tr>
<tr>
<td>5 min</td>
<td>Start individual exercise, bring collage</td>
<td>Explain the purpose of this session, distribute the tools and collages. Participants are expected to use images and words to express their thoughts and feelings of PFAS usage from their first day usage till current</td>
</tr>
<tr>
<td>20 min</td>
<td>Work on the exercise</td>
<td>Provide help and answer questions when needed</td>
</tr>
<tr>
<td>20 min</td>
<td>Present their work</td>
<td>Reaction on participants’ work</td>
</tr>
<tr>
<td>5 min</td>
<td>Start group session, bring collage</td>
<td>Explain the purpose of this session, distribute the tools and collages, and divide participants into two groups. Participants are expected to use tools and collages to design a PFAS for future generations of construction workers.</td>
</tr>
<tr>
<td>30 min</td>
<td>Work on the exercise</td>
<td>Provide help and answer questions when needed</td>
</tr>
<tr>
<td>5 min</td>
<td>Present their work and discussion</td>
<td>Reactions to two groups’ work</td>
</tr>
<tr>
<td>10 min</td>
<td>Exercise on training method</td>
<td>Show pictures of different methods of training, ask participants’ opinions on their preference</td>
</tr>
<tr>
<td>5 min</td>
<td>Appreciation</td>
<td>Show appreciation and distribute incentives</td>
</tr>
</tbody>
</table>

Table 5.1: Timetable used for the first PFAS design participatory workshop

The objective of the group session in the second workshop was to propose ideas on how to conduct a successful and effective fall protection training program in the construction industry. At the beginning of the session, the participants had been asked to
discuss several questions, such as “How many of you learned how to use a harness through fall protection training?” “Do you think it is important to have this topic covered during training?”, “How many of you think fall protection training is useful?” That discussion, along with the individual (timeline) session helped participants recall their past and current experiences of fall protection training, in participation for the group session portion of the workshop.

These participants were also divided into two groups; each group was expected to design a future fall protection training session for construction workers. Posters were provided as a tool to aid participants considering various factors of a training session, such as length, content, methods and materials, as shown in Figure 5.7. Both groups were asked to use color pens, markers or labels to mark their selections under each category on the posters and they were also allowed to add any comments related to the fall protection training programs. The purpose of the poster was to assist them to think of all the choices under each category.

<table>
<thead>
<tr>
<th>Length</th>
<th>Number of trainees</th>
<th>Distributed Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 2 hours</td>
<td>less than 10</td>
<td>printed hand-outs</td>
</tr>
<tr>
<td>2-4 hours</td>
<td>10-25</td>
<td>OSHA code books</td>
</tr>
<tr>
<td>4-8 hours</td>
<td>25-50</td>
<td>CDs</td>
</tr>
<tr>
<td>8-40 hours</td>
<td>50-100</td>
<td>videos</td>
</tr>
<tr>
<td>other</td>
<td>over 100</td>
<td>other</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Content</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>lecturing/talking</td>
<td>OSHA regulations</td>
<td>written test</td>
</tr>
<tr>
<td>discussion</td>
<td>accidents statistics</td>
<td>short answer test</td>
</tr>
<tr>
<td>video-watching</td>
<td>pictures of accidents</td>
<td>multiple-choice test</td>
</tr>
<tr>
<td>Powerpoint presentation</td>
<td>case studies</td>
<td>discussion</td>
</tr>
<tr>
<td>hands-on</td>
<td>fall protection</td>
<td>presentation</td>
</tr>
<tr>
<td>games</td>
<td>equipment usage</td>
<td>project</td>
</tr>
<tr>
<td>computer games</td>
<td>other</td>
<td>other</td>
</tr>
<tr>
<td>role play (scenario)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5.7: Tools used in the group session of the second training design workshop
Similar to the first workshop, these participants were asked to participate in a ten-minute group discussion session at the end of the workshop, this time on PFAS design. Pictures of different styles of PFAS were posted on a board to aid the participants to recall their personal experiences of PFAS usage. Questions such as “which type of harness are you currently using” and “what do you think of the retractable lifeline” were raised by the facilitator to enhance discussion. This discussion session was included in order to discover more insights on PFAS design from the second group of construction workers. The detailed timeline of the second workshop is provided as Table 5.2.

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
<th>Checklist for the facilitator</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 min</td>
<td>Introduction</td>
<td>Welcome everyone, explain the objectives of the study, goal and address that their experiences in using PFAS is highly appreciated</td>
</tr>
<tr>
<td>5 min</td>
<td>Warm up and Ice breaking</td>
<td>Introduction of the facilitator, researchers and participants, ask an ice-breaking question</td>
</tr>
<tr>
<td>5 min</td>
<td>Start individual exercise, bring collage</td>
<td>Explain the purpose of this session, distribute the tools and collages. Participants are expected to use images and words to express their thoughts and feelings of PFAS usage from their first day usage till current</td>
</tr>
<tr>
<td>20 min</td>
<td>Work on the exercise</td>
<td>Provide help and answer questions when needed</td>
</tr>
<tr>
<td>20 min</td>
<td>Present their work</td>
<td>Reaction on participants’ work</td>
</tr>
<tr>
<td>5 min</td>
<td>Start group session, ask questions</td>
<td>Explain the purpose of this session, ask several questions related to the participants’ experiences of fall protection training</td>
</tr>
<tr>
<td>5 min</td>
<td>Start group projects, bring collage</td>
<td>Distribute the tools and collages, and divide participants into two groups. Participants are expected to use tools to design their preferred fall protection training session.</td>
</tr>
<tr>
<td>25 min</td>
<td>Work on the exercise</td>
<td>Provide help and answer questions when needed</td>
</tr>
<tr>
<td>5 min</td>
<td>Present their work and discussion</td>
<td>Reaction on two groups’ work</td>
</tr>
<tr>
<td>10 min</td>
<td>Exercise on PFAS design</td>
<td>Show pictures of different types of PFAS design, participants discuss on their experiences of using PFAS</td>
</tr>
<tr>
<td>5 min</td>
<td>Appreciation</td>
<td>Show appreciation and distribute incentives</td>
</tr>
</tbody>
</table>

Table 5.2: Timetable used for the second training design participatory workshop
5.4. Results

5.4.1. Results from the workbooks

In the literature review in Chapter 2, it was mentioned that personal attributes, such as risk perception, experiences, and self-efficacy are considered factors that impact one’s PFAS usage. However, these traits were not specifically studied in the first two phases of this study. The workbooks in Phase Three provided an interface for participants to present their true character and the results from the workbooks will help us analyze the relationship between one’s personal attributes and PFAS usage behavior.

In this study, although all fifteen participants were provided with blank workbooks a week prior to the workshops, none of them completed the workbooks before the workshops. They were given an extra fifteen minutes at the beginning of the workshops (before introduction session) to fill them out. In order to more succinctly present the information from fifteen different workbooks, personas of workshop participants were created. Pruitt and Adlin (2006, P.11) defined personas as “fictitious, specific, concrete presentations of target users”. Persona is often used as a tool to help designers and researchers place their focus on specific users of products or systems (Pruitt and Adlin, 2005). Due to various characteristics of the participants, three personas were generated:
Persona 1: Mike Nelson

![Mike Nelson](http://www.flickr.com)

<table>
<thead>
<tr>
<th>Name:</th>
<th>Mike Nelson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age:</td>
<td>35</td>
</tr>
<tr>
<td>Years in construction:</td>
<td>15</td>
</tr>
<tr>
<td>Job title:</td>
<td>Iron worker</td>
</tr>
<tr>
<td>Household:</td>
<td>Wife and three children</td>
</tr>
</tbody>
</table>

Figure 5.8: Picture of “Mike Nelson”

Mike is an iron worker with ABC Construction Company. He is 35 years old and he has been working in the construction industry for 15 years. He was born and raised in Cleveland, OH. After he graduated from high school he worked in some local retail stores for a couple of years. Then he decided to join ABC Construction Company, because the pay and benefits were much better, and he gets to work overtime. Mike is married and he has three children, two daughters and one son. His hobbies are watching football games and NASCAR racing.

We will now describe Mike’s typical workday. Mike gets up at 4:30 am everyday. He leaves for work around 5:10 am and normally he has his breakfast on the way to work. Although he had 5-7 hours of sleep, he still feels tired and not well rested. He arrives on the job site at 5:50 am. Normally his work day starts with the supervisor’s daily motivation and brief safety talk, which takes about five minutes. After that, Mike puts on his hard-hat and safety harness, and takes his tool box to the work-site with his co-workers. During the whole morning, he constantly feels tired and hungry and not very

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11 Picture is from: http://www.flickr.com
focused on what he is working on. But he tries to maintain 100% tie-off, because his supervisor mentions that every morning, although Mike thinks the harness often makes him uncomfortable. He has a quick break every morning at 9:30 am for ten minutes. His lunch break starts at noon and he normally eats some sandwiches his wife made for him the night before. Normally he takes up some challenging jobs in the afternoon. Mike finishes working at 3:30 pm and he thinks that is the happiest moment of his day.

Mike uses a harness whenever he works at heights of 6 ft or higher. He chooses to use it because he has children at home and he wants to be able to go home safely every day. Mike’s company provides him with the regular Miller harness, the model is Miller 850, as shown in Figure 5.9.

![Figure 5.9: Picture of Miller 850 fall protection equipment](http://www.glenallentelecom.com)

![Figure 5.10: Picture of DBI/SALA Exofit fall protection equipment](http://www.sentrysafetysupply.com)

While using this harness for three months on the job, Mike felt it was not comfortable and he suffered shoulder and back pain after wearing the harness for about five hours a day. He often feels that it restricts his movement while he is doing iron-work. Mike decided that since he had to wear a harness that much everyday, he would rather

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12 Picture is from: http://www.glenallentelecom.com
13 Picture is from: http://www.sentrysafetysupply.com
choose one that was lighter, more comfortable, and has some shoulder and back support.

After trying out different models of harnesses in a safety equipment store, he purchased his own harness: the new DBI/SALA Exofit harness (Figure 5.10). This type of harness incorporates a new type of material which “immediately draws moisture away from the body” to keep workers dry and comfortable. It is also ergonomically designed with shoulder and back padding to spread the weight on the worker evenly and make them comfortable. Even though Mike had to pay for it from his pocket, he thinks it is worthwhile to make his working time more comfortable and he may be able to claim it as a work-related expense on his taxes. He has been using this harness ever since he bought it. He keeps it into his own tool box. It is adjusted to his size so it does not take long for him to put it on. He is very satisfied with this product and he shares this information with his co-workers.

Mike never had any type of fall protection training. When he first started in the construction industry, the harness was not even mandated. He still remembers the days when he used a body-belt. He learned how to use fall protection equipment by himself and from his co-workers. It is mandatory for him to attend his company’s general safety training once a year, but he thinks he does not learn much from the training because it is two-day-lecture. He would rather have some kind of hands-on training. He believes he can learn more when it is demonstrated to him and he is able to experience it hands-on.

“I like this job and I am proud that I can support my family with it”—Mike Nelson.
Persona 2: Brandon Jones

<table>
<thead>
<tr>
<th>Name:</th>
<th>Brandon Jones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age:</td>
<td>22</td>
</tr>
<tr>
<td>Years in construction:</td>
<td>One and a half years</td>
</tr>
<tr>
<td>Job title:</td>
<td>Welder</td>
</tr>
<tr>
<td>Household:</td>
<td>No wife, no children</td>
</tr>
</tbody>
</table>

Brandon is a welder with ABC Construction Company. He is 22 years old and he has only worked in the construction industry for one and a half years. Brandon was born and raised in Dayton, OH. In his spare time, he enjoys playing golf and watching football games. Brandon is single with no children. He chose to work for a construction company because he thinks it is challenging work.

Brandon’s job does not require him to use harnesses as much as his colleagues. However, he learned through the training that he has to have a harness on and be properly tied-off if he performs welding jobs 6 ft or more above the ground when there is no other fall protection in place. He normally uses a harness one hour a day. The one he is using is the universal harness provided by the company. He does not like it because it always tangles together when he tries to pull it out from the company’s tool box and it takes him about five minutes every time try to put the harness on and adjust it to his size. He also feels it is a little uncomfortable if he has to have the harness on for a longer period. Sometimes he wonders if sparks from the welding process make the harness wear out.

14 Picture is from: http://www.flickr.com/
more quickly. He does not pay much attention to this and just drops the harness back into the tool box once he finishes using it. He never considered purchasing his own harness or requesting the company to purchase a harness especially for him and making it personalized, because he only wears it once or twice a day and less than one hour each time.

Brandon had OSHA 10 hour training a year ago with Construction Craft Academy when he was still an apprentice. He really liked the training because it integrated hands-on experiences with lecturing. He experienced a fall from 6 ft with a harness on during the training demonstration (Figure 5.12). That experience made him realize how much force his body would experience in falling from just 6 ft and how important a harness is to arrest him after falling. He also learned how to inspect fall protection equipment and recognize fall hazards through the hands-on training. He thinks the training was excellent.

![Figure 5.12: Picture of hands-on fall protection training](http://www.epiccompanies.com/safety.html)

“I like construction work because it is challenging”—Brandon Jones.

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15 Picture is from: http://www.epiccompanies.com/safety.html
John is a construction superintendent for XYZ Construction Company. He is 48 years old and he has been working in the construction industry for almost 30 years. He was born and raised in West Virginia. He likes fishing and hunting in his spare time. John has been married for 25 years. He has four children and one grand-child. He thinks family is the most important thing to him.

John chose to work in the construction industry because he always liked hands-on work. He thinks it is very challenging for him. John graduated from high school when he was 17 and then he worked for another construction company as an iron worker for 12 years. He quit the job because he did not like the safety equipment that his company provided. One day his company purchased retractable lifelines (Figure 5.14) and workers were required to use them. John tried it for couple of days and felt it was very heavy (weigh about 5 lb) and the worst part is he could not find the tie-off points above his head. He reported to the management that he did not see any sense in using them. The feedback he received from management was “if you do not use this equipment, you will be fired”. John decided to quit the next day. John said he understood that the company

16 Picture is from: http://www.wvdo.org/business/compensation.html
should follow safety regulations; but when situations do not comply, the company should seek other alternatives.

Figure 5.14: Picture of a retractable lanyard

John has been a superintendent for almost five years. He still works on sites most of his day and he wears a harness when needed. In addition, being a superintendent, making sure everyone else is tied-off is part of his job. He said personally he does not like the harness at all, because it is not comfortable and is very heavy. The reason he uses it is because it was mandated. John has his own harness, for which he paid about $400. It is better quality than what most companies provide, light-weight, and has shoulder-padding on. In addition, he prefers big snap-hooks rather than small ones. He thinks they are easier to use.

John has taken the OSHA 30 hour construction safety training. He admitted that the training was beneficial to him. However, he thinks the format of the training, lecturing and showing PowerPoint slides, was boring. He liked the part where the trainer showed them how to calculate the proper tie-off distance and the force generated when a person falls. John is now responsible for training new employees coming to his site. This is how he conducted his first-day fall protection training: When a new employee comes

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17 Picture is from: http://www.professionalequipment.com
in, he asks questions like “Have you ever used a harness?” or “Do you know how to use a harness?” Since the answers he receives are always positive he assumes they all know how to use a harness. He also explains some basic safety rules to the new employees. He knows this type of fall protection training is not adequate, but his company never provided any guidance to superintendents on how to conduct comprehensive training for new employees.

“I love my job, especially when I see the finished job of what we built” – John Smith.

5.4.2. Results from individual sessions

As two workshops had the same individual sessions, all fifteen completed collages were analyzed together. In order to manage the data from the collages, an individual file was created for each participant, including everything the participant said during the individual session and his collages (Sleeswijk Visser et al., 2005). Figures 5.15 and 5.16 show two examples of the completed collages from the individual sessions.
Figure 5.15: Example 1 of completed collages from the individual session

Figure 5.16: Example 2 of completed collages from the individual session
A total of 212 words and pictures were used by the fifteen participants, including 100 pictures and 112 words. It gave an average of 24 words and pictures per person. The top ten most frequently used pictures and words are listed as Figure 5.17.

Since a picture or a word can be interpreted either positively or negatively, interpretation by the participant was important to consider during data analysis. In addition, the centerline of the paper represents the time stream from past to now. For each frequently used picture or word that was listed on Figure 5.17, a graph was generated to represent the participants’ placement of that picture or word. For example, the word “uncomfortable” (Item No.1 in Figure 5.17) was selected by 10 participants and all responses from participants indicated either “negative” or “neutral”. Interpretations from three participants explained why they chose this word (Figure 5.18).
Nine out of fifteen participants selected the picture of “training” (Item No.2 in Figure 5.17), which indiected the importance of safety training relating to PFAS usage.

Nine out of fifteen participants selected the picture of “training” (Item No.2 in Figure 5.17), which indicated the importance of safety training relating to PFAS usage.

Picture of “mandatory” (Item No.3 in Figure 5.17) was also selected by nine participants. Most of the responses gave positive feedback, while a couple considered it as negative. This revealed that workers perceive that the mandatory use of PFAS influences its usage.
Properly tied-off was also considered important from participants’ perspectives, as eight of them selected the word “tie-off point” (Item No.4 in Figure 5.17).

As a component of PFAS, “lanyard” (Item No.5 in Figure 5.17) was selected seven times and it was not always considered positive. However, the pattern shows the participants’ perspectives on “lanyard” seem to be improving over time.
In contrast, the picture of “retractable lanyard” was perceived negatively by three participants.

Six participants selected the picture of “money” (Item No.6 in Figure 5.17) and it was interpreted in different ways.

Figure 5.22: Picture of “lanyard” in the toolkit was interpreted in different ways

Quote 1: It makes me feel safe
Quote 2: I like it because it has a shock absorber
Quote 3: Lanyard is a tripping hazard
Quote 4: Lanyard adds additional cost to PFAS

Quote 1: When an accident happened, the company would lose a lot of money
Quote 2: I am making good money in the construction company

Figure 5.23: Picture of “retractable lifeline” in the toolkit was interpreted in different ways

Quote 1: It weighs about 5 lb
Quote 2: I quit my job before because I was forced to wear it when there was no place to tie off

Figure 5.24: Picture of “money” in the toolkit was interpreted in different ways
The picture of “falling” (Item No. 10 in Figure 5.17), the word “falling” and the word “accident” were used eleven times altogether by fifteen participants to express their negative feelings towards falls. However, there was one positive response due to the participant’s unique interpretation of the picture.

In addition, the word “lecture” was used three times and all three times were negative. The explanations by the participants indicated that they thought the lectures during safety training were boring and routine.

Overall, the data generated from the individual collages presented a clear picture of participants’ opinions and emotions towards PFAS, by recalling and expressing their own experiences of using PFAS. The results corresponded with the data from the preliminary survey and the interviews that “comfort” of the harness, difficulty to find a tie-off point, and fall protection training were viewed as factors that influence PFAS use. Further, most construction workers used PFAS and tied-off because PFAS use was mandated. In addition, lanyard and retractable lanyard were considered negative factors by some participants, because the lanyard could be a tripping hazard and the retractable lanyard can be too heavy to carry.
5.4.3. Results from group sessions

5.4.3.1. PFAS design

The group session in the first workshop focused on PFAS design. The harnesses designed by the two different groups both featured a spring-loaded D-ring (Figure 5.26 and Figure 5.27), which would make the connection between lanyard and harness much quicker and easier. A worker can reach out with one hand and connect the lanyard to the D-ring. The new DBI/SALA Exofit already has this feature (Figure 5.28). In addition, some models of Exofit also include features such as front D-ring or side-D-ring to assist ladder climbing and positioning, respectively. Group 2 created a one-handed easy put-on and adjustable buckle to make a harness easier to wear (Figure 5.29). Their design also integrated body-belt to the harness to make the user feel safer. Some Exofit models also have the same feature (Figure 5.30).

Figure 5.26: Spring-loaded D-ring (designed by group one)  
Figure 5.27: Spring-loaded D-ring (designed by group two)
Due to the limitations of the strapping material provided in the design toolkit, the participants were not able to mock-up their requirements of the materials of their new designs. As all the conversations were recorded, some selected conversations with regard to materials were discovered by analyzing the data from the audio-tapes. Almost everyone agreed that the harness has to be light-weighted. One person mentioned that he

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18 Picture is from: http://ww.seedburo.com/online_cat/categ11/1110100.asp
19 Picture is from: http://www.toolsmet.com/fall-arrest-kits/12.html
prefers stretchable material for the harness due to its comfortableness. While another was opposed to the idea, stating that he thought the room between the body and a harness which would be allowed by a harness made of stretchable-materials would make him feel unsafe. The other participant added that stretchable lanyard is preferred in terms of avoiding trips and falls.

The second workshop had a short group discussion on PFAS design at the end of the session. Because most of the designs from the first workshop already existed, the researcher prepared a poster (Figure 5.31) with various types of current harness designs and informed the participants that the ideas they were creating should be innovative. Although due to the time limit, they were not requested to make a new design, as participants did in the first workshop, the discussions were beneficial for future PFAS design. One welder commented that sometimes he had to perform welding work while wearing a harness and the current harness he had was not spark-resistant. He suggested a harness should be designed for different trades instead of generalized. Half of the participants in the second workshop had their own harness. They believed one would be more motivated to use a harness and take better care of it if it is personalized.
5.4.3.2. Fall protection training

The group session of the second workshop was intended to generate ideas on fall protection training. However, it was discovered that among six participants, only two had received some type of fall protection training. Some of the rest had training on construction safety, but not specifically on fall protection. When asked how they learned to use PFAS correctly, most answered that they muddled through and they learned from their co-workers. Between the two who had the fall protection training, one was a superintendent, who had to take OSHA 30 hour training as one of his job requirements; the other took OSHA 10 hour when he was an apprentice. They both agreed that the training they had was beneficial to their job.

The participants were divided to two groups and each group were asked to use color pens, markers or labels to mark their selections on a poster, regarding length,
content, methods, number of trainees, materials and evaluation of their preferred fall protection training sessions. Figure 5.32 shows a picture of the poster.

When discussing training methods, both groups preferred hands-on training or demonstration of fall protection equipment, rather than lecturing or PowerPoint training (both groups pasted the picture of hands-on training on the poster). They understand the lecture is necessary, but it should integrate with some hands-on experiences to motivate attendees. They also believe that hands-on training and demonstration are more direct than other types of training. Safety video has also been a popular training method in the construction industry. However, many participants complained that most safety videos they watched appear dated. The repetitive use of same training materials makes trainees
less interested in topics and reduces the effectiveness of the materials. All types of safety games, including computer games, video games and board games, were not selected as training methods by the participants. They believe safety is a serious topic and that games would not convey the seriousness of safety. The ten-minute mini-session on training methods at the end of the first workshop also produced strong negative feedback regarding use of computer “games” to train workers on the use of PFAS. When further asked about their opinions of receiving training and achieving a certificate online, all participants opposed the idea because they were not that familiar with computer use.

In terms of materials distributed in the training session, participants think the OSHA codebook would be beneficial for managers, supervisors or other competent persons on job sites. However, the workers would prefer laminated brochures with instructions and pictures of how to manipulate fall protection equipment and handle hazardous situations.

When discussing the contents included in typical fall protection training, both groups agreed that a variety of content, such as OSHA regulations, accident statistics, pictures of accidents, fall protection equipment usage, should all be covered. But instead of instructors reading and explaining the regulations, the participants preferred demonstrations of how to follow the regulations, with case studies or pictures.

When considering the evaluation methods of a training session, one group of participants mentioned commonly applied evaluation methods, including written test, multiple choice test and discussion. The other group identified that hands-on testing along with short discussion should be applied instead of written exams.
In terms of the length of fall protection training, the two groups came to an agreement on 4-8 hours. They believed that four to eight hours would be enough to cover the necessary and required materials. Meanwhile, the size of a training session was not a concern for the participants.

5.5. Discussion

A participatory methodology was applied in this phase of the study to explore both workers’ and supervisors’ insights on the factors that appear to affect PFAS usage. The results from the workshops provide more information for refining the PFAS use path model. In order to incorporate the workshop information, there is a need to look back at the cause-effect diagram proposed in Chapter 2 (reproduced in Figure 5.33) and discuss how each factor affects workers’ PFAS use, based on the results from the two workshops.

Figure 5.33: Cause-effect diagram of factors that might contribute to PFAS usage
5.5.1. Individual factors

The results from the workbooks indicated that construction workers have some unique attributes, and some of the information was not discovered from the first two phases of the study. For example, the highest degree of education achieved among the participants was high school diploma, which showed that they have relatively low education level. In the second workshop, all of the participants admitted that they were not familiar with computers, and they also showed a reluctance to learn how to use computers. Some participants mentioned that they have never had any fall protection training, which indicated their inadequate safety knowledge.

By analyzing the data from the audio-tapes recorded during the workshops, it was found that some participants thought one of the reasons of their non-use of PFAS is they perceived low or no risk of performing construction jobs on heights. Some further commented that they chose construction work because it is physically challenging to them. This could also be interpreted as the target population has relatively low safety concern. It was discovered in the preliminary survey (Chapter 3) that the people who did not consider PFAS use as a “personal safety concern” are more likely to believe that not using PFAS is a not a problem at all.

However, how ones’ risk perception relates to one’s safety concern, and further to one’s self-protective behavior has been a point of controversy in the previous studies, as mentioned in Chapter 2. Rimal (2001) stated that higher risk perception indicates lower intention of self-protective behavior, while Weinstein et al. (1990) discovered the positive relation between risk perception and self-protective behavior. Whether risk perception and safety concern of construction workers would affect their PFAS use, and
how these two factors interact with each other, will be investigated in the next stage of this study.

5.5.2. Organizational factors

Among the fifteen collages the participants created during the individual session to express their experience of using PFAS, the picture of “mandatory” was selected by nine of them (see Figure 5.20). Some of them stated that the main reason they were using PFAS on jobsites was because it was mandated by their company; some stated that mandatory use of harness would reduce fall accidents. Sa (2005) and the preliminary survey conducted in this study (Chapter 3) both revealed that the top reason for commercial construction workers to use harness is “requirement of employment”. The finding also correlated with the results from the interviews in this study (Chapter 4) in which all the interviewees mentioned that company enforcement plays an important role in PFAS usage.

The interviews (Chapter 4) found that safety managers and other professionals considered fall protection training important in helping construction workers recognize fall hazards, realize the importance of fall protection, and encourage PFAS use. In the preliminary survey (Chapter 3), 91% of the respondents answered that they had received fall protection training, but only 47% of the respondents had received training from professional trainers. The rest had training either through “toolbox talk” or “lectures from supervisors”. Similarly, the results of the workshops discovered that more than half of the participants had never received any type of formal fall protection training. The majority
of the participants learned how to use a harness by themselves or through help from co-workers or supervisors.

"Training" was also the second most frequently used picture in the participants’ collages (see Figure 5.19) and they mentioned that training is needed to help them realize the importance of using PFAS and provide instructions of how to correctly use a harness and tie-off. It was also suggested by the participants that general fall protection training, including use of fall protection equipment and recognizing fall hazards should be provided by the competent person on site on the first day of working for a new employee. Furthermore, the participants suggested that a company should provide regular safety meetings and annual general safety training to refresh workers’ knowledge. In terms of training method, most participants believed hands-on training, as well as demonstration of equipment, would be more beneficial than PowerPoint slides and lectures. Safety-video watching is feasible, but not preferred. All types of safety games and on-line training were strongly opposed by all participants.

In terms of PFAS availability, all participants mentioned that their companies provided them with PFAS and other safety equipment. This answer is consistent with the results from the preliminary survey (Chapter 3) and the interviews (Chapter 4), in which 92% of the survey respondents and all safety managers and superintendents that were interviewed answered that their companies provided them with PFAS.

Provision of anchorage points (tie-off points) is considered as an environmental factor in the cause-effect diagram. However, since anchorage is one of the three imperative components of PFAS and it is an employers’ responsibility to provide all the necessary fall protection equipment, it could also be considered as an organizational
factor. “Tie-off point” was one of the most frequently selected words among the collages created by the fifteen participants during the individual sessions and one of them interpreted it as “sometimes it is difficult to find a tie-off point” (see Figure 5.21). This showed that the proper provision of tie-off points might influence one’s actual PFAS use. The similar finding was discovered in the survey (Chapter 3). When sixteen respondents who answered that they never or rarely used a harness when it was needed were further asked about the reasons they chose not to use it, eight of them (50%) replied that it is “difficult to find a tie-off point for it”.

In addition, some participants suggested that some type of incentive should be provided by a company to prompt workers to take care of their harnesses. Incentives were also mentioned by superintendents and safety managers during their interviews. Two superintendents believed that a certain amount of safety incentive would be a motivation for workers to work safely. However, only one participant in the workshop had the experience working with a construction company that provided safety incentives. Thus, whether safety incentive is an organizational factor affecting PFAS use needs to be further explored.

5.5.3. Environmental factors

There were only two environmental factors included in the cause-effect diagram, which are the heights of the building and the anchorage point. The provision of anchorage points was interpreted as an organizational factor in section 5.2, which showed that anchorage points might be related to proper use of PFAS. Meanwhile, the workshops were not able to supply any quantitative information on the heights of the buildings.
which participants have been working on. However, based on their conversations during the workshops, all participants had experiences working at heights where usage of PFAS was required. Some of them commented that they have always used PFAS when it has been required, regardless of the height. The limited amount of information on work height gathered during the workshops was not sufficient to further inform the development of PFAS use path model.

5.5.4. Task-related factors

During both workshops, it was suggested by some participants that the harnesses should be specially designed for various trades and that a personalized harness might strongly motivate one to use it. For example, spark-resistant harnesses would be a better choice for welders than the generalized ones.

In terms of duration of the task that requires PFAS use, there has not been any quantitative data collected during the survey, interview or workshops. However, through their discussions in the workshops, it appeared that the shorter the task, the less likely workers may use a harness because they think that “I am just going to be there for a minute”.

5.5.5. PFAS factors

The results of the individual sessions revealed that “uncomfortable” is the most frequently mentioned word when participants were asked to describe their experiences of PFAS usage from the past to current (see Figure 5.18). This finding was consistent with the results from the survey (Chapter 3), where 96 of the 167 respondents (57%) selected
“comfort level” when they were asked “What do you dislike the most about your harness?”.

Meanwhile, the pictures of “lanyard” and “retractable lifeline” were both selected frequently by the participants (see Figure 5.22 and Figure 5.23). As important components of PFAS, their designs and functions appear to influence workers’ correct use of PFAS.

During the group session of the design workshops, two designs of PFAS were created by the participants. Although similar designs already existed in the market, one group of the participants was not aware of the situation and they believed that the design they created was new and original. The other group presented their design knowing that it already existed. Their comments on the design indicated that the spring-loaded D-ring is one of their favorite features of a harness and the harnesses that they are currently using lack that specific feature. Their employers chose to purchase the universal harnesses lacking the spring-loaded D-ring because of the lower cost. This result reinforced that the cost and design of PFAS are contradictory factors of PFAS usage.

Moreover, some participants mentioned that personalized harnesses will motivate their PFAS use. Similar comments were made by one superintendent during the interviews, who suggested that a harness attached with an employee’s nametag would motivate the employee to use it more frequently. The question of how personalized harnesses are related to PFAS use needs to be studied further.
5.5.6. Other factors

**Fall experience.** Chapter 3, the survey found that 34% of the sampled population (n=167) had experienced falls on jobsites. The results of the survey also showed a significant correlation between PFAS use and experiences of falls: the respondents who did not use a harness or rarely use a harness had a higher probability of fall experience. During the interviews (Chapter 4), one interviewee mentioned that his experience of falling with PFAS in safety training prompted his PFAS use.

Fall experience was also studied in this phase of the study. Discovered from the collages which were made by participants during the individual sessions of the workshops, the majority of these participants have experienced falls on jobsites and almost all of them described fall from heights as a horrible experience (see Figure 5.25). Some participants mentioned that the fall experience kept reminding them to wear a harness when it was needed. Although experience of falls was not included in the cause-effect diagram of PFAS use, it should be further investigated as a factor that might affect PFAS use.

**Regulatory factors.** As explained in Chapter 2, regulatory factors include establishment and enforcement of fall-protection regulations. The workshops focused on workers’ perspectives on PFAS use and the majority of workers have not had direct contact with OSHA. Therefore, the investigation of OSHA factors has not been indicated in this Chapter.

Overall, the participatory workshops were successful in collecting information on workers’ perspectives on current PFAS usage. Most factors that were shown to be
significant from the workshops correspond with the factors included in the cause-effect diagram of PFAS use (see Figure 5.32).

5.6. Limitations of the workshops

First, it was the first time that the generative toolkits were applied in the construction industry to discover the feeling and thoughts of the workers. The toolkits also helped the participants to convey some ideas about improvements to PFAS design and fall protection training. However, the toolkits were developed by the researcher alone and they were only pilot tested once before the workshops. Moreover, due to the difficulty of recruiting construction workers to participate in the pilot tests, the participants of the pilot tests were graduate students at The Ohio State University. Although the toolkits helped participants in generating ideas successfully during the pilot test, they might not work as well in the target group. Based on the discussions between the researcher and a professional in participatory design, more tools, such as bigger pieces of cloth and other 3-D foam shapes, should be included in the toolkits to assist participants.

Second, it was the researcher’s first time conducting a participatory workshop among the construction workers and the researcher was inexperienced. Although the researcher was well prepared, it was difficult to coordinate with everyone and provide a clear direction during the workshop. In terms of coordination and cooperation with the participants, the second workshop was much better than the first one.

Third, each participant was asked to complete a workbook a week before the workshops and to bring the completed workbook to the workshops. However, none of the
participants chose to complete the workbooks prior to the workshops. In that situation, they were given some extra time to fill out the workbooks before “introduction” of each workshop. The purpose of the workbook was to help participants recall their experience (including work experience and experience with PFAS) and to be prepared for the workshops. The participants’ failure to complete the workbooks ahead of time might reduce the effect of workbooks and in turn, participants might need a longer period of time, to be immersed in their experiences before the sessions.

Fourth, as mentioned earlier, the two designs created during the PFAS design workshop are not new in the market and one group did not know about this. This showed that if we prepared a poster or a slide of all current PFAS designs and showed it to the participants before the group session, it will prevent them from creating some designs which already existed.

At last, compared with the participants in the second workshop, the first group of workshop participants did not show much interest in the group session. They only spent a short period of time (one to two minutes) thinking and discussing as a group before they started making the designs. Ideally, repeating the first workshop would be beneficial for this study in terms of collecting more ideas on PFAS design. However, because it is extremely difficult to recruit construction workers as participants, and the second workshop turned out to be a success, the PFAS design workshop was not repeated in this study.

In addition, the findings in the workshops were only from the male workers’ perspectives. The researcher intended to recruit at least one female worker during the recruitments for participants. However, the only female workers who worked on the sites
that the researcher visited were clerks and an operator of industrial vehicles. Through the conversations with their supervisors, they were not typical PFAS users, which determined that they were not qualified as potential participants. Thus, the results of the workshops only represented the perceptions of male construction workers.

5.7. Conclusion

Two participatory workshops were conducted in this phase of the study to collect information on construction workers’ perspectives on how to improve PFAS usage. Fifteen construction workers and supervisors participated in the workshops and successfully completed three projects during each workshop, which included the projects from sensitization, individual session and group session. Comparing with other methods applied in the first two phases, including the preliminary survey and interviews, participatory workshops are more focusing on encouraging participants to generate ideas by expressing their experiences and opinions in the workshop. Most findings from the workshops are consistent with the results from the first two phases in this study and the cause-effect diagram of factors that might contribute to PFAS usage. The results from the workshops reinforced that comfortableness of PFAS, safety training and a company’s enforcement are considered important in affecting PFAS usage from construction workers and supervisors’ perceptions.

In addition, there are some unique findings discovered exclusively by the participatory workshops. For example, construction workers’ perception of risk was first studied in this phase of the research. It was also discovered in the workshops that the construction workers believed that personalized PFAS and PFAS specially designed for
their tasks are expected to increase its usage. The findings from first three phases lead us to refine and finalize the path model of PFAS use in the next phase.

Although the two designs created during the PFAS design workshop already existed in the market, which was not expected by the researcher, the participants were able to express their thoughts and emotions regarding PFAS use during both workshops. As the first generative toolkit used among construction workers, the toolkit in this study was exploratory. In addition, the experience of these workshops was consistent with Sanders’ article in 2006 that a sufficient toolkit, an experienced facilitator, well-planned directions and cooperative participants are prerequisite for a successful participatory workshop.

Considering the four-phase investigation chart which was proposed at the end of Chapter 2, this and the prior phases of this study successfully fulfilled their objectives: gain information on factors influencing PFAS usage from various aspects. Both PFAS design and training were consistently viewed as important by various stakeholders in the construction industry. The decision to investigate the effects of training, in the remaining phase of the study, was a practical choice. Designing a study to investigate training was seen as somewhat more feasible than a study of PFAS design, given the time and resources available to the researcher. The next Chapter will focus on the details of test and finalize the path model of PFAS use.
CHAPTER 6

PATH MODEL OF PFAS USE

6.1. Introduction

Chapter 3 to Chapter 5 attempted to fulfill the knowledge gaps which were not addressed in the previous studies of PFAS use, and gather additional information on factors that appear to influence PFAS use, from the perspectives of construction workers, superintendents, managers, and safety professionals. The results from the first three phases showed that although fall protection training is viewed by superintendents and safety professionals as a tool to prompt PFAS use, a majority of the workers reported that their fall protection training was inadequate. It was suggested by safety professionals during the interviews that professional fall protection training should be delivered to construction workers, instead of a safety orientation or safety talk provided by superintendents alone. In the participatory workshops (Chapter 5), it was frequently mentioned by participants that comprehensive fall protection training sessions, including lecture, demonstration and hands-on training, are needed to help them realize the importance of PFAS use, recognize fall hazards, and provide instructions for proper PFAS use.

Some previous research studied the effectiveness of safety training. DeJoy (1986) stated that safety training is effective in influencing one’s self-protective behavior. A
survey conducted by Harvey (2001) indicated that proper safety training will change safety attitudes and safety culture, including responsibility, complacency, job satisfaction and risk awareness, within a company. The preliminary survey (Chapter 3) discovered that fall protection training significantly correlated with one’s perception of importance of PFAS. In both interviews and workshops (Chapter 4 & 5), training was considered influential in terms of affecting one’s PFAS use by interviewees and participants. However, neither the previous studies, nor the first three phases of this research, quantitatively studied the effects of training in affecting ones’ intention to use PFAS or actual PFAS use behavior. Thus, the study in this phase is intended to address these topics.

More importantly, as mentioned at the end of Chapter 2, the main objective of this study is to develop and test a path model of PFAS use. Because of appeared importance and influence of training in the cause-effect diagram of PFAS use (as shown in Figure 2.9), fall protection training was selected at the end of Chapter 5 to be used to test and finalize the path model. In addition, the factors in the PFAS use path model are not expected to weight equally, and none of the prior studies on PFAS use have provided any quantitative evidence of relative importance among the factors.

Therefore, the main objectives of this phase of the study will be: (1) develop, test and finalize the path model of PFAS use; (2) identify relative weight of each factor in the model; (3) investigate how safety training affects one’s PFAS usage behavior, and other factors affecting PFAS use. The Technology Acceptance Model (TAM) will serve as a stating framework for converting the components of the cause-effect diagram of PFAS
use, into a statistically-testable path model. Detailed explanations of the TAM will be presented in the following section.

6.2. Background of the Technology Acceptance Model

Over the years, researchers have conducted many studies to investigate the factors influencing one’s actual behavior in use of a system or a tool. Davis (1989) developed the Technology Acceptance Model (Figure 6.1) to illustrate that an individual’s intention to use a system or a tool is determined by perceived ease of use and perceived usefulness (Davis, 1989; Venkatesh and Davis, 2000). Perceived usefulness is defined as “the degree to which a person believed that using a particular system would enhance his or her job performance” (Davis, 1989). Perceived ease of use is “the degree to which a person believes that using a particular system would be free of effort” (Davis, 1989). An individual’s intention to use the system or a tool is discovered to directly affect actual system or tool usage (Davis, 1989). Davis (1989) also stated that perceived usefulness was also related to perceived ease of use, because “the easier the system is to use the more useful it can be”.

![Technology Acceptance Model (Davis, 1989)](image_url)

Figure 6.1: Technology Acceptance Model (Davis, 1989)
The TAM has been widely used in different applications, such as school education (Hu, Clark and Ma, 2002), company job training (Venkatesh and Davis, 2000), computer software usage (Chau, 1996) and web usage (Lederer, Maupin, Sena and Zhuang, 2000). Legris, Ingham and Collerette (2003) conducted a critical review of the TAM model, and they concluded that TAM explained about 40% of a system’s use.

TAM was also integrated with other models, such as the Theory of Reasoned Action model (TRA) (Davis, Bagozzi and Warshaw, 1989) and the Task-Technology Fit model (TTF) (Dishaw and Strong, 2000). Venkatesh and Davis (2000) further extended the TAM to a social influence level by adding several determinants of perceived usefulness, which includes subjective norm, image, job relevance, output quality and result demonstrability. In addition, the extended model was trying to investigate how users’ experience and voluntary or mandatory use of the system would influence perceived usefulness and perceived ease of use.

![Figure 6.2: Extension of the Technology Acceptance Model (TAM2) (Venkatesh and Davis, 2000)](image_url)
In TAM2, subjective norm is explained as “a person’s perception that most people who are important to him think he should or should not perform the behavior in question” (Venkatesh and Davis, 2000). Image is defined as “the degree to which use of an innovation is perceived to enhance one’s status in one’s social system” (Moore and Benbasat, 1991; Venkatesh and Davis, 2000). Venkatesh and Davis (2000) defined job relevance as “an individual’s perception regarding the degree to which the target system is applicable to his or her job. Output quality indicates one’s perception towards how well the system performs (Venkatesh and Davis, 2000) and result demonstrability means “tangibility of the results of using the system” (Moore and Benbasat, 1991; Venkatesh and Davis, 2000). Voluntariness is “the degree to which the use of the system is perceived as being voluntary” (Moore and Benbasat, 1991). TAM 2 was tested with four longitudinal field studies. Their studies confirmed that perceived usefulness and perceived ease of use are two main determinants of intention to use. They also discovered that when the system is mandatory to use, “subjective norm” played an important role in influencing intention right after initial training and one month after implementation. In their results, perceived usefulness and perceived ease of use explained up to 60% of intention to use (Venkatesh and Davis, 2000). This showed that there are many other factors that might not be included in the model.

In this study, the TAM will be incorporated with components of some key models of health related behavior and with the cause-effect diagram of PFAS use, which was proposed in Chapter 2 (reproduced in Figure 6.3). A path model of PFAS use will be developed to explain one’s PFAS use behavior. In addition to identifying key
determinants of PFAS use, safety training is to be examined since it was considered important in affecting PFAS use in the previous three phases.

6.3. Proposed Path Model of PFAS use

As mentioned in Chapter 2, there have been several theoretical models developed to study health-related behavior, some especially aimed at self-protective behavior. Fishbein (1967) proposed the Behavioral Intention Model (BIM), in which one’s behavior is a function of the intention of that behavior, and attitude toward the behavior and subjective norm are considered as two determinants of intention. The Health Belief Model (HBM) developed by Becker (1974) explained that the determinants of self-protective behavior include perception of susceptibility (personal vulnerability), severity (possibility of getting sick or injured), benefits and barriers of taking action (outcome expectancy), and self-efficacy. Geer et al. (2005) applied the HBM model to study workplace dermal exposure and revealed that self-efficacy is a determinant of one’s precautionary behavior. Karasek and Theorell (1990) developed the job demands-control-support (DCS) model, which extended the factors affecting workers’ health-related behavior model to an organizational level. Torp et al. (2005) employed DCS model to study the social and organizational factors associated with workers’ use of hearing protective devices. Their study discovered PPE use was significantly correlated with social support and health and safety related management support. McGovern (2000) studied the factors affecting PPE compliance with universal precautions among health care workers. The factors were categorized into personal traits, work-related factors and organizational factors. Personal traits include demographics, job characteristics,
knowledge and perceptions and confidence; work-related factors include cognitive
demands, job ambiguity, workload and work-related stress; and organizational factors
that consist of safety climate, availability of PPE and PPE training (McGovern, 2000).

To date, there are no published models describing PFAS usage and factors
affecting that usage. At the end of the literature review in Chapter 2, a cause-effect
diagram of PFAS use was proposed based on the previously relevant studies and models.
It intended to explain the factors that appear to affect one’s PFAS use. The first three
phases of this study (preliminary survey, interviews, and workshops) gathered
information from construction workers and supervisors on the majority of the factors
listed in the diagram. The findings from these three phases are consistent with the
diagram. In addition, some factors which were not addressed in the diagram were
discovered. For example, the preliminary survey found that a company’s provision of
PFAS significantly affect one’s PFAS use. The interviews and workshops discovered that
a personalized PFAS and safety incentive or rewards provided by companies might
encourage workers’ PFAS use. Therefore, while incorporating the diagram with the TAM
and safety and health-related behavior models, the above factors should also be
considered. Figure 6.3 shows the updated cause-effect diagram of PFAS use.
Integrating Figure 6.3 with TAM 2, a path model of PFAS is proposed (see Figure 6.4). In the proposed path model, as one of the factors that are expected to affect intention to use, “perceived usefulness” was modified to “perceived value” because as safety equipment, PFAS’s usefulness exists in its capability to save one’s life or protect one from serious injuries. Instead of using the term “usefulness”, “value” would be a better term for the purpose of safety equipment. In the study of hearing protection use by Lusk (1997), “perceived value of use” was used to assess “the degree of importance of such items as ‘keep out noise’”. In this study, “perceived value” is used to measure an individual’s perception of benefits and advantages of PFAS use, such as “protect from serious injuries, or “save life”.

“Perceived ease of use” is another factor influencing intention to use PFAS. The results from the first three phases of this study (Chapter 3-5) revealed that workers
believed that an easy-to-use, easy-to-tie-off, and unrestricted PFAS would motivate its usage.

“Subjective norm” remains in the model because of the results from the preliminary survey (Chapter 3), which discovered that 8% of the responding workers reported that they use PFAS because of peer pressure and 52% of the respondents mentioned they use PFAS as a result of supervisory enforcement (n=147).

In addition, “voluntariness” from TAM2 was modified to “company enforcement” because the preliminary survey results showed that 76% of the respondents (n=147) reported that they use PFAS because it is a requirement of employment. Some participants of the workshops (Chapter 5) mentioned that they would not use PFAS if it was not required. “Company Enforcement” is also expected to influence “Subjective Norm” because if the use of PFAS is not required, the workers might not pay attention to each other’s safety behavior.

“Other organizational factors”, meaning the organizational factors except for the factor of fall protection training, was added as a category which influences intention. This group of factors represents a company’s actions of maintaining a safe and healthy workplace, including a company’s provision with PFAS and safety incentives. The preliminary survey revealed that if a company provided their employees with PFAS, the employees were more likely to use it. The interviews and workshops (Chapter 4 and 5) found that some superintendents believed that safety incentives provided by a company would motivate workers to behave safely.

“Risk perception” was considered a factor that is likely to affect perceived value of PFAS. Many prior articles studied how risk perception relates to one’s self-protective
behavior (Bermudaz, 1999; McGovern, 2000; Rimal, 2001; van der Plight, 1996). Low risk perception of the participants was discovered from the workshops (Chapter 5). Some mentioned that one of the reasons they did not use PFAS is that they perceived low or no risk of working on heights.

PFAS hardware itself was added as a determinant of perceived ease of use. Fifty-five percent of the respondents of the preliminary survey and all supervisors and safety managers interviewed mentioned that workers would be more willing to use PFAS if they have their own. During the workshops, some participants mentioned that they would like to have PFAS designed especially for their own trade, for example, welders and iron workers should have different types of PFAS.

It was also assumed in the model that one’s experience with PFAS would affect “perceived value” and “perceived ease of use”. The experiences include an individual’s experience of using PFAS and fall experience.

Comparing with TAM2, “job relevance” was excluded from the model. In the studies of TAM, “job relevance” referred to the extent to which the user of technology considers the technology is relevant to his or her job. For example, in Hu et al. (2003) study of PowerPoint acceptance by school teachers, the question items under “job relevance” were “I consider PowerPoint to be important to my job”, or “I consider PowerPoint to be of concern to my job”, and so on. However, in this study, use of PFAS is a requirement in the construction industry (if a worker works 6ft or above from elevation and without other types of fall protection) and the workers only use it when they are working. This shows that PFAS use is definitely job-relevant. Whether the respondents consider PFAS is “important to the job” or it is a “concern to the job” could
be discovered from the question items under “Perceived value”. Thus, “job relevance” was removed from the model in order to avoid redundancy of question items.

“Output quality” and “result demonstrability” are no longer in the model because the output or result of PFAS is to arrest one after falling and it does not happen every time a person uses it unless he or she falls. “Image” is not included in the model due to the results from our previous investigation—surveys and interviews. None of the construction workers mentioned that people in their organization who use the system might possibly have a high profile or more prestige than others. They agreed that it is mandatory safety equipment and it is a worker’s responsibility to use it.

![Proposed path model of PFAS use (PFAS_M1)](image)

Figure 6.4: Proposed path model of PFAS use (PFAS_M1)

6.4. Research questions

Based on the proposed model of PFAS use, the research questions I intend to seek for answers are:
1) Does fall protection training change ones’ intention to use PFAS
2) Does fall protection training change one’s actual PFAS use
3) Does fall protection training change the determinants of perceived ease of use and perceived value
4) Does intention to use PFAS directly contribute to actual usage of PFAS
5) Which determinant of perceived value has a significant influence
6) Which determinant of perceived ease of use has a significant influence

6.5. Instrument development and test

Since the effect of training is to be evaluated in this phase of the study, two sets of questionnaires need to be distributed to the construction workers before and after a fall protection training session to discover the immediate effect on behavior or intention due to the training. In addition, actual usage of PFAS among the participants will also be studied for a short term follow-up period of two-three weeks after the training, by asking participants to answer a self-reported question on PFAS usage subsequent to the training session.

The first set of questions (pre-training questionnaire) was designed in five sections. The first section of the questionnaire included demographic questions, asking about respondent’s age, work experience, specific trade, and general information on falls and PFAS, such as “Do you have your own harness” and “Have you experienced falls from heights when wearing a fall arrest system”.

There is one screening question included in this section to filter out the participants who are not PFAS users. The completed response will be excluded from the
study only if it is under the following two circumstances: (1) the respondent answered “not at all” to the question of “How often does your occupation require you to use a fall arrest system?”; (2) the respondent answered “very rarely” to the first question, and, reported “0” or “not applicable” on the second question on section 4: “During the most recent job you’ve held that could have required use of a fall arrest system (due to work conditions), how many hours do you use it on a daily basis”.

The purpose of the screening question is to require that the target respondents have some experience in PFAS use. This is because fall protection and use of PFAS is not always the only topic covered in construction safety training sessions. Some training session attendees might be there to learn about topics other than PFAS and fall protection, if so, they are not part of the target population. Additionally, some office workers, engineers and even company owners attended these training sessions, either because it was required by the company, or just to improve their safety knowledge. Thus the screening criteria were designed to exclude participation of people who were not construction workers or who were not in attendance to learn about fall protection.

The major sections of the questionnaire are sections 2, 3, and 4, which consist of ten categories and a total of forty-one items. The questions were constructed by incorporating questions validated in previous studies of the TAM and behavior models. Some wording changes were made to suit the target research questions. Table 6.1 provides a list of all questions in the major sections.
<table>
<thead>
<tr>
<th>Construct</th>
<th>Question item</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Perceived Value (PV)</strong></td>
<td>PV1: Proper use of fall arrest systems could protect me from serious injuries</td>
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<td>PV2: Proper use of fall arrest systems could save my life</td>
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<td></td>
<td>PV3: I feel safer when I have my harness on and I am properly tied-off</td>
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<td></td>
<td>PV4*: I believe fall arrest systems reduce productivity</td>
<td>Davis, 1989; Davis et al., 1989</td>
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<td></td>
<td>PV5: I believe the potential benefits of fall arrest systems outweigh the disadvantages</td>
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<td>PV6: I believe proper use of fall arrest systems by all crew members is important to the successful completion of a job</td>
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<tr>
<td><strong>Perceived Ease of Use (PEU)</strong></td>
<td>PEU1*: When properly adjusted, wearing a harness restricts my movement</td>
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<td></td>
<td>PEU2*: Using a harness makes it harder to get the job done</td>
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<tr>
<td></td>
<td>PEU3*: I find it difficult to put on a harness</td>
<td>Davis et al., 1989</td>
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<tr>
<td></td>
<td>PEU4*: I find it difficult to adjust a harness</td>
<td>Davis et al., 1989</td>
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<tr>
<td></td>
<td>PEU5*: Finding a proper tie-off point is time consuming</td>
<td>Geer et al., 2007</td>
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<td>PEU6: I am confident that I know how to use a harness and tie-off correctly</td>
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<td></td>
<td>PEU7*: Until now, it has been difficult for me to learn to properly use a fall arrest system</td>
<td>Davis et al., 1989</td>
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<td></td>
<td>PEU8*: Overall, I find fall arrest systems difficult to use</td>
<td>Davis et al., 1989</td>
</tr>
<tr>
<td><strong>Subjective Norm (SN)</strong></td>
<td>SN1: My co-workers (other than my supervisors) believe in the value of fall arrest systems</td>
<td>Vankatesh and Davis, 2000</td>
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<td>SN2: My supervisors believe in the value of fall arrest systems</td>
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<td></td>
<td>SN3: My co-workers routinely wear their fall arrest systems properly</td>
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<td></td>
<td>SN4: My co-workers encourage each other to use their fall arrest systems properly</td>
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<tr>
<td><strong>Company Enforcement (CE)</strong></td>
<td>CE1: My use of fall arrest systems is mandatory where I currently work</td>
<td>Moore and Benbasat, 1991</td>
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<td></td>
<td>CE2: My supervisor requires me to use fall arrest systems</td>
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<td></td>
<td>CE3*: I would not use a fall arrest system if it was not required</td>
<td>Moore and Benbasat, 1991</td>
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<tr>
<td></td>
<td>CE4: My supervisor checks my fall arrest system use: ___ daily ___ 2-3 times a week ___ once a week ___ rarely or never</td>
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</tbody>
</table>

Table 6.1: The questions in the section 2, 3, 4 of the questionnaire (note: *reverse-scored)
Table 6.1 continued

<table>
<thead>
<tr>
<th>Construct</th>
<th>Question item</th>
<th>Source</th>
</tr>
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<tbody>
<tr>
<td><strong>Other Organizational Factors (OF)</strong></td>
<td>OF1: Regarding use of fall arrest systems and exposure to risk of falls, my supervisor goes out of his way to make sure I am protected</td>
<td>Geer et al., 2007</td>
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<td></td>
<td>OF2: My company provides all the necessary fall protection equipment for me and my co-workers</td>
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<td>OF3: My company provides rewards to encourage safe workplace behaviors</td>
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<td>OF4: My company provides rewards based on the number of accidents reported monthly</td>
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<tr>
<td><strong>Risk Perception (RP)</strong></td>
<td>RP1: Some activities I participate in are perceived as physically risky by others</td>
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<td>RP2: Construction industry jobs are more dangerous than most other types of manual jobs</td>
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<tr>
<td><strong>PFAS</strong></td>
<td>PFAS1*: The harness I am currently using is uncomfortable</td>
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<td></td>
<td>PFAS2*: As best I know, all harnesses are uncomfortable to wear</td>
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<td></td>
<td>PFAS3: Purchasing my own harness would be a good investment</td>
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<td></td>
<td>PFAS4: A harness that is particularly designed for my trade would be easier to use</td>
<td></td>
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<tr>
<td><strong>Experience (EXP)</strong></td>
<td>EXP1: How many years have you used a fall arrest system?</td>
<td>Vankatesh and Davis, 2000</td>
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<td></td>
<td>EXP2: During the most recent job you’ve held that could have required use of a fall arrest system (due to work conditions), how many hours did you use it on a daily basis? _______ hours</td>
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<td></td>
<td>EXP3: During the most recent job you’ve held that could have required use of a fall arrest system (due to work conditions), how many days did you use it during a week? _____ days</td>
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<td></td>
<td>EXP4: During the most recent job I’ve held that could have required use of a fall arrest system (due to work conditions), ___ % of my working time I have to hook up my lanyard to a new tie-off point on a daily basis.</td>
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<td></td>
<td>EXP5: During the most recent job I’ve held that could have required use of a fall arrest system (due to work conditions),</td>
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<td></td>
<td>___ % of the time I was supposed to do so.</td>
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<tr>
<td><strong>Intention to Use (IU)</strong></td>
<td>IU1: From this point forward, I intend to wear a properly adjusted harness when required</td>
<td>Vankatesh and Davis, 2000</td>
</tr>
<tr>
<td></td>
<td>IU2: From this point forward, I intend to properly tie-off when required</td>
<td>Vankatesh and Davis, 2000</td>
</tr>
<tr>
<td><strong>Usage Behavior (UB)</strong></td>
<td>UB1: I always wear a properly adjusted harness when required</td>
<td></td>
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<tr>
<td></td>
<td>UB2: I always make sure my harness is tied-off properly when it is required</td>
<td></td>
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</tbody>
</table>

Continued
All items in “Perceived Value” (PV), “Perceived Ease of Use” (PEU), “Subjective Norm” (SN), “Risk Perception” (RP), “Intention to Use”, “Usage Behavior” (UB) and some items from “Company Enforcement” (CE1-3), and “Other Organizational Factors” (OF1) are measured using a five-point scale ranging from “strongly disagree” to “strongly agree”. CE-4 “My supervisor checks my fall arrest system use” was asking about a frequency. “__ daily”, “__ 2-3 times a week”, “__ once a week” and “__ rarely or never” were listed below the question, and the participants were asked to place a check mark on their selected answer. Similarly, “__ yes”, “__ no” and “__ don’t know” were provided for the rest of the three questions under category “Other Organizational Factors” (OF2-4) because the purpose of these questions was to seek binary answers on a company’s safety behavior. In addition, opened ended questions were used to collect information on participants’ experiences with PFAS, including all five questions under the category “Experience”.

Section 5 is the recruitment for the follow-up to the survey. If the participants were willing to participate in the follow-up, they were asked to provide their name, phone number and mailing address in this section.

The post-training questionnaire was almost identical with the pre-training one, because the purpose of the survey was to discover how training affects the path model of PFAS use. Since the answers to some questions were not expected to change due to training, including all demographic questions, CE4, OF3, OF4 and all questions under “Experience”, these questions did not appear in the post-training questionnaire.

The follow-up to the survey took place two to three weeks after the day the survey was conducted. The participants who provided their contact information in the pre-
training questionnaires were sent a post card with the following question: Within the last two weeks, I wore my harness ___ % of the time I was supposed to do so. The objective of the follow-up study is to discover the actual usage of PFAS after training.

The pilot test of the questionnaire was conducted in the form of informal discussions in June, 2008. Participants of the pilot test were five construction workers who were working on a major project on campus. Participants were asked to look through the questionnaire thoroughly and provide feedback to the investigators. The purpose of the pilot test was to screen for poorly-worded questions and refine the overall quality of the questionnaire. The questionnaire was modified based on the feedback from the pilot test. The draft of the questionnaire was also examined by a professional safety trainer who is certified to provide OSHA 30 hour and OSHA 10 hour construction safety courses. A copy of both questionnaires, as well as the follow-up postcard, can be found in Appendix D (beginning on page 257).

6.6. Training courses, sample selection and sample size calculation

The first three phases of the study revealed that professional fall protection training session is recommended, by both construction workers and managers, to increase perception of PFAS importance, recognition of fall hazards, and provide appropriate instructions for PFAS use. The most commonly recommended fall protection training programs (by the participants of the workshops (Chapter 5)) were the portions of the OSHA 30 hour and OSHA 10 hour construction safety courses that focused on fall protection. The OSHA 10 hour and 30 hour courses provide in-depth explanations of OSHA CFR 1926 construction safety regulations. Fall protection is a mandatory topic
covered in these courses, with general length of 1.5 hour – 2 hours. The methods used in typical OSHA 30 hour and OSHA 10 hour training courses include lecturing, videos, demonstration, and, sometimes, interactive participation with trainees.

Participants in the current survey included construction workers and supervisors who participated in OSHA 30 hour and OSHA 10 hour construction safety courses which were offered in the state of OH between July and October, 2008. Several types of entities offer this type of training, including commercial businesses, industry organizations and government agencies. Although the length, methods, and detailed content of the training may vary with the specific organization that provides the training, the core topics and guidelines are mandated by OSHA, including the content on fall protection. This provided support for combining responses collected from different training centers within the data analysis.

In addition, those who attend training courses that focused exclusively on fall protection were also considered as target population of the current survey. Such training is conducted by professional safety training organizations. The attendees of fall protection training courses are frequent users of PFAS, based on a conversation between an experienced trainer of this course and the researcher. The specific fall protection training generally lasts 8-16 hours, and addresses only fall protection issues. Compared with OSHA 30 hour and 10 hour courses, it is more in-depth and intensive.

Sample size of the study is always determined by the methodology applied in the study. In the current phase of this study, both exploratory factor analysis and path analysis would be conducted to evaluate the measurements of the factors and the correlations among them. Hatcher (1994) stated that “factor analysis is a large-sample
and the sample size of factor analysis should be the larger of 100 or 5 times the number of variables being analyzed. Munro (2005) mentioned that in factor analysis, 10 subjects for each variable are desirable. However, Munro (2005) also noted that since factor analysis is based on correlation, in most cases 100 to 200 samples should be enough. In this study, there are total of 37 variables in the questionnaire (except for the demographic questions, questions of intention to use and actual use). Five times 37 results in a sample size of 185, which is within the recommendations of both Munro (2005) and Hatcher (1994).

In terms of sample size calculation for path analysis, Munro (2005) cited from Nunnally and Bernstein (1994) that 30 subjects per independent variable in the model is appropriate for path analysis. However, Mueller (1996) suggested that the recommended sample size for path model is 5 to 10 times per estimated parameter (links and variance terms) in the proposed model. In the proposed model of PFAS use (PFAS_M1), there are 22 parameters altogether. Thus, 110- 220 sample would be appropriate for this model. Hatcher (1994) stated that at least 200 samples are needed for path analysis. Additionally, since path analysis is based on the concept of linear multiple regression, the method of calculating sample size for liner multiple regression could also be applied. Cohen, Cohen, West & Aiken (2003) stated that sample size for multiple regression depends on four parameters: the probability level, the number of predictors in the linear model, the anticipated effect size (f-square) and the desired statistical power level. Assuming probability level is 0.05, f-square value is 0.15 and statistical power level is 0.8, the calculated minimum required sample is 108, based on the formulae provided in Cohen et al. (2003). The following table lists previous studies on the TAM and the
sample size for each study. As it shows, all studies listed had sample size fewer than 150.

<table>
<thead>
<tr>
<th>Study</th>
<th>Purpose of study</th>
<th>Sample size</th>
<th>Number of predictors in the path model</th>
<th>Training length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hu et al., 2003</td>
<td>Testing use of PowerPoint by school teachers</td>
<td>138 respondents / 170 targeted participants</td>
<td>6</td>
<td>Four two-hour training sessions over a 4-week period</td>
</tr>
<tr>
<td>Venkatesh and Davis, 2000 (study 1)</td>
<td>Extension TAM</td>
<td>38 respondents / 48 participants</td>
<td>9</td>
<td>Two days training</td>
</tr>
<tr>
<td>Venkatesh and Davis, 2000 (study 2)</td>
<td>Same as above</td>
<td>39 respondents / 50 participants</td>
<td>Same as above</td>
<td>One and half day training</td>
</tr>
<tr>
<td>Venkatesh and Davis, 2000 (study 3)</td>
<td>Same as above</td>
<td>43 respondents / 51 participants</td>
<td>Same as above</td>
<td>One day training</td>
</tr>
<tr>
<td>Venkatesh and Davis, 2000 (study 4)</td>
<td>Same as above</td>
<td>36 respondents / 51 participants</td>
<td>Same as above</td>
<td>Four hour training</td>
</tr>
<tr>
<td>Chau, 1996</td>
<td>Acceptance of Computer-aided software engineering</td>
<td>97 respondents from one organization / 200 questionnaires</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>Davis, 1989 (study 1)</td>
<td>Usage of electronic mail</td>
<td>112 respondents / 120 participants</td>
<td>N/A</td>
<td>Six months</td>
</tr>
<tr>
<td>Davis, 1989 (study 2)</td>
<td>Usage of graphic systems</td>
<td>40 participants</td>
<td>N/A</td>
<td>One hour hands-on experience</td>
</tr>
</tbody>
</table>

Table 6.2: Sample size of previous TAM studies

In the current survey, the sampling goal was to collect 185-200 valid samples from the training sessions. With consideration of 60% - 70% response rates (response rate is expected to be high because the participants will be asked to fill out the questionnaires in class), a maximum of 300 subjects were expected to be recruited in the training
sessions to respond to the survey. Since the regular size of a construction training session is 15-40 people, recruitment efforts were planned for 8-12 training sessions.

6.7. Response processing and statistical analysis

Measures of most questions were five-point-scales ranging from “strongly disagree” to “strongly agree”. However, there were some negative items included in the questionnaire, such as PV4 “I believe fall arrest systems reduce productivity” and all questions under PEU except for PEU 6 (as listed in table 6.1). These items needed to be reverse scored by subtracting the score from 6. For example, if a person rated “agree” on PV4, which was a “4” before reversing, the final score will be 6-4=2 for data analysis.

In addition, some questions, such as CE4 and OF2 are scaled differently. Therefore, recoding of all answers to a five-point scale was done before data analysis. For example, CE4 is assessed on a four-point frequency scale of “__ daily”, “__ 2-3 times a week”, “__ once a week” and “__ rarely or never”, and it is also negatively scored (if a person chose “rarely or never”, it meant that Company Enforcement was low). The final score was calculated as (5- “original score”)* 5/4.

The available answers for OF2, OF3 and OF4 were “yes”, “no” and “I don’t know”. In these three questions, “no” is considered 1, “I don’t know” is scored 2 and “yes” is 3. However, this three-point-scale was also converted to five-points by multiplying “original score” by 5/3 to be comparable with other items for data analysis.

The statistical methods applied in this phase of study include: Spearman’s correlations, exploratory factor analysis, item analysis and path analysis. The step-by-step process is listed in Figure 6.5.
Exploratory Factor Analysis of Varimax with Kaiser normalization rotation was applied to examine the validity of the constructs in order to determine how items should be grouped together (Hu et al., 2003; Moore and Benbasat, 1991, Munro, 2005). The factors with eigenvalue below 1.0 were not extracted (Hu et al, 2003). Then the rotated factor matrix was examined for the items that had low loadings. Munro (2005) mentioned that there is no arbitrary cutoff point for an item loading. In the studies of TAM, the cut-off point for item loading is in the range of 0.40 to 0.60 (Hu, et al, 2003; Moore and Benbasat, 1991; Venkatesh and Davis, 2000). In this study, the cut-off item loading was set to 0.40. Based on the results from the initial factor analysis, the constructs of the items in the proposed model could be revised, and the path model would be updated on the basis of revised constructs, if needed.

Cronbach’s alpha was used to test the reliability of the questions under each construct (Cronbach, 1970). Moore and Benbasat (1991) cited that Nunnally (1967, p. 226) mentioned in his study that levels of reliability of 0.50 to 0.60 would be sufficient in the early stages of research. Legris et al. (2001) reviewed previous studies on the TAM
and found that the Cronbach’s alpha values in these studies ranged from 0.70-0.80. In this study, the cutoff point of Cronbach’s alpha was set to 0.60-0.70.

Once the constructs and the items under each construct were assessed and confirmed, Spearman’s correlation was applied to examine the relationships between the revised constructs. Additionally, binary logistic regression was used to calculate the association between the factors and whether a person has fall experiences because the answer to “fall experience” is a binary response. The purpose of examining correlations and other associations was to avoid multicollinearity between the variables in the path model and provide more insight for each variable.

At last, path analysis was applied to test and validate the revised path model of PFAS use. Path analysis is a multiple regression method to study the correlation of one variable to another in causal models. The cutoff p value in path analysis is 0.05 for significance.

SPSS 15 Statistical Package was used for all data analysis in this phase of the study.

6.8. Results

6.8.1. General information about the participants and training courses

Between July and October, 2008, a total of 236 questionnaires were distributed in eleven training sessions, within the state of Ohio. After filtering out the invalid responses on the screening questions, 124 questionnaire sets were considered completed and valid. The response rate was 53%.
Table 6.3 displays detailed information of each training session and the number of completed valid questionnaire sets\textsuperscript{20} collected before and after training. Considering the confidentiality of the respondents, the names of the training organizations are not provided in the table.

<table>
<thead>
<tr>
<th>Time order</th>
<th>Type of training</th>
<th>Training length</th>
<th>Methods</th>
<th>No. of completed questionnaires (after screening)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OSHA 10 hour</td>
<td>1.5 hours</td>
<td>Lecture, demonstration</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>OSHA 30 hour</td>
<td>2 hours</td>
<td>Lecture, demonstration</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>Fall protection</td>
<td>8 hours</td>
<td>Lecture, vendor demonstration, participation, discussion</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>OSHA 30 hour</td>
<td>2 hours</td>
<td>Lecture, video, demonstration</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>OSHA 30 hour</td>
<td>2.5 hours</td>
<td>Lecture, video, demonstration, discussion</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td>OSHA 10 hour</td>
<td>1.5 hours</td>
<td>Lecture, demonstration</td>
<td>22</td>
</tr>
<tr>
<td>7</td>
<td>OSHA 10 hour</td>
<td>1.25 hours</td>
<td>Lecture, video, demonstration, participation</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>OSHA 30 hour</td>
<td>2.5 hours</td>
<td>Lecture, demonstration, video</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>Fall protection</td>
<td>2 days (16 hours)</td>
<td>Lecture, video, vendor demonstration, discussion</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>OSHA 30 hour</td>
<td>2.5 hours</td>
<td>Lecture, video</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>OSHA 30 hour</td>
<td>2 hours</td>
<td>Lecture, video</td>
<td>13</td>
</tr>
</tbody>
</table>

**Total** | 124

Table 6.3: Details of the training sessions in which the questionnaires were distributed

Among these eleven training sessions, three of them were OSHA 10 hour constructions safety courses, with the length varied from one hour and fifteen minutes to one and a half hours on the topic of fall protection. Six were OSHA 30 hour courses, which provided longer coverage (two hours to two and a half hours), and provided more detailed information on fall protection. Two specific fall protection training courses, which concentrated only on fall protection, lasted one and two days, respectively.

The types of training applied in these eleven training sessions included lectures with PowerPoint presentations, viewing of video tapes, and demonstration of fall

\textsuperscript{20} “Valid questionnaire sets” means that the sets of questionnaires were not filtered out through the screening question, as mentioned in Section 6.5.
protection equipment. Some lecturers invited trainees to participate in equipment demonstrations, such as putting on a PFAS and discussing problems that have occurred when they were using a PFAS. In two specific fall protection training courses, PFAS manufacturers (generally called “vendors”) were invited to the training courses to demonstrate how to use PFAS and properly tie-off. A dummy or sand-bag was used to demonstrate a 6ft free fall with a PFAS tied-off.

Although the length of training varied in different sessions, all topics covered in each session remained consistent. All eleven sessions provided information on OSHA construction regulations, construction accident statistics, fall hazards recognition, engineering prevention, and instructions for fall protection equipment use.

6.8.2. Results from the background questions

Among 124 completed and valid questionnaires, only one was from a female construction worker, the others (n=123) were from male PFAS users. The average age of participants was 38 years old (SD=10.3), which is comparable to the sample in the preliminary survey (Chapter 3), in which the average age of participants was 37 years old (SD=10.8).

Figure 6.6 displays the distribution of participants’ types of work. Some respondents answered more than one type of work. This distribution does not represent the general distribution of all different trades in the construction industry and is a typical outcome of using a convenience sample.
When answering the screening question “how often does your occupation require you to use a fall arrest system”, 10 respondents answered “always”, 35 selected “most of the time”, and 79 chose “very rarely”. However, a few respondents felt that they could not find the proper answer for this question. They selected “very rarely”, and added comments as “regularly”, or “sometimes”. When answering the screening question in section 4, the average number of hours of PFAS used during a day among the respondents who answered “very rarely” was 3.8 hours, and the average number of days of PFAS use during a week among the same respondents was 2.82. This showed that these respondents could still be considered frequent PFAS users. In a future study, a five-point frequency scale (1=Always, 2= Often, 3=Sometimes, 4=Rarely, 5=Never) should be used instead of four-point scale in this question.

The next question asked about whether the respondents have their own harness. Pearson’s Chi-square test of association was used to determine the relationship between
owning a harness and PFAS use. A significant association was found (p= 0.017). It showed that the more frequently a construction worker uses a harness, the more likely the person would have his or her own harness. Table 6.4 shows the distribution of answers for these two questions.

<table>
<thead>
<tr>
<th>PFAS use</th>
<th>own harness</th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>yes</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>always</td>
<td>6</td>
<td>4</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>most of the time</td>
<td>20</td>
<td>15</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>very rarely</td>
<td>25</td>
<td>54</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>51</td>
<td>73</td>
<td>124</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.4: Cross-table of PFAS use vs. own harness (p=0.017)

The last question in section 1 (background questions) asked whether or not the respondents had experienced falls when using a fall arrest system. Eighteen respondents answered “yes” and 106 answered “no”. A significant correlation was found between the answer to this question and PFAS use by Pearson’s Chi-square test of association (p=0.010). Table 6.5 indicated that those who had fall experiences were more likely to use PFAS more frequently. This finding is opposite to what was discovered in the preliminary survey (Chapter 3).

<table>
<thead>
<tr>
<th>Fall experience</th>
<th>PFAS use</th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>always</td>
<td>most of the time</td>
<td>very rarely</td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>2</td>
<td>10</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>no</td>
<td>8</td>
<td>24</td>
<td>74</td>
<td>106</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>34</td>
<td>80</td>
<td>124</td>
</tr>
</tbody>
</table>

Table 6.5: Cross-table of fall experience vs. PFAS use (p=0.010)
6.8.3. Results from factor analysis on the basis of post-training responses

Since part of the research purposes in studying the path model of PFAS use was to discover whether or not fall protection training affects one’s usage intention and actual usage of PFAS, the data collected before and after training sessions would be compared based on the same path model. Therefore, only the post-training responses were used for model development (including factor analysis and item analysis). Once the model was built, both pre and post-training data would be applied to the model to examine the effectiveness of training.

Exploratory Factor Analysis was conducted by Varimax with Kaiser normalization rotation. The results showed that twelve factors had eigenvalues greater than 1.0 (Figure 6.7). The twelve factors together explained 73.8% of the variance.

Figure 6.7: Scree plot of all items based on the post-training responses

Next, the rotated factor matrix (Figure 6.8) was examined for items having relatively high loadings (>0.40).
<table>
<thead>
<tr>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV1</td>
<td>.778</td>
<td>-.095</td>
<td>.147</td>
<td>.122</td>
<td>.046</td>
<td>-.159</td>
<td>-.002</td>
<td>.075</td>
<td>.177</td>
<td>.077</td>
<td>.211</td>
<td>.342</td>
</tr>
<tr>
<td>PV2</td>
<td>.803</td>
<td>-.033</td>
<td>.149</td>
<td>.095</td>
<td>.024</td>
<td>-.157</td>
<td>.004</td>
<td>.091</td>
<td>.129</td>
<td>.088</td>
<td>.242</td>
<td>.324</td>
</tr>
<tr>
<td>PV3</td>
<td>.715</td>
<td>.165</td>
<td>.024</td>
<td>.009</td>
<td>.332</td>
<td>.021</td>
<td>.094</td>
<td>-.085</td>
<td>.014</td>
<td>-.178</td>
<td>-.172</td>
<td>-.108</td>
</tr>
<tr>
<td>PV5</td>
<td>.727</td>
<td>-.068</td>
<td>-.137</td>
<td>.075</td>
<td>.111</td>
<td>.110</td>
<td>.052</td>
<td>E-005</td>
<td>.065</td>
<td>.026</td>
<td>-.233</td>
<td>-.157</td>
</tr>
<tr>
<td>PV6</td>
<td>.687</td>
<td>.028</td>
<td>.053</td>
<td>-.051</td>
<td>.376</td>
<td>.051</td>
<td>.060</td>
<td>.157</td>
<td>.006</td>
<td>.271</td>
<td>-.113</td>
<td>-.191</td>
</tr>
<tr>
<td>CE3</td>
<td>.615</td>
<td>.339</td>
<td>-.029</td>
<td>.148</td>
<td>.147</td>
<td>.275</td>
<td>.142</td>
<td>-.141</td>
<td>-.044</td>
<td>-.063</td>
<td>.004</td>
<td>-.001</td>
</tr>
<tr>
<td>PEU1</td>
<td>.067</td>
<td>.845</td>
<td>.089</td>
<td>.092</td>
<td>.062</td>
<td>-.070</td>
<td>-.109</td>
<td>.101</td>
<td>.119</td>
<td>-.110</td>
<td>-.018</td>
<td>-.139</td>
</tr>
<tr>
<td>PEU2</td>
<td>.054</td>
<td>.906</td>
<td>.098</td>
<td>.120</td>
<td>.073</td>
<td>.028</td>
<td>.009</td>
<td>-.033</td>
<td>.022</td>
<td>.015</td>
<td>-.094</td>
<td>.012</td>
</tr>
<tr>
<td>PEU5</td>
<td>.052</td>
<td>.448</td>
<td>.217</td>
<td>.060</td>
<td>-.043</td>
<td>-.140</td>
<td>.146</td>
<td>.150</td>
<td>.264</td>
<td>-.063</td>
<td>-.006</td>
<td>-.571</td>
</tr>
<tr>
<td>PV4</td>
<td>.050</td>
<td>.858</td>
<td>.128</td>
<td>.042</td>
<td>-.018</td>
<td>-.020</td>
<td>.142</td>
<td>-.098</td>
<td>-.009</td>
<td>.045</td>
<td>-.108</td>
<td>.059</td>
</tr>
<tr>
<td>PFAS1</td>
<td>.068</td>
<td>.469</td>
<td>-.341</td>
<td>.418</td>
<td>.076</td>
<td>.042</td>
<td>-.138</td>
<td>-.023</td>
<td>.071</td>
<td>-.363</td>
<td>.128</td>
<td>-.012</td>
</tr>
<tr>
<td>PFAS2</td>
<td>.125</td>
<td>.484</td>
<td>-.279</td>
<td>.217</td>
<td>-.089</td>
<td>.149</td>
<td>-.109</td>
<td>.307</td>
<td>.129</td>
<td>-.163</td>
<td>.291</td>
<td>.100</td>
</tr>
<tr>
<td>PEU3</td>
<td>.095</td>
<td>.104</td>
<td>-.001</td>
<td>.805</td>
<td>-.021</td>
<td>-.028</td>
<td>.105</td>
<td>.015</td>
<td>.119</td>
<td>.028</td>
<td>.218</td>
<td>.010</td>
</tr>
<tr>
<td>PEU4</td>
<td>.059</td>
<td>.152</td>
<td>.058</td>
<td>.579</td>
<td>.196</td>
<td>.150</td>
<td>.140</td>
<td>.086</td>
<td>.353</td>
<td>.352</td>
<td>.008</td>
<td>-.115</td>
</tr>
<tr>
<td>PEU6</td>
<td>.103</td>
<td>.122</td>
<td>.458</td>
<td>.426</td>
<td>.067</td>
<td>.286</td>
<td>-.094</td>
<td>.215</td>
<td>.164</td>
<td>.087</td>
<td>-.335</td>
<td>.011</td>
</tr>
<tr>
<td>PEU7</td>
<td>.078</td>
<td>.005</td>
<td>.081</td>
<td>.663</td>
<td>.041</td>
<td>.050</td>
<td>-.122</td>
<td>.162</td>
<td>-.123</td>
<td>.380</td>
<td>-.165</td>
<td>.112</td>
</tr>
<tr>
<td>PEU8</td>
<td>.049</td>
<td>.178</td>
<td>.068</td>
<td>.815</td>
<td>.202</td>
<td>.106</td>
<td>.070</td>
<td>.052</td>
<td>-.064</td>
<td>.046</td>
<td>-.132</td>
<td>-.040</td>
</tr>
<tr>
<td>SN1</td>
<td>.184</td>
<td>.078</td>
<td>.177</td>
<td>.024</td>
<td>.752</td>
<td>.066</td>
<td>-.049</td>
<td>.173</td>
<td>-.090</td>
<td>.034</td>
<td>-.198</td>
<td>-.006</td>
</tr>
<tr>
<td>SN2</td>
<td>.223</td>
<td>-.093</td>
<td>.454</td>
<td>.154</td>
<td>.597</td>
<td>.154</td>
<td>.093</td>
<td>.286</td>
<td>.012</td>
<td>.066</td>
<td>.056</td>
<td>.027</td>
</tr>
<tr>
<td>SN3</td>
<td>.212</td>
<td>-.030</td>
<td>.091</td>
<td>.142</td>
<td>.753</td>
<td>-.091</td>
<td>.065</td>
<td>-.078</td>
<td>.154</td>
<td>-.074</td>
<td>-.159</td>
<td>.092</td>
</tr>
<tr>
<td>SN4</td>
<td>.115</td>
<td>.077</td>
<td>-.024</td>
<td>.072</td>
<td>.806</td>
<td>-.031</td>
<td>.168</td>
<td>-.095</td>
<td>.090</td>
<td>.046</td>
<td>-.022</td>
<td>.087</td>
</tr>
<tr>
<td>CE1</td>
<td>.090</td>
<td>.107</td>
<td>.805</td>
<td>.015</td>
<td>.211</td>
<td>.236</td>
<td>-.049</td>
<td>-.022</td>
<td>-.164</td>
<td>-.108</td>
<td>-.115</td>
<td>.083</td>
</tr>
<tr>
<td>CE2</td>
<td>.149</td>
<td>.167</td>
<td>.720</td>
<td>.165</td>
<td>.294</td>
<td>.188</td>
<td>.004</td>
<td>.148</td>
<td>-.038</td>
<td>-.061</td>
<td>-.125</td>
<td>.137</td>
</tr>
<tr>
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Figure 6.8: Rotated factor matrix of all items (highlighted items have relatively higher loadings (>0.40) under each factor)
Examining the rotated factor matrix, it was discovered that PV4 was pulled out from “Perceived Value” (PV). The rest of the items under PV have high loadings (>0.60) in factor 1, along with CE3. CE3 ("I would not use a fall arrest system if it was not required") was grouped under the category of “Company Enforcement (CE)”. However, CE3 indicated one’s perception of how valuable PFAS use is. If an individual used a PFAS in spite of whether it was required or not, he/she would have a high perceived value of PFAS. Thus, it is appropriate to group CE3 under PV.

PV4 ("I believe fall arrest systems reduce productivity”) was grouped together with PEU1, PEU2, PEU5, PFAS1 and PFAS2 in factor 2. PEU1 (“when properly adjusted, wearing a harness restricts my movement”) and PEU2 (“Using a harness makes it harder to get the job done”) are asking about workers’ perception of a harness’s restrictiveness. Although PV4 focused on the value of PFAS because “productivity” was considered to represent “value”, it might be more appropriate to group PV4 with PEU1, PEU2 and PEU5, not only based on the results from factor analysis, but also because of the actual meaning of the question: a worker’s productivity when using PFAS also depends on a harness’s restrictiveness. While PFAS1("The harness I am currently using is uncomfortable") and PFAS2 (“As best I know, all harnesses are uncomfortable”) asked about the comfortableness of harnesses, it would be proper to group PFAS1, PFAS2 with PEU1, PEU2, PEU5 and PV4, by proposing a new category: “Restrictiveness”.

In factor 3, CE1, CE2 and CE4 are categorized under CE with loadings above 0.50. Although PEU6 (“I am confident that I know how to use a harness and tie-off correctly”), SN2 (“My supervisors believe in the value of fall arrest systems”) and RP2 ("Construction industry jobs are more dangerous than most other types of manual jobs")
have loadings >0.40, it is more logical to arrange PEU6 with other items under “Perceived Ease of Use” (PEU), sort SN2 under “Subjective Norm” (SN), and isolate RP1 as an individual category, based on the literal and underlying meaning of the questions.

In factor 4, PEU3, PEU4, PEU6, PEU7 and PEU8 have relatively high loadings (>0.40). These five questions intend to discover “Perceived Ease of Use” of PFAS. In factor 5, all items under “Subjective Norm” (SN1 –SN4) have loadings above 0.60. Although a person’s years of experience of PFAS use, hours of PFAS use per week and percentage of tie-off PFAS were all loaded high in factor 6, these three items cannot be grouped together because each of them has a separate meaning.

In factor 7, both OF3 (“My company provides rewards to encourage safe workplace behaviors”) and OF4 (“My company provides rewards based on the number of accidents reported monthly”) have loadings above 0.80. Since both items seek for answers in “rewards” and “incentives”, they were separated from “Organizational Factors” (OF). A new category “Incentives” was created with these two items. The other two items under OF were not grouped together (the loading of OF1 is 0.642 in factor 12 and OF2 is 0.744 in factor 8). Therefore, OF1 and OF2 will be considered two individual categories in the revised path model.

Similarly, RP1 and RP2, PFAS 3 and PFAS 4 loaded in different factors. These four items had to be categorized individually. In addition, “fall experiences” had a loading of 0.481 in factor 8.
6.8.4. Results from reliability analysis (item analysis) on the basis of post-training responses

After the items under all categories were reconstructed based on the results from the factor analysis, internal consistency of each new category was examined by conducting a reliability analysis. Table 6.6 on the next page shows the average, standard deviation of each item (after score conversion), and Cronbach’s alpha values based on the responses from pre-training and post-training questionnaires (The original responses to the questionnaires are provided in the Appendix E (page 271).

The results showed that other organizational factors (OF1 and OF2), risk perception (RP1 and RP2) and PFAS (PFAS 3 and PFAS4) have relatively low Cronbach’s alpha value (<0.60). This validated the assumption based on the factor analysis results that all these six items should be considered separate factors in the revised path model. Meanwhile, Company Enforcement (CE) has Cronbach’s alpha below 0.60 before training. When checking the item details of CE, CE1 (“My use of fall arrest systems is mandatory where I currently work”) and CE2 (“My supervisor requires me to use fall arrest systems”) were focused on discovering how safety regulations were conducted in the company, while CE4 (“My supervisor checks my fall arrest system use”) asked about the supervisor’s reaction towards safety, regardless of regulations. Based on this understanding, CE4 was pulled from CE and became a separate item, named “supervisory enforcement”. Checking Cronbach’s alpha value between CE1 and CE2, the results showed that it was 0.83 before training and 0.88 after training, which were higher than the cut-off range (0.60-0.70).
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Table 6.6: Results from item analysis, based on pre-training and post-training responses (note: *reverse-scored)
Therefore, the proposed path model of PFAS use (Figure 6.4) was revised to the following model (PFAS_M2) (Figure 6.9) based on the results from factor analysis and reliability analysis.

![Revised path model of PFAS use (PFAS_M2)](image)

Figure 6.9: Revised path model of PFAS use (PFAS_M2)

As shown in Figure 6.9, there are total of 39 parameters in PFAS_M2, which is substantially higher than the number of parameters in the proposed model (PFAS_M1). This indicates that the required sample size for PFAS_M2 is larger. Based on “at least five times the number of parameters in the model” (Mueller, 1996), the minimum sample size for PFAS_M2 should be 195. However, only 124 valid responses were collected. The lack of sample might reduce the power of significance tests in this study.
6.8.5. Correlations and associations

In order to further understand the relationships among variables and to avoid redundant variables in the path model, Spearman’s correlation and binary logistic regression were conducted. The correlation tables are provided in Appendix E (page 294).

From the correlation table we can see that before training, usage intention was significantly correlated with Perceived Value, Perceived Ease of Use, Subjective Norm, Company Enforcement, Supervisory Enforcement (CE4), OF1 (“Regarding use of fall arrest systems and exposure to risk of falls, my supervisor goes out of his way to make sure I am protected”), OF2 (“My company provides all the necessary fall protection equipment for me and my co-workers”), Incentives, RP2 (“Construction industry jobs are more dangerous than most other types of manual jobs”), PFAS3 (“Purchasing my own harness would be a good investment”), PFAS4 (“A harness that is particularly designed for my trade would be easier to use”) and actual usage behavior. Actual usage behavior was found to significantly correlate with Perceived Value, Perceived Ease of Use, Subjective Norm, Company Enforcement, Supervisory Enforcement (CE4), OF1, OF2, Incentives, RP2 and years of experience of PFAS use. It was found that the longer a worker uses PFAS, the more likely he or she would answer that they always use PFAS and properly tie-off when required.

However, the correlation between years of experience and actual usage behavior was not discovered from the post-training responses. This might due to the increase of usage behavior score after training (mean value of U1 increased from 4.06 to 4.15 and U2 increased from 4.11 to 4.22). After training, usage intention was significantly correlated
with Perceived Value, Perceived Ease of Use, Subjective Norm, Company Enforcement, Supervisory Enforcement (CE4), OF1, RP2 and PFAS4.

The details of the intercorrelations among variables are provided in section 6.9: discussion.

6.8.6. Results from path analysis

Path analysis was applied to the model PFAS_M2 in order to test the model and compare the results before and after training. Figure 6.10 and 6.11 showed statistically significant (direct or indirect) paths to intention to use PFAS and actual PFAS usage behavior based on the responses from pre-training and post-training responses.

![Figure 6.10: Model testing results based on pre-training responses (PFAS_M2 pre-training results) (Model fit based on Chi-square goodness of fit test, p=0.560, indicating adequate fit) (note: numbers on paths are path coefficients; *: p-value<0.05; **: p-value<0.01; ***: p-value<0.001)
In terms of explaining “intention to use”, the model was able to account for 35% of the variance before training and 40% after training. The variances explained for Perceived Ease of Use (PEU) and Perceived Value (PV) were close before and after training. Before training, the model explained 25% for PEU and 21% for PV; while it explained 23% for PEU and 24% for PV at the training completion.

The path coefficient between PV and “intention to use” increased from 0.185 to 0.309 through training. There was no significant path discovered from PEU to “intention to use” before training, while the path was found after training (p<0.001, r=0.321). The path coefficient between Subjective and “intention to use” also increased from 0.214 to 0.355.
In the results from responses before training, OF1 (“Regarding use of fall arrest systems and exposure to risk of falls, my supervisor goes out of his way to make sure I am protected”) was found to significantly contributed to “intention to use” \( (p=0.048, r=0.195) \). This link disappeared after training. Instead, CE4 (“My supervisor checks my fall arrest system use”) had a marginally significant influence on “intention to use” \( (p=0.052, r=0.163) \). It was also interesting to find out that Company Enforcement (CE1 and CE2) had a negatively direct effect on “intention to use” after training \( (p=0.002, r=-0.280) \). However, the indirect influence from Company Enforcement to “intention to use” was positive. The total effect (TE) should be calculated as the sum of both direct effect (DE) and indirect effect (IE) (Mueller, 1996), which is:

\[
\text{TE} = \text{IE} + \text{DE} = 0.465 \times 0.355 + 0.465 \times 0.418 \times 0.309 + (-0.280) = -0.055.
\]

This showed that the total effect from Company Enforcement to “intention to use” was slightly negative. This could be understood that company’s enforcement on safety regulations is not as influential in motivating one’s intention to use PFAS as supervisor’s actual behavior towards safety, for example, regular checking of PFAS use.

“Restrictiveness” was found to be a significant determinant of both PV \( (p=0.010, r=0.239) \) and PEU \( (p=0.012, r=0.276) \) based on the results before training. However, it only affected PEU \( (p<0.001, r=0.348) \) after training. This might imply that the fall protection training helped respondents to realize that although use of PFAS was considered restrictive, the value of using PFAS was still perceived.

It was also discovered that PFAS 4 (“A harness that is particularly designed for my trade would be easier to use”) was a significant predictor of PEU, on the results from the responses after training. The comparisons of the answers to this question between the
pre- and post-training responses also showed a shift (see results of question 28 on page 280 and page 292). Sixty-nine of the respondents answered “agree” or “strongly agree” to this question before training, while the distribution increased to 73% after training. This could be explained that the respondents learned through the training that a harness for specific trade could be easier to use.

In addition, there were significant paths established from Subjective Norm to PV, and from “hours of PFAS use every week” to PEU, before and after training.

There were no statistically significant paths from the other factors to intention, either before or after training. These factors include: incentives (OF3 and OF4), fall protection provision (OF1), risk perception (RP1 and RP2), own harness (PFAS3), percentage of time spent on tying-off a harness, and years of PFAS use.

Path analysis was also applied to test the theoretical model, which was proposed in Figure 6.4 (PFAS_M1), based on the post-training responses. The statistically significant paths in the theoretical model are shown in Figure 6.12.

![Figure 6.12: Path analysis results of the theoretical model (PFAS_M1 post training results) (Model fit based on Chi-square goodness of fit test, p=0.385, indicating adequate fit) (note: numbers on paths are path coefficients; *: p-value<0.05; **: p-value<0.01; ***: p-value<0.001)](image-url)
The results showed that the theoretical model (PFAS_M1) explained 27% of the variance in intention to use PFAS, which was substantially lower than explained by the revised model (40%). As shown in Figure 6.12, PV and SN were the strongest predictors of intention to use. PEU marginally contributed to intention (p=0.086, r=0.151). Enforcement was not found to be a direct predictor of usage intention. The theoretical model explained 25% of the variance accounted for PV and 23% for PEU, which was similar to 23% and 24% explained by the revised model (PFAS_M2). In addition, there was a significant path from PEU to PV (p=0.002, r=0.263), which was not shown in the revised model.

Furthermore, path analysis was conducted to test all estimated paths from all of the constructs to “intention to use” in the revised model (PFAS_M2). As shown in Figure 6.13, PV and SN were two strongest predictors of intention, before and after training. PEU and Enforcement were significant after training, while Restrictiveness negatively influenced usage intentions before training. These findings confirmed the direct paths from the factors to “intention to use” which were discovered previously in Figure 6.10 and 6.11.
Examing the paths between all constructs and “intention to use” in the theoretical model (PFAS_M1), it showed that PV and SN are the only predictors of intention to use. Both factors only explained 29% of the variance (Figure 6.14).

6.8.7. Results from the follow-up postcards

A total of seventy-nine participants provided their contact information on the last page of the pre-training responses for the follow-up study. A post card with the question “Within the last two weeks, I wore my harness __ % of the time I was supposed to do
so.” was mailed to them two to three weeks after the day the questionnaires were filled out. Thirty-two completed postcards were returned to the researcher. The response rate was 41%.

![Figure 6.15: Comparison on percentage of PFAS use before and after training](image)

Figure 6.15 displays the comparison between the responses on the last question of the pre-training questionnaire and the results from the postcards. As shown on the figure, 21 out of 32 responses did not have any room for improvement (100% in both responses). However, 7 out of 11 responses (64%) which had room for improvement did improve. Although paired t-test did not detect any significance of difference between the values of two groups of data, the mean value of the responses increased from 90.4% to 95.8%, with a 5.4% increment. The difficulty to discover the significance of difference in PFAS use may because that most respondents who provided their contact information might be those who were confident enough that they always use PFAS, regardless of training.
Examining only the data that showed change after training (11 data points), 7 of them showed improvement. The mean value of these 11 data points was 72.1% before training; while it increased to 87.8% after training. The difference between before and after training responses also increased to 15.7%, which was greater than 5.4% within the total 33 data points. However, the significance in mean difference was not found by t-test, which might due to either the small number of observations, or an effect of little variation possible in the data.

6.8.8. Comparisons between the responses from exclusive fall protection training sessions and OSHA 10 & 30 hour courses

As mentioned in section 6.8.1, among all eleven training sessions in which the survey was conducted, there were two exclusive fall protection training sessions. These two sessions provided longer coverage (one and two days, respectively) and only concentrated on fall protection. Table 6.7 showed comparisons of the results between these two groups of training sessions.
<table>
<thead>
<tr>
<th>Construct</th>
<th>Exclusive fall protection (n=16)</th>
<th>OSHA 10 &amp; 30 hour (n=108)</th>
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<tr>
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<td>Pre</td>
<td>Post</td>
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<tr>
<td></td>
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<td>S.D.</td>
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<tr>
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<td>3.88</td>
<td>1.09</td>
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</table>

Table 6.7: Comparisons between the responses from exclusive fall protection training sessions and OSHA 10 & 30 hour courses (highlighted constructs have an increase of >0.20 on post-training scores, *: reverse-scored)
As shown in Table 6.7, based on the sixteen responses from exclusive fall protection training sessions, PV5 (“I believe the potential benefits of fall arrest systems outweigh the disadvantages”), CE3* (“I would not use a fall arrest system if it was not required”), PEU1* (“When properly adjusted, wearing a harness restricts my movement”), PEU2* (“Using a harness makes it harder to get the job done”), PEU5* (“Finding a proper tie-off point is time consuming”), PEU6 (“I am confident that I know how to use a harness and tie-off correctly”), SN1 (“My co-workers (other than my supervisors) believe in the value of fall arrest systems”), SN3 (“My co-workers routinely wear their fall arrest systems properly”), OF1 (“Regarding use of fall arrest systems and exposure to risk of falls, my supervisor goes out of his way to make sure I am protected”), OF2 (“My company provides all the necessary fall protection equipment for me and my co-workers”), and UB2 (“I always make sure my harness is tied-off properly when it is required”), had an increase in mean value of above 0.20 on post-training scores. From the other 108 responses from the OSHA 10 hour and 30 hour training courses, only one item: PEU1* had such increase in score after training. Paired T-test was then conducted to examine the significant difference in mean value before and after training. Only OF1 was found to be significant (p=0.028), although the change in the answers before and after training were not expected based on nature of the questions.

The comparisons of two groups of training courses showed that the training focused exclusively on fall protection appeared to have a modest trend of an effect on more items than OSHA 10 hour and 30 hour courses which had shorter coverage on fall protection. This indicates that the length and the breath of training sessions may affect the effectiveness of training.
6.9. Discussion

In examining the effectiveness of fall protection training, the path model of PFAS use was analyzed according to both pre-training and post-training responses. In addition, we compared the results from both a theoretical model and an empirical model that was based on both the initial theoretical model results for factor analysis.

Explaining Intention and Usage. The 2000 study of TAM2 by Venkatesh and Davis explained 34-52% of the variance in usage intention. When Hu et al. (2003) further adopted TAM2 to study school teachers’ acceptance of PowerPoint, their proposed model explained 47% of usage intention before training and 72% after training. The causal model which was proposed by Lusk (1997) to study construction workers’ use of hearing protection, explained 50% of the variance in use of hearing protection. In the current study, the revised path model of PFAS use (PFAS_M2) accounted for 40% of the variance in intention to use PFAS after training. This finding was consistent with prior studies of path models of technology acceptance and usage of protective behavior, and it was substantially higher than explained by the initially proposed theoretical model (PFAS_M1).

Comparing the results from pre-training and post-training responses in the current study, showed that the paths from Perceived Value, Perceived Ease of Use and Subjective Norm to Intention to Use became more significant after training, on the basis of the statistical significance, the strength of the path, and explanatory power. This indicated that fall protection training is at least somewhat effective in improving the influence from PV, PEU and SN to PFAS usage intention. Meanwhile, though based on more limited data, the explanatory power of usage intention and actual usage behavior improved after
training. The correlations between intention and usage behavior were found to be 0.668 before training and 0.711 at the training completion.

Perceived Ease of Use to Perceived Value. In the prior studies of TAM, perceived ease of use has always been discovered an important predictor of Perceived Usefulness (Davis, 1989; Hu et al., 2003; Venkatesh, 2000; Venkatesh and Davis, 2000). As explained in section 6.3, Perceived Usefulness was modified to Perceived Value in this study (as in Lusk, 1997). However, the significant contribution from PEU to PV was not established in the revised path model (PFAS_M2), either before or after training, while the link was found in the theoretical model (PFAS_M1). But the low explanatory power of the theoretical model and low statistical significance of PEU showed that the theoretical model might not be very representative in explaining the determinants of usage intentions.

The lack of a link from PEU to PV might be due to the separation from “Restrictiveness” from PEU, in the revised path model (PFAS_M2). In the theoretical model (PFAS_M1), PEU included PEU1- PEU8. But based on factor analysis results, PEU1, PEU2, and PEU5 were separated from PEU, and became a new category “Restrictiveness”, along with PV4, PFAS1 and PFAS2. It might also be because PV4 was moved to Restrictiveness. Since PV4 is asking about whether or not use of PFAS reduces productivity, it is expected that there is a link between ease of use and PV4. The 1997 study by Lusk, which proposed a causal model of hearing protection usage, did not explore the relationship between value of use and perceived barriers (similar to “restrictiveness” in this study) either. The findings from the current study and the study
by Lusk (1997) indicate that for safety equipment, its perceived value was not determined by perceived ease of use.

Restrictiveness. The category of “restrictiveness” was formed on the basis of factor-analysis results. It consists of respondents’ perception of restrictiveness and uncomfortableness of the harness they are using and they have used before. “Restrictiveness” could also be understood as a form of “perceived barriers to use”, as described in many studies of safety and health behavior. The 1997 study by Lusk revealed that workers’ perceived barrier to use was the strongest predictor of their use of hearing protection in his theoretical model.

In the revised path model of PFAS use (PFAS_M2), it was discovered that Restrictiveness was a significant predictor of both PV and PEU before training, while it only linked to PEU after training. Meanwhile, among all the factors, Restrictiveness is the strongest predictor of PEU, both before and after training. Examining the correlations between Restrictiveness and other variables, showed that Restrictiveness was correlated with PV, PEU and SN before training, but only related to PEU after training. In Figure 6.13, the direct path from Restrictiveness to Intention disappeared after training. The differences in the significance of Restrictiveness in the path model before and after training may be that it no longer affected the respondents’ perception of the value of PFAS after training. Additionally, the paired T-test was used to examine the difference in mean value of Restrictiveness before and after training, and the result showed there was a significant increase in scoring after training (p=0.006). This indicated that the respondents might have reduced their perception of restrictiveness of PFAS after training (all items under Restrictiveness are reverse-scored).
Subjective Norm. Venkatesh and Davis (2000) discovered that subjective norm significantly influenced both intention to use and perceived usefulness. Hu et al. (2003) discovered that subjective norm appeared to strongly affect intention to use before the training, while after training, the link from subjective norm to intention disappeared. They explained this as the teachers (the subjects in their study) had no experience in PowerPoint before the training, and they were more reliant on colleagues’ opinions of their use of PowerPoint at that stage. After training, they became more independent of others’ opinions or suggestions.

In the current study, Subjective Norm was significantly correlated with Intention and Perceived Value, in both before and after training responses. The paired T-test was also applied to study the responses for subjective norm before and after training, and there was no significant difference discovered. This indicated that subjective norm did not change significantly immediately after training. Also the nature of the questions under SN determined that the pre- and post-training responses to the questions were not expected to be different.

The difference in the findings between the current study and the study of Hu et al. (2003) might be due to the length of the training and experience of respondents. The training in the study of Hu et al. (2003) lasted 4 weeks, and the respondents had no previous experience in PowerPoint before the training. In the current study, the maximum training length was two days, and the respondents were expected to have some experience in PFAS use. The responses from those who had no experience in PFAS or their job did not require them to use PFAS were filtered out by the screening question.
**Enforcement.** According to the findings from the responses after training, Company Enforcement (CE1 and CE2) had a directly adverse effect on Intention. However, CE4 (“My supervisor checks my fall arrest system use”) was found to directly contribute to Intention in the path model. As explained earlier, it could be understood that a company’s enforcement of safety regulation itself might not directly influence one’s PFAS usage intention, unless actual supervisory actions take place. Examining correlations between Enforcement and other factors, it was found that Enforcement positively correlated with PV, PEU, CE4, Intention and Usage Behavior, in both pre- and post-training responses. In addition, Enforcement was determined to significantly contribute to Subjective Norm, before and after training.

**Organizational factors.** Based on the answers on the questionnaires, it was noticeable that some respondents answered that their company’s provision of PFAS was not adequate. OSHA Safety and Health Regulations for Construction 1926.502 (a) (2) states that “employers shall provide and install all protection systems required for an employee, before that employee begins the work that necessitates the fall protection.” However, fifteen respondents (more than 10%) reported in question OF2 that either their companies did not provide PFAS or they were not sure about the company’s provision of PFAS. It was also discovered that OF2 corresponded with actual usage behavior: if an employer provides PFAS, its employees were more likely to use PFAS properly. This result was consistent with what was discovered in the preliminary survey (Chapter 3). Meanwhile, OF2 was found to correlate with Subjective Norm, Company Enforcement and Supervisory Enforcement, based on both pre-training and post-training responses.

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This indicated that a company’s provision of PFAS might be a reflection of management commitment to safety, which could strongly influence workers’ safety behavior.

According to the results from path model testing, safety incentive (OF3 and OF4) was not found to significantly contribute to intention to use. Ingram (2008) mentioned that instead of providing an incentive or reward system, recognition should be provided to prompt safety behavior. He pointed out that employees tend to “see these incentives as part of their compensation”. He also stated that incentives may cause under-reporting of accidents on job sites. Instead, recognition methods, including a thank-you letter to employees’ homes, positive comments from supervisors or some small reward, would make employees feel that their safety behavior is “recognized” and “appreciated” (Ingram, 2008).

Vredenburgh (2002) studied the effectiveness of six of the most frequently used management practices in hospital safety programs, of which reward, recognition, and feedback is one. In his questionnaire, he asked “To what extent are employees rewarded for reporting a safety hazard (e.g., “thanked, have employee recognized in hospital newsletter, receive cash or other awards?”). However, his study did not discover a significant relationship between safety reward and recognition system and employee injury rate. In this study, we only focused on rewards, and overlooked recognition. In future study of PFAS or other safety performance, questions addressing this topic should be included

In addition to safety incentive and recognition, communication and feedback between workers and managers are frequently mentioned as safety practices that may prompt a safe and healthy workplace (Burke, et al., 2002; Dejoy, 1986; Dejoy, Murphy &
Gershon, 1995; Vredenburgh, 2002). DeJoy (1986) mentioned that a good communication system between workers and management is a predictor of a successful safety program. Vredenburgh (2002) stated that “consistent and forthright communication is an essential characteristic of any strong organization”. He also mentioned that feedback regarding employees’ safety performance is important because “behaviors resulting in industrial accidents are not typically new occurrences” (Vredenburgh, 2002). In the Dejoy et al. (1995) study of factors affecting adherence to universal precautions among nurses, feedback was discovered to be a strong indicator of safety climate. However, in the proposed path model of PFAS, communication and feedback was not addressed. The following question used in Dejoy et al. study: “I am given feedback regularly on how safely I perform my job”, and the other question listed in the Burke et al. survey: “Appropriately communicates with other workers while wearing personal protective equipment”, could be added as to address this concept, under the category of “other organizational factors”.

**Personal Fall Arrest System.** During the interviews (Chapter 4), some supervisors mentioned that those who use PFAS frequently preferred to have their own harness, so that they do not have to adjust it every time before it is used. The participants of the workshops (Chapter 5) mentioned that one’s own harness is always more comfortable and fits better than a universal one provided by the company. Therefore, in the path model, it was expected that whether or not an individual owns a harness might influence perceived ease of use. However, such relationship was not discovered (from PFAS3 to PEU). However, the correlation table shows that having one’s own harness has a significantly positive correlation with PEU and PV, before and after training. Those who
agreed “Purchasing my own harness would be a good investment” were more likely to perceive the ease of use and value of PFAS.

It was mentioned during the workshops (Chapter 5) that some participants would like to have a harness designed for their own trade. Therefore, PFAS4 (“A harness that is particularly designed for my trade would be easier to use”) was included in the questionnaire to investigate whether a harness for specific trade would be associated with PEU. The post-training responses supported this assumption: PFAS4 was a significant predictor of PEU. However, this path was not found based on the pre-training data. This could be understood that the respondents realized the importance of having a harness for specific trade through fall protection training, though the mean score for PFAS4 did not significantly increase after training (but there is a shift from “neutral” to “agree” after training).

Risk Perception. The results from path model testing showed that risk perception did not significantly contribute to perceived value. The correlation table shows that RP1 (“Some off the job activities I participate in are perceived as physically risky by others”) is not correlated with PV, PEU, intention or actual PFAS usage behavior. However, it was significantly associated with years of PFAS use. This indicated that the more experienced an individual was with PFAS, the higher risk perception he/she had. RP1 also correlated with PFAS3, which showed that if one believed the value of having ones’ own harness, he or she would be more likely to have a higher perception of risk.

RP2 (“Construction industry jobs are more dangerous than most other types of manual jobs”) was found to be positively correlated with intention to use and actual usage behavior, before and after training. After training, it also corresponded with PEU and PV.
This indicated that high risk perception of construction industry jobs is associated with high perception of ease of use and value of PFAS.

*Experiences.* In the revised path model of PFAS use, experiences include an individual’s years of PFAS use, hours of PFAS use every week and fall experiences. These three factors were expected to influence both PV and PEU. Among the three factors, hours of PFAS use every week was determined to be a significant predictor of PEU, before and after training.

The results from binary logistic regression determined that fall experiences positively correlated with hours of PFAS use. A person who had fall experiences had longer hours of PFAS use every week. It was also discovered, based on the post-training data, that fall experiences corresponded with PEU, RP2 and Usage Behavior. The association between fall experience and PEU could be explained as fall experience relates to hours of PFAS use, and hours of PFAS use influences PEU. In this part of the study, a person who had fall experiences also had a higher risk perception of the construction industry. He or she was more likely to perceive the danger of construction jobs. The correlation between fall experience and Usage behavior showed that after training, those who experienced falls were more likely to answer that they always use PFAS and properly tie-off when required. This finding corresponded to what was discovered in Table 6.5.

6.10. Limitations

First, sample size in this study was limited by the number of training sessions that were offered, within the timeframe in which data could be collected. Exploratory factor
analysis is considered a large sample analysis and it was suggested that 10 subjects for each variable are desirable (Munro, 2005). However, in most studies of TAM2, 3-5 subjects for each variable were acceptable. Additionally, based on the formulae of sample size calculation for path analysis which was provided in Cohen et al. (2003), the minimum number of samples required for the revised path model (PFAS_M2) is 148. In this study, the number of valid questionnaires collected was 124, which is slightly higher than three times the number of variables (n=37). A larger sample size could increase the power of significance tests in this study. In addition, a larger sample size might also increase the number of responses in the follow-up study (postcards). This might help in examining the difference in percentage of PFAS use before and after training.

Second, the current survey relied on use of a convenience sample. All respondents of the survey are commercial construction workers who attended professional training sessions from the same geographic region. However, the respondents are from a variety of trades, with a variety of ages and years of experience in PFAS use. Additionally, the current survey did receive responses from a variety of training centers.

Third, all responses to the questionnaires are self-reported. Usage of self-report is commonly used, such as in the TAM2 studies and many self-protective behaviors research studies; it remains a controversial issue (Straub, Limayem and Karahanna, 1995; Venkatesh and Davis, 2000).

Fourth, the nature of training sessions, including length of training, content of lectures and number of the attendees, are not consistent. Within the eleven training sessions, there were two exclusive fall protection training sessions, which lasted one and two days, respectively. These two fall protection training sessions were more interactive
than the other sessions. Section 6.8.8 compared the responses from these two fall protection training sessions and the other training courses. The results showed that training focused exclusively on fall protection appeared to have a trend of an effect on more items than OSHA 10 hour and 30 hour courses (see Table 6.7). However, due to the limited sample size of these two training sessions (n=16), it was not possible to perform factor analysis on those few responses alone.

6.11.  Conclusion

This phase of the study provided a theoretical and empirical foundation for understanding the factors contributing to construction workers’ usage intentions and usage behaviors of PFAS use. A path model of PFAS use was developed and validated for the first time. The developed empirical model (PFAS_M2) explained 40% of the variance accounting for usage intentions. Perceived Value, Perceived Ease of Use, Subjective Norm and Supervisory Enforcement (CE4) were determined to be positive drivers of intentions. The results from pre-training and post-training responses indicated that fall protection training is effective in increasing the combined influence from Perceived Value, Perceived Ease of Use and Subjective Norm to usage intentions.

Supervisory Enforcement (CE4) was found to directly contribute to usage intentions (r=0.163). Additionally, a company’s enforcement on safety regulations (CE1&CE2) contributed to Intentions indirectly (r=0.165). This finding suggested that for a company, supervisors’ regular check on construction workers’ PFAS and enforcement on safety regulations are both effective in encouraging workers to use PFAS.
Restrictiveness and Subjective Norm were strong determinants influencing Perceived Value based on the data collected before training. The significant path from Restrictiveness to Perceived Value disappeared at training completion. This could be explained that Restrictiveness no longer affected the respondents’ perception of the value of PFAS after training. The determinants of Perceived Ease of Use included Restrictiveness, hours of PFAS use every week and a harness designed for specific trade, based on post-training responses. Among these three factors, a harness for specific trade was not found to contribute to PEU before training.

The path model (PFAS_M2) only explained 40% of the variance accounting for usage intentions. The explanatory power was consistent with prior studies of path models in self-protective behavior and technology acceptance (TAM2). The 1997 study of Lusk in construction workers’ workers’ use of hearing protection explained 50% of the variance. Venkatesh and Davis (2000) developed TAM2 and their model explained 34-52% of the variance in usage intention of technology. However, there are other factors, which were not demonstrated in PFAS_M2, that contribute to PFAS use. For example, recognition instead of incentive, communication and feedback between workers and managers, may need to be added to the model and be investigated in the future study.

Overall, the path model was the first attempt to explain the factors that affect construction workers’ behavior of PFAS use, and the relationships among the factors. It was also the first path model addressing both individual factors, and social and organizational factors influencing self-protective behaviors. In the future, this model may be extended to investigate other safety and health behavior, and it may also lead to intervention research that targets the contributing factors.
CHAPTER 7

CONCLUSION AND FUTURE WORK

This research study has investigated the problem of inadequate PFAS usage among workers in the construction industry. Through this investigation, a path model examining construction workers’ usage intentions and actual behaviors of PFAS use was developed and validated for the first time. The path model systematically explained factors contributing to workers’ usage intentions of PFAS, and the interactions between factors. This study also showed promising results that fall protection training influences a number of significant drivers of usage intentions.

7.1. Research summary

The research first retrieved data from BLS in order to study fall-related injuries statistics in the construction industry. The results showed that fall accidents accounted for between 32% and 36% of all construction fatalities from 1994-2005. Some articles mentioned that approximately 30-50% of the accidents occurred when PFAS was not used properly (Cattledge, et al. 1996b; Chi, Chang & Ting, 2005; Huang & Hinze, 2003). In order to understand the relationship between PFAS use and fall-related injuries, the factors contributing to PFAS needed to be studied through a review of relevant literature.
After reviewing the relevant literature concerning factors affecting PFAS use and examining the factors that were studied in other models of technology adoption behavior and health and safety behavior, six categories of factors were identified to be associated with PFAS use. They are: individual, organizational, regulatory, environmental, PFAS, and task-related factors. Individual factors include both demographic and personality factors, which are: age, gender, unionized, risk-perception and self-efficacy. Organizational factors consisted of an organization’s safety culture, safety committee, compliance with regulations, enforcement of regulations, safety training and provision of safety equipment. Regulatory factors include OSHA regulations and enforcement of regulations. Environmental factors are comprised of work heights, weather and provision of anchorage points. PFAS factors include PFAS design, cost of PFAS and its sizing and fitting issues. The last group, task-related factors consist of types and duration of the tasks that workers were engaged when fall occurred.

However, some factors identified in the literature are either from researchers’ perspectives, or have not been evaluated in any model of health and safety behavior. Therefore, a four-phase approach was proposed for further investigation of the factors in this study (reproduced in Figure 7.1).
Figure 7.1: Four-phase approach of development and testing of the Path Model of PFAS use

From phase one to phase four of this study, the researchers intended to discover the factors that contribute to PFAS use, from the perspectives of all stakeholders within the construction industry, including construction workers, supervisors, managers, safety professionals, and architects.

During the phase one, a preliminary survey was conducted within 14 construction companies and organizations in order to gather information on PFAS use among construction workers. A total of 167 completed responses were collected. The results from the survey, revealed that “requirement of employment”, “personal concern for safety” and “supervisory enforcement” were the top three reasons why construction workers chose to use PFAS. The same group of respondents attributed the reasons of non-use of PFAS to: they feel PFAS reduces their productivity, PFAS restrains their movement, sometimes it is difficult to find a tie-off point, everyone shares them in the
company, and design of harness is uncomfortable. This could be interpreted as that from workers’ perspectives, improved PFAS designs would increase PFAS use.

In phase two, nine professionals, including four supervisors, two OSHA officers, one safety manager, one safety consultant and one architect were interviewed to obtain information on PFAS use from professionals’ perspectives. The results from the interviews identified fall protection training, along with company enforcement and safety incentives as being more important in influencing workers to use PFAS, than design of PFAS. In order to further study the disparate perceptions among the various stakeholder groups in the construction industry, small group interviews, in the form of participatory workshops, were conducted in phase three to explore more insights of PFAS design and fall protection training.

Two participatory workshops in this study focused on encouraging participants to generate ideas related to PFAS design and training, by expressing their experiences and opinions. In phase three of this study, the participants were construction workers, supervisors and safety managers. The outcomes from the workshops reinforced that comfortableness of PFAS, safety training and company enforcement are important factors that affect PFAS use, from the participants’ perception. Meanwhile, the participants also mentioned that construction workers’ risk perception, having their own harness and harnesses specially designed to their trade are related to PFAS use. At the end of phase three, fall protection training was selected as an important and practical factor to be evaluated in the model of PFAS use in the subsequent phase.

In phase four, the TAM and its extension were found to be analogous and applicable to adoption of PFAS. Although differences were recognized between the
adoption of technology and PFAS, a model of PFAS use was proposed by integrating the cause-effect diagram of PFAS use, the TAM and other safety behavior models. A survey was distributed to eleven training sessions and 124 completed questionnaires were collected. The survey included two sets of questionnaires: one was for data collection before training, the other was after training. The objectives of the survey were to 1) investigate the effectiveness of fall protection training in affecting usage intention and actual behavior of PFAS use among construction workers; 2) discover the significant drivers of PFAS usage intentions; 3) reveal the correlations among the factors contributing to usage intentions and actual usage behavior.

Based on the results of exploratory factor analysis and reliability testing (Cronbach’s alpha value), the proposed path model of PFAS was revised. Path analysis was applied in the revised model to study the relationships among variables. The model testing result based on the post-training responses is presented in Figure 7.2 (reproduced from Figure 6.11).
Figure 7.2: Model testing results based on post-training responses (PFAS_M2 post-training results) (Model fit based on Chi-square goodness of fit test, $p=0.665$, indicating adequate fit)
(note: numbers on paths are path coefficients; *: $p$-value<0.05; **: $p$-value<0.01; ***: $p$-value<0.001)

The revised path model of PFAS use explained 40% of the variances in usage intentions, which was consistent with prior research on path models of technology acceptance behavior and usage of protective behavior (Hu et al., 2003; Lusk, 1997). Perceived Value, Perceived Ease of Use, Subjective Norm and Supervisory Enforcement were found to be positive determinants of intention. Meanwhile, it was found that Perceived Value was significantly determined by Subjective Norm, and Perceived Ease of Use was associated with restrictiveness of PFAS, users’ hours of PFAS use every week, and the responses on “A harness that is particularly designed for my trade would be easier to use”.

The comparisons between pre-training and post-training responses indicated that the paths from Perceived Value, Perceived Ease of Use and Subjective Norm to Intention to use became more significant after training, according to the statistical significance, the strength of path and explanatory power (referring to Figure 6.8 and Figure 6.9). This could be interpreted that fall protection training is effective in improving the influence from PV, PEU and SN to usage intentions.

7.2. Implementations in the workplace -- as seen through the eyes of the personas

On the basis of the results from the workbooks in phase three (Chapter 5), three personas were generated to present various characteristics of PFAS users in the construction industry. Now the results of the current study are implemented to these three personas and their workplace. The following shows the changes occurred to the three personas, respectively.

**Persona 1: Mike Nelson.** Mike is a 35-year-old iron worker and he had never had any type of formal fall protection training. After Mike’s company learned from the results of this study that professional training on fall protection would prompt workers’ intention to use PFAS, the company just announced a new safety regulation that all employees were mandated to take OSHA 10 hour construction safety training session and achieve the certification. A two-hour-period of fall protection session was covered during the training. Through fall protection training, Mike learned the importance of using PFAS, the general fall hazard in the construction industry and the proper instructions to use PFAS and properly tied off. Mike felt the training is very beneficial to him.
**Persona 2: Brandon Jones.** Brandon is a welder with only one and a half years of experience in company ABC. Brandon’s company learned from this study that a harness designed for an employee’s special trade would make him/her more likely to use it. Thus, the company purchased a flame-resistant harness especially for Brandon. Brandon adjusted the harness to his own size and keeps it into his tool box. He likes the product very well and he uses it every time he has to perform welding jobs where use of PFAS is required.

**Persona 3: John Smith.** John is a superintendent and he has 30 years of experience in the construction industry. After learning the results from the current study, John started to check his workers’ PFAS use everyday to make sure that they are properly tied-off and used correctly. He also suggested to the company that comprehensive safety training courses should be provided to the workers, instead of only supervisors conducting a ten-minute tool-box talk every morning. In addition, John realized that showing recognition and appreciation to workers’ performance would help to build a safety culture in workplace. John started to send positive messages to his workers, such as “I’ve noticed that what you did yesterday prevented a serious incident from occurring”, to influence workers’ safety behavior (Ingram, 2008).

7.3. Suggestions for future work

First, the path model of PFAS use developed in this study only explained 40% of the variance accounting for usage intentions. This indicated that the model might have overlooked some other factors which may contribute to PFAS use. For example, safety incentive was not found to significantly affect usage intentions. Instead, recognition
should be provided in the company to prompt safety behavior (Ingram, 2008). In addition to incentive and recognition, many studies mentioned that communication and feedback between workers and managers were commonly used safety practices to motivate safety behavior (Burke, et al., 2002; Dejoy, 1986; Dejoy, Murphy & Gershon, 1995; Vredenburgh, 2002). In future studies, these factors should be taken into consideration. The questions related to these factors, such as “My company recognized my safety behavior”, or “what are the methods that your company applied to present their recognition of your safety behavior?” might need to be added to the current questionnaires to refine the current path model.

Second, a negative relationship was discovered between fall experiences and PFAS use in phase one, the preliminary survey (Chapter 3). It showed that the person who experienced falls were more likely to answer they “do not use PFAS” or “use PFAS rarely. The finding is the opposite of what we always believe (fall experiences might motivate ones to use PFAS more frequently). Through the discussions during the interviews and workshops (Chapter 4 and 5), some interviewees and participants mentioned that they had experienced falls, and the fall experience reminded them to wear a harness and properly tied-off when needed. The findings from phase four (Chapter 6) indicated that those who had fall experiences were more likely to use PFAS more frequently, which was consistent with the findings from Chapter 4 and 5. For future study, a key question as “Did your use of PFAS affect (increase/ decrease) your fall experiences?” should be added to the questionnaire, in order to determine whether fall experiences actually affects safety behavior from PFAS users’ perception.
Third, in this study, the data collected from the eleven training sessions were pulled together to develop the path model of PFAS use. However, the length, lecturer, style and number of attendees of each training session varied. This might lead to inconsistency in some of the post-training responses due to the effectiveness of training. In the future, the different path models of PFAS use could be studied based on different types of training sessions, if a larger sample size is achievable. This might lead to the answers of the questions as “Is the longer training (above 2 hours) more effective than the training less than two hours”? and “Is hands-on training more effective than PowerPoint lectures only?”

Forth, the study can lead to intervention research that targets the contributing factors. Take the factor “supervisory enforcement” as an example: an intervention research study could be designed in a company where “supervisory enforcement” did not take place at the beginning of the study. The length of the intervention could be planned as three months. Before the intervention took place, the subjects (construction workers who use PFAS regularly) would be asked to fill out a questionnaire regarding PFAS usage intention and behaviors. During the three months, the supervisors would be asked to check workers’ PFAS regularly (at least on daily basis). Every other week, the subjects would have to take the same questionnaire on usage intentions. At the end of the intervention, six sets of responses would be completed for each subject. Statistical analysis would be conducted to evaluate the effectiveness of “supervisory enforcement” in influencing workers’ usage intentions throughout three months. The same methodology could be applied to study the effectiveness of other contributing factors.
7.4. Conclusion

This study provided a theoretical and empirical foundation for understanding the factors contributing to PFAS use. A path model of PFAS use was developed and validated for the first time. The developed path model explained 40% of variance accounting for usage intentions.

The Technology Acceptance Model was adopted in this study to evaluate the effectiveness of fall protection training. The results from pre-training and post-training responses indicated that fall protection training is effective in increasing the influence from Perceived Value, Perceived Ease of Use and Subjective Norm to usage intentions.

Although fall protection training was found to be effective in influencing construction workers’ PFAS use intentions, this study showed that professional fall protection training in the construction industry was not adequate. Only 47% of the respondents of the preliminary survey (Chapter 3) had received training from professional trainers. More than half of the participants of the workshops (Chapter 5) had never received any type of formal fall protection training. This indicated that providing professional safety training to employees would be first necessary for a company to maintain and prompt a safety and healthy workplace.

Further research will need to determine how each contributing factor in the path model influences PFAS use and how nature of training (e.g. length of training and training method) affect training effectiveness.
BIBLIOGRAPHY


than young adults. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*, 51(3), M116-22.


APPENDIX A
DOCUMENTS USED IN PHASE ONE
(PRELIMINARY SURVEY)
Survey on Personal Fall Arrest Systems

The following survey is conducted by the Department of Industrial, Welding & Systems Engineering at the Ohio State University.

The purpose of this survey is to investigate Personal Fall Arrest Systems in order to reduce fall-related injuries and fatalities in the construction industry. Your participation in this survey is voluntary and anonymous. If you choose to participate, please complete this survey and return it to the researcher. The researcher will not share the information obtained from you with your employer or co-workers. The researcher will not even ask for your name or address. So your responses are strictly confidential. **Please place a checkmark in boxes or write what you think.** There are no right or wrong answers. Please answer each question honestly. The survey takes approximately 10-15 minutes. Thank you for your time, in advance.

We anticipate that we will be able to use what we learn from this survey to help companies employ better designed safety harnesses and fall protection training sessions. These improvements may directly impact you or your fellow construction workers in the future.

If you have questions or require additional information about the survey, please do not hesitate to contact the researcher: Di Liu, (614) 292-1718, or liu.640@osu.edu

*If you have questions or concerns about your rights as a research participant contact Sandra Meadows at The Office of Responsible Research Practices, 1-800—678-6251 or 1-614-688-4792.*
1. General demographics and information

Age: __

Gender: ☐ Male  ☐ Female

Race: ☐ Black  ☐ Hispanic  ☐ White  ☐ Asian/Pacific Islander  ☐ Other

How many years have you worked as a construction worker in the United States? __ years and __ months

What trade do you work most often? (Please check all applicable)
☐ carpenter  ☐ general laborer  ☐ iron worker  ☐ carpet layer
☐ drywall  ☐ electrician  ☐ heavy equipment operator
☐ insulation  ☐ painter  ☐ iron worker
☐ plumber or pipefitter  ☐ sheet metal worker
☐ bricklayer or mason  ☐ roofer
☐ heating, ventilation, or air conditioning installer
☐ other (specify) ____________

2. Work conditions

What types of surface conditions are you commonly walking on? (Please check all applicable)
☐ Roof  ☐ Ladder  ☐ Scaffold  ☐ Ground  ☐ Other (Please Specify)

What is the most common height in feet when you work? (Check all applicable)
☐ Less than 6 feet  ☐ 7-10 feet  ☐ 11-15 feet  ☐ 16-20 feet
☐ 21-25 feet  ☐ More than 25 feet

3. General information on falls

Have you ever experienced falls at the jobsite? ☐ Yes  ☐ No

If yes, please answer several questions below:

What caused the falls? (Please check all applicable)
☐ Slip  ☐ Trip  ☐ Loss of balance
☐ Not wearing personal fall arrest systems (harness)
☐ Other (please explain) ____________________________

Have you ever had injuries at the jobsite due to falls? ☐ Yes ☐ No

If yes, what types of injuries have you had? (Please check all applicable)
☐ Sprain/Strain  ☐ Fractures  ☐ Burns  ☐ Cuts  ☐ Other ____________

How long have you remained in the hospital after the injury occurred?
Was there any form of fall protection systems in place when the accident happened?
☐ Yes    ☐ No

**If yes,** what was the fall protection system? (Please check all applicable)
☐ Guardrail    ☐ Safety net    ☐ Safety monitor
☐ Personal fall arrest systems (harness)    ☐ Other (please specify) ______________

4. Training

Have you received any training on fall protection?
☐ Yes    ☐ No

**If yes,** what is the training format?
☐ Tool box (A short talk given by supervisors at the beginning of the shift)
☐ Video watching
☐ Lecture from supervisors
☐ Lecture from professional trainers (Such as OSHA 10-hour training)
☐ Other ______________

How long did your most recent training take place?
☐ less than 10 minutes    ☐ 10-30 minutes    ☐ 30 minutes-1 hour
☐ 1 hour-10 hours    ☐ 10 hours or longer

5. Personal Fall Arrest Systems (harness)

Does your company supply you with a harness?
☐ Yes    ☐ No    ☐ don’t know

Do you have your own harness?
☐ Yes    ☐ No    ☐ don’t know

Do you **actually use** your harness when needed?
☐ Always    ☐ Most of the time    ☐ Very rarely    ☐ Not at all

<table>
<thead>
<tr>
<th><strong>If “always” or “most of the time”,</strong> what makes you wear harness? (Please check all applicable)</th>
<th><strong>If “very rarely” or “not at all”,</strong> what makes you <strong>not</strong> wear harness? (Please check all applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Requirement of employment</td>
<td>☐ They make me uncomfortable</td>
</tr>
<tr>
<td>☐ Personal concern for safety</td>
<td>☐ They make me work slower than usual</td>
</tr>
<tr>
<td>☐ Supervisory enforcement</td>
<td>☐ They restrain my movement</td>
</tr>
<tr>
<td>☐ Peer pressure</td>
<td>☐ Hard to find a tie-off point for it</td>
</tr>
<tr>
<td>☐ Other (please explain)</td>
<td>☐ Nobody wears them at the jobsite</td>
</tr>
<tr>
<td>☐ Other (please explain)</td>
<td>☐ Other (please explain)</td>
</tr>
</tbody>
</table>
What do you dislike the most about your harness? (Please check all applicable)

☐ Material ☐ Color ☐ Comfort level ☐ Difficulty to use

☐ Everyone shares them in the company ☐ Other (please explain) ______

Would you like it more if it you had a harness that was assigned to you personally?

☐ Yes ☐ No ☐ Other (Please specify) __________

Do you have any concerns about not wearing harness when needed?

☐ There is no problem at all

☐ A minor problem

☐ A serious problem

☐ A very serious problem

6. Other comments or suggestions

_______________________________________________________________________

_______________________________________________________________________

Thank you very much for your cooperation.
To: Di Liu
Carolyn M. Sommerich, PhD
Department of Industrial, Welding & Systems Engineering
The Ohio State University

I understand that you are conducting a research project on the use of personal fall arrest systems in the construction industry. I give you permission to talk to our construction workers on our site at ______________________________________________________ (worksite location) to invite them to participate in your survey and to distribute and collect completed questionnaires from these trainees.

________________________(name; print first and last)

________________________(signature)

________________________(job title)

________________________(company)

________________________(phone number)
APPENDIX B
DOCUMENTS USED IN PHASE TWO
(INTerviews)
Interview questions for supervisors

1. What is your job title?

2. How long have you been working in construction industry?

3. How many construction workers you are responsible for? How many of them are female? How many do not speak English?

4. Does your company provide employees with PFAS (harness)? What is the harness model that your company is using?

5. What do you think are the key criteria to make harness acceptable?

6. Can you tell me about the fall protection training program in your company?

7. Have you ever experienced or observed a fall on a job site?

8. (Question 8 will be conducted if the interviewee answered “yes” on question 7):
   Can you explain to me how fall occurred? Was any form of fall protection in place when fall occurred? Was anyone injured from the accident?

9. Do you have any ideas of improving harness or fall protection training?
Interview questions for OSHA officers

1. What is your job title?

2. Among all the accidents you have investigated, what is the main factor that causes fall?

3. Have you investigated any specific fall-related cases that the victims were not wearing harness? If yes, can you briefly describe the case? If not, do you know any of your colleagues have? Do you happen to know any details of the case?

4. From your point of view, what might be the main reasons that workers do not wear harness? Do you have any thoughts on how to increase current harness usage?

5. What do you think are the key criteria to make harness acceptable?

6. Do you conduct fall protection training sessions to construction workers and supervisors? If yes, can you tell me some details of the training program?

7. Do you have any specific thing s you know about the training methods that you want to talk about?

8. Do you have any ideas of improving harness or fall protection training?
Interview questions for architects

1. What is your job title?

2. How long have you been working in the construction industry? How long have you been involved in industrial safety and health?

3. How do you describe the teamwork between architects (designers), engineers and contractors?

4. Can you explain “safety through design” from your perspective?

5. Can you tell me about the fall protection training programs among the contractors at OSU?

6. Do you have any ideas of improving harness or fall protection training?
The Ohio State University Consent to Participate in Research

Study Title: A study of Personal Fall Arrest Systems (PFAS) usage in construction companies
Researchers: Carolyn Sommerich and Di Liu
Sponsor: There is no sponsor for this study.
This is a consent form for research participation. It contains important information about this study and what to expect if you decide to participate.

Your participation is voluntary.
Please consider the information carefully. Feel free to ask questions before making your decision whether or not to participate. If you decide to participate, you will be asked to sign this form and will receive a copy of the form.

Purpose:
The purpose of this interview is to help researchers understand the problems and possible risks existing in current PFAS design and related fall protection training programs. The result of the interview is anticipated to assist researchers in order to improve current PFAS design.

Procedures/Tasks:
The interview will take approximately twenty to thirty minutes. You will discuss with the researchers your safety ideas and concerns on PFAS and compliance with fall protection regulations. You will also be given an opportunity to state your own opinions on how to improve fall protection training programs. The interview will be audio-recorded for further data analysis.

Duration:
The interview will take approximately twenty to thirty minutes. You may leave the study at anytime. If you decide to stop participating in the interview, there will be no penalty to you, and you will not lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.

Risks and Benefits:
You might be asked about your personal information and job-related experiences, which might be considered as a potential risk to your job. However, your participation is voluntary and you have the option of providing only the information you are willing to share with the researchers. You are not forced to answer any questions that you do not feel comfortable with. The results from our study may benefit you and your company in the future in terms of increasing usage of PFAS.
Confidentiality:

Efforts will be made to keep your study-related information confidential. However, there may be circumstances where this information must be released. For example, personal information regarding your participation in this study may be disclosed if required by state law. Also, your records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
- The sponsor, if any, or agency (including the Food and Drug Administration for FDA-regulated research) supporting the study.

Incentives:

You will not be paid to participate in the study.

Participant Rights:

You may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled. If you are a student or employee at Ohio State, your decision will not affect your grades or employment status.

If you choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form, you do not give up any personal legal rights you may have as a participant in this study.

An Institutional Review Board responsible for human subjects research at The Ohio State University reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

Contacts and Questions:

For questions, concerns, or complaints about the study you may contact the researcher: Di Liu, (614) 805-3726, or liu.640@osu.edu.

For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

If you are injured as a result of participating in this study or for questions about a study-related injury, you may contact Dr. Carolyn Sommerich at (614)292-9965.
Signing the consent form

I have read (or someone has read to me) this form and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study. I am not giving up any legal rights by signing this form. I will be given a copy of this form.

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Investigator/Research Staff
I have explained the research to the participant or his/her representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or his/her representative.

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APPENDIX C
DOCUMENTS USED IN PHASE THREE
(PARTICIPATORY WORKSHOPS)
Volunteers Needed to Study Safety Harness

conducted by:
The Ohio State University

Background
The safety harness is a common type of Personal Protective Equipment (PPE) used to protect workers in a fall. In this project, we are trying to improve current harness designs and fall protection training programs to reduce fall-related injuries and fatalities in the construction industry.

We ask for your help to participate in a workshop in which you and other volunteers will speak discuss what you think about harnesses and training, and how you want to improve them.

Incentives
- Volunteers will be given a $25 gift card for their participation (gift cards to a variety of retail stores will be available)
- Volunteers who do not have parking permits on OSU campus will be given a parking pass
- Refreshments will be provided during the workshop

Requirements for Volunteers
- Age: 18 and above
- Gender: Both males and females are needed
- Experience: Volunteers must have used safety harness before

Study Details
- Location: The workshop will be conducted on OSU’s main campus, in the Baker Systems Building (1971 Neil Ave.)
- Time Commitment: The workshop will last approximately 60-90 minutes

Contact Information
Interested in participating or have questions? Contact Di Liu:
- Email: liu.640@osu.edu
- Phone: 614-825-3726
hi,

Thanks for agreeing to take part in this study. By participating, you are helping to improve the current harness design in order to increase its usage on construction sites.

In order to get you prepared before the workshop, please fill out this workbook and we will pick up the workbook from you at our next visit on __________.

Thanks again! If you have any questions you can call us anytime. We can also be reached by email.

Di Liu
liu.640@osu.edu
614.805.3726

Carolyn Sommerich
sommerich.1@osu.edu
614.292.9965
about me

gender( ) male ( ) female

age (optional)

where I grew up

my hobbies

my favorite TV show

a little bit about my household, spouse? parents? kids? pets? ...

Please fill in the following questions on this page if you currently work or used to work in the construction industry.

about me at work

what I do (for employment)

I have been working in the construction industry since

I chose to work in the construction industry because

what I enjoy the most at work is
**a typical workday of my life**

The **next two pages** are for you to keep a log of your activities on a typical workday of your life. Please keep the workbook with you through the day and fill out the table. Below is an example so that you can see how someone might fill it out.

**day of week:** Monday  

**type of day:** 🙄 (please cross the face that represents your feelings the most during the day.)

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Location</th>
<th>Thoughts or feelings</th>
<th>Related to safety, for example, harness?</th>
<th>If yes, please explain</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:30 am</td>
<td>Got up, showered</td>
<td>Home</td>
<td>Feel well rested</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>6:00 am</td>
<td>Ate breakfast</td>
<td>Home</td>
<td>The coffee tastes good</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>7:00 am</td>
<td>Drove to work</td>
<td>Work</td>
<td>Not too late</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>7:30 am</td>
<td>Had a safety meeting</td>
<td>Work</td>
<td>First thing this morning, important</td>
<td>yes</td>
<td>Weekly safety meeting conducted by the supervisor</td>
</tr>
<tr>
<td>8:00 am</td>
<td>Started to work</td>
<td>Work</td>
<td>Lots to do today</td>
<td>yes</td>
<td>Went to get harness</td>
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<td>Went to bed</td>
<td>Home</td>
<td>Really tired</td>
<td>No</td>
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**this page is for you to fill out**

**day of week:** _________________________

**type of day:** [ ] [ ] [ ] [ ] [ ]

(please cross the face that represents your feelings the most during the day.)

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are there any other things you normally do in your workday which you did not list on this log because you did not happen to do it on that day?  (   ) Yes  (   ) No

If yes, what are they? (please specify)  ___________________________________________________________
the harness through my eyes

I learnt how to properly put on the harness through

I feel the need to use a harness for/when

I store my harness at

I dislike the harness because

I like the harness because

if I were to make my own harness, it would have

there is one type of harness I really like; here is how it looks like: (please either find a picture of the harness and paste it into the following box, or you can sketch it)
thanks!

Your workbook is complete. We will come to pick it up at our next visit.

Thanks for participating our workshop. We will see you at ________________ on ________________.

Carolyn Sommerich and Di Liu
WORKBOOK FOR TRAINING WORKSHOP

Please print your name here___________________________________
Hi,

Thanks for agreeing to take part in this study. By participating, you are helping to improve the current fall protection training programs.

In order to get you prepared before the workshop, please fill out this workbook and we will pick up the workbook from you at our next visit on __________.

Thanks again! If you have any questions you can call us anytime. We can also be reached by email.

Di Liu
liu.640@osu.edu
614.805.3726

Carolyn Sommerich
sommerich.1@osu.edu
614.292.9965
about me

gender(   ) male (   ) female

age (optional)

where I grew up

my hobbies

my favorite TV show

a little bit about my household, spouse? parents? kids? pets? ...

Please fill in the following questions on this page if you currently work or used to work in the construction industry.

about me at work

what I do (for employment)

I have been working in the construction industry since

I chose to work in the construction industry because

what I enjoy the most at work is
a typical workday of my life

The next two pages are for you to keep a log of your activities on a typical workday of your life. Please keep the workbook with you throughout the day and fill out the table. Below is an example so that you can see how someone might fill it out.

day of week: Monday

type of day: ![Face](image) (please cross the face that represents your feelings the most during the day.)

<table>
<thead>
<tr>
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<th>Related to safety, for example, fall protection?</th>
<th>If yes, please explain</th>
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</thead>
<tbody>
<tr>
<td>5:30 am</td>
<td>Got up, showered</td>
<td>Home</td>
<td>Feel well rested</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>6:00 am</td>
<td>Ate breakfast</td>
<td>Home</td>
<td>The coffee tastes good</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>7:00 am</td>
<td>Drove to work</td>
<td>Work</td>
<td>Not too late</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>7:30 am</td>
<td>Had a safety meeting</td>
<td>Work</td>
<td>First thing this morning, important</td>
<td>yes</td>
<td>Weekly safety meeting conducted by the supervisor</td>
</tr>
<tr>
<td>8:00 am</td>
<td>Started to work</td>
<td>Work</td>
<td>Lots to do today</td>
<td>yes</td>
<td>Went to get a fall protection equipment</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
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</tr>
<tr>
<td>10:00 pm</td>
<td>Went to bed</td>
<td>Home</td>
<td>Really tired</td>
<td>No</td>
<td></td>
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this page is for you to fill out

day of week: ____________________________

type of day: [Faces representing different emotions] (please cross the face that represents your feelings the most during the day.)

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table continues on next page...
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If yes, what are they? (please specify)  

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</table>
the fall protection training through my eyes

I received my training on fall protection through______________________________________________________________

most of my workers receive their training through______________________________________________________________

I dislike the fall protection training program because___________________________________________________________________________

I like the fall protection training program because ________________________________________________________________________________

if I were to design my own fall protection training program, it would be like (please specify)________________________________________________________

______________________________________________________________________________________________________________________

______________________________________________________________________________________________________________________
thanks!

Your workbook is complete. We will come to pick it up at our next visit.

Thanks for participating our workshop. We will see you at _________________ on ______________.

Carolyn Sommerich and Di Liu
SAMPLE CONSENT FORM FOR DESIGN WORKSHOP:

The Ohio State University Consent to Participate in Research

Study Title: A study of Personal Fall Arrest Systems (PFAS) usage in construction companies
Researchers: Carolyn Sommerich and Di Liu
Sponsor: There is no sponsor for this study
This is a consent form for research participation. It contains important information about this study and what to expect if you decide to participate.

Your participation is voluntary.

Please consider the information carefully. Feel free to ask questions before making your decision whether or not to participate. If you decide to participate, you will be asked to sign this form and will receive a copy of the form.

Purpose:
The purpose of the workshop is to help researchers understand the problems and possible risks existing in current PFAS designs. The result of the workshop is anticipated to assist researchers in order to improve current PFAS designs.

Procedures/Tasks:
Before the workshop, you will be asked to complete a workbook which consists of several questions to describe yourself, your everyday life and PFAS from your point of view. The researchers will make arrangements to collect the completed workbooks from you several days before the workshop. The purpose of workbook is to assist you to recall your experiences and feelings in order to help idea generations.
During the workshop, the facilitators will announce the purpose of workshop and what they expect from you. You will then have a discussion session for approximately ten minutes to describe your everyday experiences with PFAS and the problems you encountered with it. Then the group will split in two and have each spend a certain amount of time (no more than half an hour) working independently on designs that address the selected problems. Some assisting tools, such as images, stickers, straps and boards will be distributed during the workshop to help the idea generation. At the end of workshop, each group presents its design and the group discusses relative advantages. The whole session will be documented and video-taped for further data analysis. The length of workshop session will be approximately one hour.

Duration:
The workshop will take approximately 60-90 minutes. You may leave the study at any time. If you decide to stop participating, there will be no penalty to you, and you will not lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.
Risks and Benefits:

You will be asked about your personal information and job-related experiences in the workbook and you will have to introduce yourself at the beginning of the workshop, which might be considered as a potential risk to your job. However, your participation is voluntary and you have the option of providing only the information you are willing to share with the researchers. You are not forced to provide any information that you do not feel comfortable with. The results from our study may benefit you and your company in the future in terms of improving PFAS design and increasing usage of PFAS.

Confidentiality:

Efforts will be made to keep your study-related information confidential. However, there may be circumstances where this information must be released. For example, personal information regarding your participation in this study may be disclosed if required by state law. Also, your records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
- The sponsor, if any, or agency (including the Food and Drug Administration for FDA-regulated research) supporting the study.

Incentives:

A twenty-five dollars gift-card will be provided as an incentive for participating the study. By law, payments to subjects are considered taxable income. If you are an OSU employee, any compensation you receive as a result of participating in the study will be made through the payroll system and applicable taxes will be deducted.

Participant Rights:

You may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled. If you are a student or employee at Ohio State, your decision will not affect your grades or employment status.

If you choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form, you do not give up any personal legal rights you may have as a participant in this study.

An Institutional Review Board responsible for human subjects research at The Ohio State University reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.
Contacts and Questions:

For questions, concerns, or complaints about the study you may contact the researcher: Di Liu, (614) 805-3726, or liu.640@osu.edu.
For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

If you are injured as a result of participating in this study or for questions about a study-related injury, you may contact Dr. Carolyn Sommerich at (614)292-9965.
**Signing the consent form**

I have read (or someone has read to me) this form and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study. I am not giving up any legal rights by signing this form. I will be given a copy of this form.

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**Investigator/Research Staff**

I have explained the research to the participant or his/her representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or his/her representative.

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Your participation is voluntary.

Please consider the information carefully. Feel free to ask questions before making your decision whether or not to participate. If you decide to participate, you will be asked to sign this form and will receive a copy of the form.

Purpose:
The purpose of the workshop is to help researchers understand the problems in current fall protection training programs. The result of the workshop is anticipated to assist researchers to improve training programs in order to reduce fall-related accidents ultimately.

Procedures/Tasks:
Before the workshop, you will be asked to complete a workbook which consists of several questions to describe yourself, your everyday life and fall protection training from your point of view. The researchers will make arrangements to collect the completed workbooks from you several days before the workshop. The purpose of workbook is to assist you to recall your experiences and feelings in order to help idea generations.
During the workshop, the facilitators will announce the purpose of workshop and what they expect from you. You will then have a discussion session for approximately ten minutes to describe your everyday experiences with fall protection training and the problems you encountered with it. Then the group will split in two and have each spend a certain amount of time (no more than half an hour) working independently on a new training program that corrects the selected problems. Some assisting tools, such as images, stickers and boards will be distributed during the workshop to help the idea generation. At the end of workshop, each group presents its training program and the group discusses relative advantages. The whole session will be documented and videotaped for further data analysis. The length of workshop session will be approximately one hour.

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Incentives:

A twenty-five dollars gift-card will be provided as an incentive for participating the study. If you do not have parking permit on OSU campus, you will also be given a parking pass. By law, payments to subjects are considered taxable income. If you are an OSU employee, any compensation you receive as a result of participating in the study will be made through the payroll system and applicable taxes will be deducted.

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APPENDIX D
DOCUMENTS USED IN PHASE FOUR
(PATH MODEL OF PFAS USE)
THE QUESTIONNAIRE BEFORE TRAINING

Survey on Personal Fall Arrest Systems

The following survey is conducted by Di Liu, at the Department of Industrial, Welding & Systems Engineering at the Ohio State University.

The purpose of this survey is to help us understand more about PFAS training. If you have questions or require additional information about the survey, please do not hesitate to contact the researcher: Di Liu, (614) 805-3726, or liu.640@osu.edu

For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

If you are injured as a result of participating in this study or for questions about a study-related injury, you may contact Dr. Carolyn Sommerich at (614) 292-9965.

If you would like to have the above contact information, you may keep the cover sheet of the survey.

Thank you for your time, in advance.
Participant ID Number: _____________________

Section 1: Background questions:

Please place a checkmark in front of your selected answer or write what you think. Please answer each question honestly to the best of your ability.

Age: __

Gender: ___Male ___Female

What trade do you work most often? (Please check all applicable)
___ carpenter ___ general laborer ___ iron worker ___ carpet layer
___ drywall ___ electrician ___ heavy equipment operator
___ insulation ___ painter ___ iron worker
___ plumber or pipefitter ___ sheet metal worker
___ bricklayer or mason ___ residential roofer ___ commercial roofer
___ heating, ventilation, or air conditioning installer
other (specify)____________

How many hours do you work everyday? ________ hours

How many days do you work during a week? ________ days

How often does your occupation require you to use a fall arrest system?
___Always ___Most of the time ___Very rarely ___Not at all

Do you own your own harness?
___Yes ___No ___ don’t know

Have you experienced falls from heights when wearing a fall arrest system (including in the training session where you actually get to try it on and tied-off)?
___Yes ___No ___ don’t remember
Section 2:

Please indicate whether you (1) SD: strongly disagree, (2) D: disagree, (3) N: neutral, (4) A: agree, or (5) SA: strongly agree with each of the following statements. Circle one answer only for each statement. There are no right or wrong answers.

<table>
<thead>
<tr>
<th>Statement</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
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<tbody>
<tr>
<td>Proper use of fall arrest systems could protect me from serious injuries.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>Proper use of fall arrest systems could save my life.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>I feel safer when I have my harness on and I am properly tied-off.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>I believe fall arrest systems reduce productivity.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
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<td>I believe the potential benefits of fall arrest systems outweigh the</td>
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<tr>
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</tr>
<tr>
<td>Statement</td>
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<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
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<td>A harness that is particularly designed for my trade would be easier to use</td>
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<td>D</td>
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<td>From this point forward, I intend to wear a properly adjusted harness when required</td>
<td>SD</td>
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<td>N</td>
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<td>SA</td>
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<tr>
<td>From this point forward, I intend to properly tie-off when required</td>
<td>SD</td>
<td>D</td>
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<tr>
<td>I always wear a properly adjusted harness when required</td>
<td>SD</td>
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<tr>
<td>I always make sure my harness is tied-off properly when it is required</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
<td>SA</td>
</tr>
</tbody>
</table>
Section 3:

This section relates to your company’s behavior with regard to the use of fall arrest systems. For each question, please place a check mark in front of your selected answer.

1. My supervisor checks my fall arrest system use
   ___ daily       ___ 2-3 times a week       ___ once a week       ___ rarely or never
2. My company provides all the necessary fall protection equipment for me and my co-workers
   ___Yes       ___No       ___ don’t know
3. My company provides rewards to encourage safe workplace behaviors
   ___Yes       ___No       ___ don’t know
4. My company provides rewards based on the number of accidents reported monthly
   ___Yes       ___No       ___ don’t know

Section 4:

The section intends to ask about your experiences with fall arrest systems. Please answer the following questions.

1. How many years have you used a fall arrest system? ______ years (or ______ months if less than one year)
2. During the most recent job you’ve held that could have required use of a fall arrest system (due to work conditions), how many hours did you use it on a daily basis? ________ hours
3. During the most recent job you’ve held that could have required use of a fall arrest system (due to work conditions), how many days did you use it during a week? _____ days
4. During the most recent job I’ve held that could have required use of a fall arrest system (due to work conditions), ___ % of my working time I  have to hook up my lanyard to a new tie-off point on a daily basis.
5. During the most recent job I’ve held that could have required use of a fall arrest system (due to work conditions), I wore my harness ___% of the time I was supposed to do so.
Section 5:

If you are willing to participate in the follow-up of the study, we would like to send you a post card in the next few weeks. There is only one question included in the post card and it only takes you one minute to answer the question and place the post card back into your mailbox.

Please provide your name, phone number and the mailing address. A dollar bill will be sent along with the post card to show our appreciation of your help.

Name: ______________________
Address: _____________________
______________________

Phone number: _____________________

Thank you.

This page will be removed from the questionnaire by the researcher so that your name will not appear on the survey.
THE QUESTIONNAIRE AFTER TRAINING

Participant ID Number: _____________________

Please indicate whether you (1) SD: strongly disagree, (2) D: disagree, (3) N: neutral, (4) A: agree, or (5) SA: strongly agree with each of the following statements. Circle one answer only for each statement. There are no right or wrong answers.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<td>Proper use of fall arrest systems could protect me from serious injuries</td>
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<td>A</td>
<td>SA</td>
</tr>
<tr>
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<td>SD</td>
<td>D</td>
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<td>A</td>
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My co-workers encourage each other to use their fall arrest systems properly  | SD  | D  | N  | A  | SA  |
--- | --- | --- | --- | --- | --- |
My use of fall arrest systems is mandatory where I currently work  | SD  | D  | N  | A  | SA  |
My supervisor requires me to use fall arrest systems  | SD  | D  | N  | A  | SA  |
I would not use a fall arrest system if it was not required  | SD  | D  | N  | A  | SA  |
Regarding use of fall arrest systems and exposure to risk of falls, my supervisor goes out of his way to make sure I am protected  | SD  | D  | N  | A  | SA  |
Some off-the-job activities I participate in are perceived as physically risky by others  | SD  | D  | N  | A  | SA  |
Construction industry jobs are more dangerous than most other types of manual jobs  | SD  | D  | N  | A  | SA  |
The harness I am currently using is uncomfortable  | SD  | D  | N  | A  | SA  |
As best I know, all harnesses are uncomfortable to wear  | SD  | D  | N  | A  | SA  |
Purchasing my own harness would be a good investment  | SD  | D  | N  | A  | SA  |
A harness that is particularly designed for my trade would be easier to use  | SD  | D  | N  | A  | SA  |
From this point forward, I intend to wear a properly adjusted harness when required  | SD  | D  | N  | A  | SA  |
From this point forward, I intend to properly tie-off when required  | SD  | D  | N  | A  | SA  |
I always wear a properly adjusted harness when required  | SD  | D  | N  | A  | SA  |
I always make sure my harness is tied-off properly when it is required  | SD  | D  | N  | A  | SA  |

My company provides all the necessary fall protection equipment for me and my co-workers. *(Please a check mark in front of your select answer).*

___Yes    ___No    ___don’t know

**Thank you.**
THE “THANK YOU” LETTER IN THE FOLLOW-UP STUDY

Dear _________

Thank you so much for participating in the OSU research study on PFAS use and training, which was conducted in __________ a short time ago.

At that time, you expressed a willingness to answer one final question for us, which would be sent to you on a post card. That is why we are contacting you today.

Please take a minute to complete the question on the enclosed postcard, and then put the postcard in the mail.

Your participation in this research project is very much appreciated.

Sincerely,

Di Liu
Graduate Student
Industrial, Welding and Systems Engineering
The Ohio State University
(614)805-3726
The post card will be enclosed in an envelope and sent to participants along with a Thank You letter a few weeks after the survey. The postage will also be provided.
VERBAL SCRIPTS FOR THE SURVEY

My name is Di Liu. I am a graduate student of the Department of Industrial, Welding & Systems Engineering at the Ohio State University. The following survey is a part of my research project.

(Purpose)
The purpose of this survey is to help us understand more about PFAS training. Since you are the actual users of PFAS, your participation in this survey will be appreciated.

(Your participation is voluntary)
Your participation in this survey is voluntary. Feel free to ask questions before making your decision whether or not to participate. You refusal to participate will involve no penalty to you.

(Procedures and duration)
If you choose to participate, you will be asked to respond to two questionnaires today—one before the fall protection training and the other after the training. Each questionnaire will take approximately ten to fifteen minutes. Please answer the questions honestly in this survey and return it to me. You may stop participating in the survey any time and it will involve no penalty to you.

If you are willing to participate in the follow-up of the survey, you will be asked to provide your name, mailing address and phone number on the last page of the first questionnaire. We would like to ask you one question by sending you a post card in the next few weeks. It only takes you a minute to answer the question and put the post card back to your mailbox.

(Confidentiality)
Before the survey, each of you will receive a card with a participant ID number on it. Instead of providing your name, you will be asked to fill out your participant ID number on the first page of the survey.

If you choose to participate in the follow-up of the survey and provide your name on the last page of the first questionnaire, this page will be removed from the survey and your name will not appear on the questionnaire. Meanwhile, your participant ID number will be copied to the same page where your name and contact information appears.

The purpose of participant ID number is to connect the three segments (two questionnaires and one follow-up) together during the study and once we receive the post card from you, the page which includes both the name and the ID number will be destroyed so that there will be no link between your name and ID number. In addition, I will not share the information obtained from the results of your survey with your employer or co-workers.
(Incentives)
Once you participate in the survey, you will have the opportunity of winning a $25 Lowes gift card.
If you participate in the follow-up of the survey, a one-dollar bill will be sent along with the post card to show our appreciation.

(Risks)
Since all the information is confidential in this study, there are virtually no risks for you to participate this session.

(Significance of the session)
We anticipate that we will be able to use what we learn from this survey to create better designed fall protection training sessions. These improvements may directly impact you or your fellow construction workers in the future.

(Contacts and Questions)
The information of whom to contact when you have questions is listed on the cover sheet of the questionnaire. You may keep the cover sheet if you would like to have the contact information.
SAMPLE PERMISSION LETTER FOR THE SURVEY

___________ (date)

To: Di Liu
Carolyn M. Sommerich, PhD
Department of Industrial, Welding & Systems Engineering
The Ohio State University

I understand that you are conducting a research project on the use of personal fall arrest systems in the construction industry. I give you permission to observe our training session at ______________________________ (please provide address of training location), invite our trainees to participate in your survey and to distribute and collect completed surveys from these trainees.

____________________ (name; print first and last)
____________________ (signature)
____________________ (job title)
____________________ (organization)
____________________ (phone number)
APPENDIX E
RESULTS FROM THE SURVEY IN PHASE FOUR
1. Proper use of fall arrest systems could protect me from serious injuries (PV1)

![Graph showing responses to the statement about protection from serious injuries.]

2. Proper use of fall arrest systems could save my life (PV2)

![Graph showing responses to the statement about saving a life.]

3. I feel safer when I have my harness on and I am properly tied-off (PV3)

![Graph showing responses to the statement about feeling safer.]

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4. I believe fall arrest systems reduce productivity (PV4)

![Bar graph showing the distribution of responses regarding fall arrest systems reducing productivity.]

5. I believe the potential benefits of fall arrest systems outweigh the disadvantages (PV5)

![Bar graph showing the distribution of responses regarding the benefits and disadvantages of fall arrest systems.]

6. I believe proper use of fall arrest systems by all crew members is important to the successful completion of a job (PV6)

![Bar graph showing the distribution of responses regarding the importance of proper use of fall arrest systems.]

272
7. When properly adjusted, wearing a harness restricts my movement (PEU1)

8. Using a harness makes it harder to get the job done (PEU2)

9. I find it difficult to put on a harness (PEU3)
10. I find it difficult to adjust a harness (PEU4)

11. Finding a proper tie-off point is time consuming (PEU5)

12. I am confident that I know how to use a harness and tie-off correctly (PEU6)
13. Until now, it has been difficult for me to learn to properly use a fall arrest system (PEU7)

14. Overall, I find fall arrest systems difficult to use (PEU8)

15. My co-workers (other than my supervisors) believe in the value of fall arrest systems (SN1)
16. My supervisors believe in the value of fall arrest systems (SN2)

![Bar chart showing responses to supervisors belief in fall arrest systems.]

17. My co-workers routinely wear their fall arrest systems properly (SN3)

![Bar chart showing responses to co-workers wearing fall arrest systems.]

18. My co-workers encourage each other to use their fall arrest systems properly (SN4)

![Bar chart showing responses to co-workers encouraging fall arrest system use.]

276
19. My use of fall arrest systems is mandatory where I currently work (CE1)

20. My supervisor requires me to use fall arrest systems (CE2)

21. I would not use a fall arrest system if it was not required (CE3)
22. Regarding use of fall arrest systems and exposure to risk of falls, my supervisor goes out of his way to make sure I am protected (OF1)

23. Some off-the-job activities I participate in are perceived as physically risky by others (RP1)

24. Construction industry jobs are more dangerous than most other types of manual jobs (RP2)
25. The harness I am currently using is uncomfortable (PFAS1)

26. As best I know, all harnesses are uncomfortable to wear (PFAS2)

27. Purchasing my own harness would be a good investment (PFAS3)
28. A harness that is particularly designed for my trade would be easier to use (PFAS4)

29. From this point forward, I intend to wear a properly adjusted harness when required (IU1)

30. From this point forward, I intend to properly tie-off when required (IU2)
31. I always wear a properly adjusted harness when required (UB1)

32. I always make sure my harness is tied-off properly when it is required (UB2)

33. My supervisor checks my fall arrest system use (CE4)
34. My company provides all the necessary fall protection equipment for me and my co-workers (OF2)

![Bar chart showing responses to question 34.]

35. My company provides rewards to encourage safe workplace behaviors (OF3)

![Bar chart showing responses to question 35.]

36. My company provides rewards based on the number of accidents reported monthly (OF4)

![Bar chart showing responses to question 36.]

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POST-TRAINING RESPONSES

1. Proper use of fall arrest systems could protect me from serious injuries (PV1)

2. Proper use of fall arrest systems could save my life (PV2)

3. I feel safer when I have my harness on and I am properly tied-off (PV3)
4. I believe fall arrest systems reduce productivity (PV4)

![Bar chart showing responses to the statement on productivity. The chart indicates that the majority of respondents agree with the statement, with only a few strongly disagreeing.]

5. I believe the potential benefits of fall arrest systems outweigh the disadvantages (PV5)

![Bar chart showing responses to the statement on benefits versus disadvantages. The chart indicates that the majority of respondents agree, with a significant number strongly agreeing.]

6. I believe proper use of fall arrest systems by all crew members is important to the successful completion of a job (PV6)

![Bar chart showing responses to the statement on crew member use. The chart indicates a strong consensus, with almost all respondents agreeing.]

284
7. When properly adjusted, wearing a harness restricts my movement (PEU1)

8. Using a harness makes it harder to get the job done (PEU2)

9. I find it difficult to put on a harness (PEU3)
10. I find it difficult to adjust a harness (PEU4)

11. Finding a proper tie-off point is time consuming (PEU5)

12. I am confident that I know how to use a harness and tie-off correctly (PEU6)
13. Until now, it has been difficult for me to learn to properly use a fall arrest system (PEU7)

![Bar Chart]

Number of responses

<table>
<thead>
<tr>
<th></th>
<th>Number of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>strongly disagree</td>
<td>12</td>
</tr>
<tr>
<td>disagree</td>
<td>65</td>
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<tr>
<td>neutral</td>
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</tr>
<tr>
<td>agree</td>
<td>21</td>
</tr>
<tr>
<td>strongly agree</td>
<td>2</td>
</tr>
</tbody>
</table>

14. Overall, I find fall arrest systems difficult to use (PEU8)

![Bar Chart]

Number of responses

<table>
<thead>
<tr>
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<tbody>
<tr>
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<tr>
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<tr>
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<td>agree</td>
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15. My co-workers (other than my supervisors) believe in the value of fall arrest systems (SN1)

![Bar Chart]

Number of responses

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</table>
16. My supervisors believe in the value of fall arrest system (SN2)

17. My co-workers routinely wear their fall arrest systems properly (SN3)

18. My co-workers encourage each other to use their fall arrest systems properly (SN4)
19. My use of fall arrest systems is mandatory where I currently work (CE1)

20. My supervisor requires me to use fall arrest systems (CE2)

21. I would not use a fall arrest system if it was not required (CE3)
22. Regarding use of fall arrest systems and exposure to risk of falls, my supervisor goes out of his way to make sure I am protected (OF1)

23. Some off-the-job activities I participate in are perceived as physically risky by others (RP1)

24. Construction industry jobs are more dangerous than most other types of manual jobs (RP2)
25. The harness I am currently using is uncomfortable (PFAS1)

26. As best I know, all harnesses are uncomfortable to wear (PFAS2)

27. Purchasing my own harness would be a good investment (PFAS3)
28. A harness that is particularly designed for my trade would be easier to use (PFAS4)

29. From this point forward, I intend to wear a properly adjusted harness when required (IU1)

30. From this point forward, I intend to properly tie-off when required (IU2)
31. I always wear a properly adjusted harness when required (UB1)

32. I always make sure my harness is tied-off properly when it is required (UB2)

33. My company provides all the necessary fall protection equipment for me and my co-workers (OF2)
## Correlation Table Based on the Data Collected Before Training

<table>
<thead>
<tr>
<th></th>
<th>Intention</th>
<th>Usage</th>
<th>PV</th>
<th>PEU</th>
<th>SN</th>
<th>CE1 &amp; CE2</th>
<th>CE4</th>
<th>CF1</th>
<th>CE5</th>
<th>Inceptive</th>
<th>RP1</th>
<th>RP2</th>
<th>years of experience</th>
<th>hours of PFAS use</th>
<th>hook up percent age</th>
<th>PFAS3</th>
<th>PFAS4</th>
<th>Restrictiveness</th>
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</tbody>
</table>

- Intention: Measured as the primary measure of interest.
- Usage: Measured as the frequency of usage.
- PV, PEU, SN, CE1 & CE2, CE4, CF1, CE5: Measured as predictors of the primary measure.
- Inceptive: Measured as the initial stage of the primary measure.
- RP1, RP2: Measured as the subsequent stages of the primary measure.
- Years of experience, hours of PFAS use, hook up percent age: Measured as additional predictors.
- PFAS3, PFAS4: Measured as other variables of interest.
- Restrictiveness: Measured as the level of restrictiveness.
## Correlation Table Based on the Data Collected After Training

<table>
<thead>
<tr>
<th></th>
<th>Intention</th>
<th>Usage</th>
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<th>PEU</th>
<th>SN</th>
<th>CE1 &amp; CE2</th>
<th>CE4</th>
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<th>OF2</th>
<th>Incidence</th>
<th>RP1</th>
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<th>Years of Experience</th>
<th>Hours of FTAS Use</th>
<th>Hookup Percentage</th>
<th>PPAS3</th>
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**Correlation is significant at the 0.01 level (2-tailed).**

*Correlation is significant at the 0.05 level (2-tailed).*
**RELATIONSHIP BETWEEN FALL EXPERIENCE AND OTHER VARIABLES**
(BASED ON THE DATA COLLECTED BEFORE TRAINING)

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<th>SN</th>
<th>CE</th>
<th>CE4</th>
<th>OF1</th>
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<table>
<thead>
<tr>
<th>Fall experience</th>
<th>Incentive</th>
<th>RP1</th>
<th>RP2</th>
<th>Years of experience</th>
<th>Hours of use</th>
<th>Hook-up percentage</th>
<th>H3</th>
<th>H4</th>
<th>Restrictiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>0.897</td>
<td>0.615</td>
<td>0.890</td>
<td>0.594</td>
<td><strong>0.004</strong></td>
<td>0.709</td>
<td>0.248</td>
<td>0.241</td>
<td>0.785</td>
</tr>
<tr>
<td>odds-ratio</td>
<td>1.03</td>
<td>0.87</td>
<td>1.04</td>
<td>1.02</td>
<td><strong>1.04</strong></td>
<td>1.00</td>
<td>1.34</td>
<td>1.52</td>
<td>1.11</td>
</tr>
</tbody>
</table>

**RELATIONSHIP BETWEEN FALL EXPERIENCE AND OTHER VARIABLES**
(BASED ON THE DATA COLLECTED AFTER TRAINING)

<table>
<thead>
<tr>
<th>Fall experience</th>
<th>Intention</th>
<th>Usage</th>
<th>PV</th>
<th>PEU</th>
<th>SN</th>
<th>CE</th>
<th>CE4</th>
<th>OF1</th>
<th>OF2</th>
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</thead>
<tbody>
<tr>
<td>p-value</td>
<td>0.264</td>
<td>0.045**</td>
<td>0.058</td>
<td><strong>0.003</strong></td>
<td>0.300</td>
<td>0.835</td>
<td>0.757</td>
<td>0.695</td>
<td>0.293</td>
</tr>
<tr>
<td>odds-ratio</td>
<td>1.70</td>
<td><strong>2.47</strong></td>
<td>3.00</td>
<td><strong>5.05</strong></td>
<td>1.52</td>
<td>1.06</td>
<td>0.95</td>
<td>1.12</td>
<td>1.53</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Fall experience</th>
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</thead>
<tbody>
<tr>
<td>p-value</td>
<td>0.897</td>
<td>0.371</td>
<td><strong>0.075</strong></td>
<td>0.594</td>
<td><strong>0.004</strong></td>
<td>0.709</td>
<td>0.194</td>
<td>0.553</td>
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<td><strong>1.99</strong></td>
<td>1.02</td>
<td><strong>1.04</strong></td>
<td>1.00</td>
<td>1.48</td>
<td>1.22</td>
<td>1.84</td>
</tr>
</tbody>
</table>

**Correlation is significant at the 0.01 level (2-tailed).**

**Correlation is significant at the 0.05 level (2-tailed).**