How Technology Diffuses through Construction User Culture: An Innovation Design to Improve Safety Technology Adoption

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ABSTRACT

Usability has long been considered an important component of an innovation (Norman, 2002), evidenced by the fact that usability research has dominated innovation design efforts for a number of years. However, recent research has shown that satisfying usability is not sufficient for the successful diffusion and adoption of an innovation (Karsh, 2004). To develop an useful innovation, one must understand the mechanisms by which people choose to adopt and use an innovation, as well as how an innovation fits different levels of a socialtechnical system (Karsh, Escoto, Beasley, & Holden, (2006). The goal of this research, therefore, was to develop an innovation analytic and design framework that would enable designers to design a more likely adopted innovation and to validate it through the design and evaluation of a fall-protection training intervention for residential roofing subcontractors.

The proposed innovation analytic and design framework was based on the traditional systems-engineering process: Requirement Analysis, Prototype Development, and Summative Evaluation. Rogers' Theory of Innovation Diffusion and Adoption, as well as Participatory Design, were utilized to obtain a holistic view of technology-adoption challenges and opportunities.

The requirement analysis involved the development and use of a questionnaire and semi-structured interviews to identify the contributors of safety technology adoption in small roofing companies, as well as to understand the practices of safety technology adoption and fall-protection training. One hundred and four questionnaires from workers in North Carolina and Virginia were collected, and 29 workers received the follow-up semi-structured interview. Results showed that (1) social influence had a significant impact on the diffusion and adoption of safety technology; (2) workers' satisfaction with existing safety performance

standards/practices, as well as disengagement during available safety training, caused difficulties in implementing regular safety training; (3) management commitment and presentation of good/bad consequences of unsafe behavior were expected to facilitate the rate of adoption of safety technology. Results also identified specific recommendations for a fall-protection training intervention.

The prototype development was performed by a six-member Participatory Design (PD) team in a PD workshop, who used the results of the questionnaire and semi-structured interviews to develop a training intervention. Four PD approaches (PICTIVE, Inspiration Card Workshop, Scenario Building, and Future Workshop) were employed in the development of a Personal Fall Arrest System (PFAS) as an industry-specific training intervention.

This research also used summative comparative evaluation to assess the developed PFAS training intervention against a standard PFAS training intervention with respect to (1) adoption propensity, (2) expected adoption outcome, and (3) results demonstrability. Eighteen roofing workers were recruited to evaluate and compare the two interventions. The standard PFAS training intervention was developed by two experts using the safety manual published by the National Roofing Contractor Association. Results suggested that (1) the developed PFAS training intervention was more likely to be adopted and easier to diffuse among roofing subcontractors than the standard PFAS training intervention, and (2) use of the developed PFAS training intervention would better improve company's safety performance in comparison to the standard training intervention. Results of the evaluations confirmed the efficacy of the proposed innovation analytic and design framework in designing a more likely adopted innovation.

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1. INTRODUCTION

1.1. Problem Statement

1.1.1. Criticism of Current Research Approaches in Technology Adoption

Current adoption studies in information and communication technology (ICT) describe three approaches for studying technology adoption: the diffusion approach (Rogers, 1995), the adoption approach (Davis, 1989), and the domestication approach (Silverstone & Hirsch, 1992). Although these approaches have resulted in a better understanding of technology adoption, they do contain some inherent limitations and weaknesses because of some of the assumptions they make about the diffusion of technology study human behaviors.

- 1. With respect to diffusion studies, researchers in this area typically assume that an innovation is rapidly diffused within a population and adopted by most, if not all, members of a social system. The drawback is that diffusion studies underemphasize the ignorance or rejection of an innovation; nor do they fully account for innovations that fail to spread within a social system (Rogers, 1995). In short, we know a great deal about innovation successes, but relatively little about innovation failures. In addition, Hill and Troshani (2010) indicated that diffusion research focuses more on the marketing world as opposed to other areas involving human behaviors, and does not adequately explore the consequences of adoption (i.e., how individuals will use a diffused innovation) (Ling, 2001; Schuurman, Courtois, & Marez, 2010, in press) (Figure 1).
- 2. With respect to adoption research, these investigators typically hypothesize causal links between beliefs (the perceived usefulness and ease of use of an ICT) and users' attitudes, intentions, and their subsequent adoption behaviors (Davis, 1989). However, Amberg, Hirschmeier, and Wehrmann (2004) and Benbasat and Barki (2007) indicated that adoption research does not systematically incorporate situational contexts and users' opinions regarding the characteristics of the proposed

technologies. Despite the fact that adoption studies have increasingly considered both technological attributes in examining users' adoption decisions (Lu, Yu, Liu, & Yao, 2003), as well as users' motivations to use technologies (Davis, Bagozzi, & Warshaw, 1992), adoption research is still limited because it does not have an agreed-upon framework that takes into account the impact of external and social influences on technology diffusion and adoption (Wijngaert, 2010) (Figure 1).

3. With respect to domestication research, these investigators typically look at what technologies mean to people, how they experience them, and the roles the technologies can come to play in their lives (Bredies, Chow, & Joost, 2010). However, as indicated by Carlsson, Walden, and Bouwman (2006), domestication research does not lend itself to making prognoses with respect to the potential diffusion of an innovation (Figure 1). In addition, Pedersen and Ling (2003) pointed out that while domestication research takes an observational approach in that it describes and explains an innovation's social elaboration, it does not discuss the intention of use of an innovation.

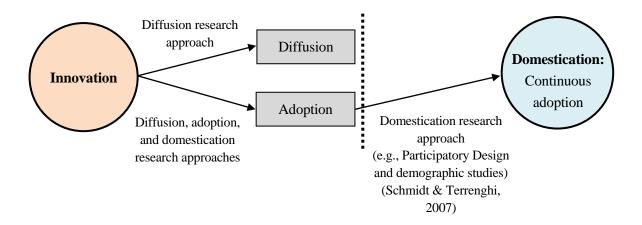


Figure 1. Current research approaches concerning technology diffusion and adoption

1.1.2. Lack of a Global Analytic and Design Framework for Technology Adoption

Scientists and researchers who study human behaviors must inevitably make a number of assumptions to justify their claims. It comes as no surprise then, that in the field of ICT the

discussed research approaches that address technology adoption problems are limited by the subjective views of the researchers. Little research has been done to assemble these research approaches and theories toward a global understanding of users' adoption behaviors with the goal of designing a more likely adopted innovation. Typically, advocates of the specific research approach/theory either stick with their own micro view (Lu, Quan, & Cao, 2009) in studying innovation diffusion/adoption, or merely add variables to their adoption models (Bhattacherjee & Sanford, 2006) to correspond to different case studies. The problem is that these various adoption models tend to be case sensitive and only address distinct situations with one or a few research perspectives, which results in a lack of construct validity in explaining users' adoption behaviors.

According to Schuurman, Courtois, and Marez (2010, in press), however, these three approaches in fact complement each other, meaning that their integration could better explain the adoption of a given technology. Thus, there is a need to synthesize current technology-adoption research approaches to broaden research insights and to ensure that an intended innovation has a higher chance of being adopted by users (Boczkowski, 2004; Wijngaert, 2010). To develop a holistic view of technology-adoption challenges and opportunities, as well as to improve users' well-being from the adoption of new technologies, it is imperative to form an analytic and design framework that examines technology adoption from different angles at one time.

1.2. Motivation

1.2.1. Resistance to Technology Adoption in the Construction Industry

Advancements in technology have impacted nearly every industry in the world. It should come as no surprise that new technologies have been developed to promote construction worker safety and health (Skattør, 2007; Yu, Jang, & Han, 2007). For example, Abderrahim, Garcia, Diez, and Balaguer (2005) developed a mechatronics security system, consisting of safety helmets and an onsite safety monitoring server, which detects possible failures and risk situations, thereby avoiding harm to machinery, installations and, most importantly, to construction workers. In a similar vein, Riaz, Edwards, and Thorpe (2006) developed a

proactive health and safety management system. Their interactive system not only notifies construction machine operators when workers are in close proximity to potentially harmful machinery, but also keeps workers informed about the hazards and risks of their physical surroundings.

Despite these potentially life-saving advancements, the construction industry in general has been slow to adopt many new technologies to promote worker safety. In order to explain this industry's resistance to the use of technologies on job sites, researchers have identified a number of key factors that continue to impede the widespread adoption of these important advancements among construction contractors (Anumba, 1998; Whyte, Bouchlaghem, & Thorpe, 2002):

- First, construction tends to be a conservative industry that is characterized by a pervasive resistance to technology (Jacqueline & Mark, 2001; Scott, Ponniah, & Saud, 1994). Construction practitioners are likely to be satisfied with traditional business methods and tools, tend to view innovations with skepticism, and do not appreciate the benefits of technological innovations (Doherty, 1997; Toole, 1998). These long-standing attitudes are key barriers to the widespread adoption of occupational health and safety (OHS) advancements on most construction sites.
- Second, the construction industry is highly competitive with unique "on-off" projects that typically operate on low margins. This translates to limited investments in new technologies for construction worker safety (Dyson & Er, 2004).
- Third, a highly-entrenched system of bonuses in the construction industry contributes to its reluctance to adopt these new technologies (Er & Kay, 2003): Specifically, penalties, which are known as "liquidated damages," are applied on a sliding scale when a project does not meet the contractual completion date. Therefore, introducing new, unproven technologies is seen as a risky source of unnecessary delays, which could result in the application of liquidated damages.

Fourth, uncertainty—defined as the state when an individual is missing information relevant to a decision—also plays a critical role in the adoption of innovations in the construction industry (Toole, 1998). Toole pointed out that most contractors lack relevant information to determine whether they should adopt new technologies.

Moreover, they feel that building innovations may not perform as promised and feel the need to seek convincing evidence of an innovation's advantages over existing products or practices.

Beyond the attitudinal factors that hinder the adoption of new technologies, Anumba (1998) pointed out that the poor dissemination of research results and a mismatch between current research and industry needs are also barriers to the adoption of innovations. He argued that academic research results—mostly disseminated through publications in technical journals and at conferences— do not usually reach industry practitioners. Moreover, he also asserted that researchers tend to focus on what is academically exciting and technologically challenging instead of addressing real industry problems with affordable and practical solutions. Other identified barriers include (1) the lack of computer training for contracted workers (Er & Kay, 2004), (2) the lack of managerial commitment to new technologies (Er & Kay, 2003), (3) the lack of effective technological solutions and self-motivational strategies for change (Samuelson, 2002), and (4) inadequate workplace support for learning the new technologies (Peansupap & Walker, 2005).

The construction industry consists primarily of small contractors (Hester, John, Leiming, James, & Dennis, 2003), which represent 91% of the total number of construction establishments (U.S. Census Bureau, 2008). The majority of these companies are associated with residential work—in fact, about five times more than those who work in the commercial sector (U.S. Census Bureau, 2008). Regardess of whether the work takes place in the residential or commercial sector, the multi-layer employment patterns in the construction industry routinely necessitate that a contractor assumes a variety of roles (e.g., an employee of a project, a subcontractor hiring temporary workers, or even a general contractor). It should be noted that

the discussed resistance to technology adoption (Section 1.2.1) relates to the general construction worker in the small construction industry, rather than employees of larger firms.

1.2.2. Prevalence of OHS Problems in the Small Construction Industry

The construction industry, which consists of both large and small construction firms (Darragh, Stallones, Bigelow, & Keefe, 2004), typically has one of the highest fatal and non-fatal injury rates compared with other industries. While larger construction companies have significantly more safety-related resources available to their employees (e.g., equipment, written safety materials, and even mandatory safety classes), smaller construction firms may not have the financial or personnel resources to similarly protect their employees.

A small construction firm is defined as a company of 20 or fewer employees that is headed by a general contractor, who also occasionally operates as a subcontractor for other builders, and/or who works as a laborer when no other worker is available (Arditi & Chotibhongs, 2005). Work done by smaller construction firms is often performed in remote sites with smaller crews, many of whom are hired on a per-job basis in the residential building sector. In comparison to larger firms, small construction companies have limited access to safety resources, such as safety training and on-the-job safety programs; nor do they have the benefit of permanent on-staff safety personnel (Holmes, Lingard, Yesilyurt, & Munk, 1999). As a result, these companies tend to have a higher frequency of lost-time injuries (Lin & Mills, 2001) compared to larger firms. Studies (Kines & Mikkelsen, 2003; Lingard & Holmes, 2001) have indicated that effectively managing OHS in small construction firms is a challenge that is too often neglected. The trend has been evident for many years and appears to be unaffected by cyclical employment patterns (McVittie, Banikin, & Brocklebank, 1997).

1.2.3. Problems of Fall Injuries and Accidents in the Roofing Industry

One of the most hazardous sectors within the construction industry is the roofing industry (Chi, Chang, & Ting, 2005; Rivara & Thompson, 2000). According to the Bureau of Labor Statistics (2009b), roofers have a higher "incident rate" (defined as the number of injuries per 100 full-time workers) in comparison to average construction trades workers. In

this industry, falls from heights are the primary event source leading to fatal injuries, accounting for 71 percent of all cases (U.S. Bureau of Labor Statistics, 2009a).

To address this industry's comparatively high OHS hazard rate, the Occupational Safety & Health Administration (OSHA) has promulgated minimum training standards (U.S. Department of Labor, 1999c) that require contractors to equip each employee with specific OHS problem-solving abilities. These include the ability to identify fall hazards, understand the use of fall protection systems, and know the correct procedures for the handling and storage of equipment and materials. However, as noted by Johnson, Singh, and Young (1998), fall protection plans are generally not prepared as required, and positive safety measures, such as guardrails and fall arrest systems, are not universally used. In fact, the high number of recordable injuries over the past 20 years (Fredericks, Abudayyeh, Choi, Wiersma, & Charles, 2005) has led to both elevated insurance premiums and worker compensation payouts from roofing companies (Choi, Fredericks, Abudayyeh, & Keslinke, 2003). More importantly, the types of injuries (e.g., neck or spinal injuries) caused by falls from roofs are often catastrophic or fatal, requiring long periods of treatment and recovery, and resulting in substantial medical costs (Gillen, Faucett, Beaumont, & McLoughlin, 1998).

A recent study conducted by Chi, Chang, and Ting (2005) investigated the various causes of fall injuries on the jobsite. By analyzing fall incident reports, Chi et al. categorized the causes under the following four types:

- Individual factors—bodily actions (e.g., climbing, walking, and leaning behaviors),
 distraction, insufficient capacity, and the improper use of personal protective
 equipment;
- Task factors—overexertion and unusual control, poor work practices, and the removal of protection measures;
- Tools and equipment factors—mechanical failure, unsafe ladder and tools;
- Management and environment factor—unguarded openings, lack of complying scaffolding, unauthorized access to hazard areas, contact with falling objects, and harmful substances.

Although a few are associated with equipment failures, most of these factors are related to workers' inadequate knowledge of the use of tools, equipments, and safe working procedures with respect to tasks, and safety regulations. The National Institute for Occupational Safety and Health (NIOSH) in its published alert drew similar conclusions with respect to the causes of injuries and deaths related to falls (NIOSH, 2000). After examining five case reports of deaths resulting from falls from heights, NIOSH determined that most falls resulted from the fact that workers did not sufficiently recognize or appreciate the fall hazards associated with their work. Moreover, Bobick, Stanevich, Pizatella, Keane, and Smith (1994) argued that a worker's inadequate perception of the strength and load-bearing capacity (e.g., of a skylight element) could also result in a slip off a roof edge.

Thus, there is a pressing need for additional research on how to (1) improve workers' fall hazard awareness, and (2) further equip workers with OHS problem-solving abilities to prevent falls from roofs through training. Indeed, a fall-protection training intervention probably will be the most effective way to address this need.

1.3. Scope

The construction industry needs not only effective technological solutions to improve its safety performance (Dyson & Er, 2004), but also a more proactive approach among management to facilitate workers' adoption of these technologies (Toole, 1998). Thus, in recognition of the slow response by the construction industry to incorporate technological innovations—as well as the need to better understand technology adoption challenges in preventing workplace injuries and accidents—this research aimed to develop a more likely adopted innovation for improving safety conditions in the construction industry. The studied population was roofing subcontractors in the residential construction sector with less than 20 employees because 20 is the minimum number generally utilized in construction research to distinguish between small and large construction firms (Kines, 2003; Lin & Mills, 2001). This cohort was selected because the job of residential roofing subcontractors involves all kinds of fall hazards and the incident rate for this worker population is higher than the average worker.

In this research, an innovation is defined as an intervention/a technology that is perceived as "new" by roofing subcontractors. The investigated innovation was a fall-protection training intervention because (1) fall-protection training is one of the most effective measures for decreasing fall incidents among construction subcontractors (Rivara & Thompson, 2000); (2) fall-protection training has been shown to improve the safety performance of residential construction workers (NIOSH, 2000); and (3) OHS information packages, regulations, and personnel are generally directed at general building enterprises, and only infrequently address the needs of smaller-scale building operations (Mayhew & Quinlan, 1997) (e.g., the small roofing industry). In addition, this research addresses several priority areas in the National Occupational Research Agenda (NORA) (NIOSH, 2008) in the context of work-related falls from roofs. The main priority areas include: (a) Falls; (b) Construction Health and Safety Culture; (c) Construction Health and Safety Management; (d) Safety and Health Training and Education in Construction; and (e) Construction Hazards Prevention through Design.

1.4. Research Questions and Hypotheses

Little research has been done to comprehensively address safety technology adoption challenges/opportunities for the small roofing industry. As indicated previously, research in ICT uses different world views to study technology adoption. Although these various studies have produced important insights with respect to innovation diffusion and adoption, there still remains a lack of a global analytic and design framework that could be used to examine adoption challenges. In addition, construction workers tend to be notoriously slow to adopt new technologies, for the reasons discussed earlier. There is also the issue of roofing subcontractors, who tend to have limited resources to invest in safety measures (e.g., safety programs, equipment) (Holmes, Lingard, Yesilyurt, & Munk, 1999; Kines, 2003). In short, few studies have been directed at developing technology-based training interventions for fall protection that are tailored to reflect roofers' work context and environmental constraints.

The above research gaps yielded the following research questions:

- (Q1) How do designers/engineers design an innovation that has a better chance of being adopted by users?
- (Q2) What are the contributing factors to the adoption of safety technologies (i.e., safety training programs and equipment) in the small roofing industry?
- (Q3) How do safety practitioners improve roofing workers' adoption of a fall-protection training intervention?
- (Q4) What is a fall-protection training intervention that improves OHS performance among small residential roofing contractors?

To address the research questions, the following three hypotheses were formulated and tested in this research:

- (H1) The theoretical components of the proposed innovation analytic and design framework will predict the rate of the adoption of safety technologies.
- (H2) The developed fall-protection training intervention will be more likely to be adopted by residential roofing subcontractors than a standard fall-protection training program.
- (H3) The developed fall-protection training intervention will improve safety performance in small roofing companies more than a standard fall-protection training program.

1.5. Objectives

The purpose of this research was twofold. The first was to construct an analytic and design framework to guide the development of an innovation that has a higher chance of being adopted by users. The second was to implement the framework in designing a more likely adopted fall-protection intervention for residential roofing subcontractors. These purposes were achieved through the following five objectives:

- (1) To develop an innovation analytic and design framework and validate its efficacy.
- (2) To identify contributing factors for the adoption of safety technologies in the small residential roofing industry.

- (3) To understand fall-protection training practices among roofing subcontractors in the field.
- (4) To understand practices of safety technology adoption in small roofing companies.
- (5) To elicit needs and requirements for a more likely adopted fall-protection training intervention.

1.6. Research Overview

The overarching goal of this research was to develop an innovation analytic and design framework that would enable designers to design an innovation that would be beneficial to users' lives and more likely to be adopted among users. An innovation analytic and design framework was constructed using traditional systems-engineering processes (Chapanis, 1996). In particular, Rogers' Model of Innovation Diffusion and Adoption (Rogers, 1995), the Theory of Innovation Domestication (Pedersen & Ling, 2003), and Participatory Design (PD) (Schuler & Namioka, 1993) were evaluated and then applied to the design of a fall-protection training intervention for roofing subcontractors. Table 1 provides an overview of the research, methods, activities, and the requirement analysis for the development of the training intervention.

Table 1: An overview of the research

Phase	1. REQUIREME	ENT ANALYSIS	2. PROTOTYPE DEVELOPMENT	3. FORMATIVE/SUMMATIVE COMPARATIVE EVALUATION
Method	Questionnaire	Semi-Structured Interview	Participatory Design (PD)	Questionnaire
Research Question	What are the contributing factors to the adoption of safety technologies (i.e., safety training programs and equipment) in the small roofing industry?	 How do safety practitioners improve roofing workers' adoption of a fall-protection training intervention? What is a fall-protection training intervention that improves OHS performance among small residential roofing contractors? 	What is a fall-protection training intervention that improves OHS performance among small residential roofing contractors?	
Purpose	To identify predictors for safety technology adoption	To understand the practices of safety technology adoption and fall-protection training	To design a fall-protection training intervention	 To verify the efficacy of the innovation design framework To assess the effectiveness and participants' adoption propensity of the developed training intervention
Activity	 Stage1: Developed questionnaire items that address the theoretical components of Rogers' model and fall-protection training needs Assessed reliability, and face and content validity of the questionnaire Stage 2: Administered questionnaires in the field 	• Conducted interviews, presented the prepared questions, and obtained participants' feedback	Conducted a 2-day PD workshop to identify the design features and systems requirements for the intended fall-protection training intervention	 Identified and adapted questionnaire items from the literature to measure user adoption propensity and expected outcome of adoption Developed a standard fall-protection training intervention Compared participants' adoption propensity of the developed training intervention against a standard training intervention
Sample	Stage 1: n = 11; Stage 2: n = 104	n= 29	n = 6	n = 18

For Requirement Analysis, two precursors were essential for developing a more likely adopted fall-protection training intervention: (1) to identify "significant" predictors for safety technology adoption; and (2) to understand current practices in safety technology adoption and fall-protection training. A mixed-methods research design was used because the combination of quantitative and qualitative data provides a more complete picture by noting any trends and generalizations, as well as by obtaining an in-depth knowledge of participants' perspectives (Creswell & Clark, 2007). For Prototype Development, a PD team was assembled that included roofing subcontractors and this research's investigative team. A PD workshop was held to discuss the viability of fall-protection training intervention ideas identified in response to insights obtained from the administered questionnaires and semi-structured interviews. The physical format, specific design features, and systems requirements of the training intervention were determined, after which a high-fidelity prototype was developed. For Formative/Summative Comparative Evaluation, a summative comparative evaluation was conducted which measured the effectiveness and workers' adoption propensity of the developed fall-protection training intervention against a standard fall-protection training intervention. A within-subject research design was used in the research.

1.7. Document Overview

This document includes the following components. Chapter 2, the Literature Review, examines the current literature relevant to innovation diffusion and adoption, followed by an overview of the OHS-related challenges in the small construction industry and the small residential roofing industry. Chapter 3, the Method section, discusses the rationales and the employed theoretical components for the construction of the innovation analytic and design framework. Chapter 4, 5, 6, and 7 describe the studies (i.e., Requirement Analysis, Prototype Development, and Summative Evaluation) used to develop and evaluate the fall-protection training intervention. Chapter 8, the Conclusions chapter, discusses the contributions and implications of this research in the field of technology adoption and construction safety.

2. LITERATURE REVIEW

2.1. Current Research Streams Concerning Technology Adoption

Current research in ICT in studying technology adoption can be divided into three major streams: (1) diffusion research, (2) adoption research, and (3) domestication research.

- 1. **Diffusion research:** Diffusion research has its foundation in marketing and economics and generally studies the aggregate diffusion and adoption of a technology in an industry, community, or society (Pedersen & Ling, 2003). Researchers believe that diffusion success is determined both by factors that influence technology adoption, as well as by the ways users within an organization adopt the technology. Rogers' Model of Innovation Diffusion (Rogers, 1995), one of the most cited works in diffusion research, provides a comprehensive approach for understanding how innovations are adopted in a particular population. Rogers' model identifies four components that impact the diffusion process. The first is the attributes of an innovation, namely the primary criteria that influence an individual's adoption decision. The second component is the social system, which influences an individual's adoption decision according to personal and social behavioral interactions. The third component corresponds to the communication channels through which technology diffusion is disseminated within a population. The fourth component is time, which states that the length of time for an individual to adopt an innovation depends on the innovativeness of the user, the innovation-decision process of the user, and the innovation's rate of adoption within an organization (as measured by the number of organizational members who adopt an innovation in a given time).
- 2. Adoption research: Adoption research, which is based in information systems research, typically studies why and how users decide to adopt a particular technology, as well as their choice of media and pattern of media use (Shin, Lee, Shin, & Lee, 2009). Adoption research goes beyond merely describing the adoption process. Rather, adoption researchers seek to explain particular adoption behaviors at the individual level. For example, Davis's Technology Acceptance Model (TAM) (Davis, 1989), which is frequently cited in adoption research, focuses on how personal attitudes impact the adoption and use of specific technologies. In essence, this model examines the determinants of consciously-intended behaviors. Two key

variables are central to TAM: perceived usefulness and perceived ease of use of a technology. The perceived usefulness of a technology is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, p. 320). The perceived ease of use of a technology is defined as "the degree to which a person believes that using a particular system would be free of effort" (Davis, p. 320). Researchers believe that both of these variables are of fundamental importance to an individual's attitude towards a system, his or her intention to use it, and ultimately to the actual utilization of a system (Carlsson, Walden, & Bouwman, 2006).

3. Domestication research: Domestication research has its foundation in sociology and studies how new technologies are incorporated into the daily life of users by means of the domestication process (Silverstone & Hirsch, 1992). Domestication researchers believe that the adoption and use of technology is dynamic and interactive, and can result in a process of mutual adaptation (Pedersen, 2005). As such, the focus of domestication studies tends to be descriptive, emphasizing the adoption and use of technology on the basis of gender, age, or cultural differences (Carlsson et al., 2006). The most cited work in this area is Silverstone and Haddon (1996), which uses five phases to describe the domestication of technology process: (1) imagination—when an innovation enters into an individual's consciousness, (2) appropriation—the point at which an individual transforms the mediated or public meaning of an innovation into his/her personal and private meaning, (3) objectification—the phase during which an individual personalizes an innovation and its uses, (4) incorporation—when an individual makes an innovation a part of his/her own life, and (5) conversion—the stage when an individual becomes identified by others through his/her particular use of an innovation. As Ling (2004) summarized, these phases describe a continuum, beginning with when an object or technology is first considered to be potentially useful, to the point at which it becomes imbedded in regular use.

To summarize, diffusion research both describes and explains the process of technology diffusion and adoption both at the individual and aggregate levels. Adoption research, however, examines a user's adoption and acceptance of various kinds of technologies and their applications at the individual level. Finally, domestication research focuses on the process of technology adoption, how individuals interact with technologies, and how individuals incorporate new technologies into daily living.

2.2. Rogers' Theory of Innovation Diffusion

2.2.1. Applications in the Field

Over the previous few decades, there has been substantial interest in technology innovation and adoption on a global basis (Rankin & Luther, 2006). A considerable body of technology diffusion literature has used Rogers' Theory of Innovation Diffusion (Aguila-Obra & Padilla-Meléndez, 2006; Chau & Tam, 2000; Cooper & Zmud, 1990) to investigate the diffusion of innovations within communities and/or the adoption of innovations by individual units.

Rogers' work—combined with a number of other innovation studies—form a common technology diffusion paradigm that sheds light on the adoption and impact of technology. For example, Iacovou, Benbasat, and Dexter (1995) combined one of the innovation attributes proposed by Rogers—namely, relative advantage—with economic costs and lack of technical knowledge, which were proposed by Cragg and King (1993), to develop an adoption framework of electronic data interchange for small business firms. Kendall, Tung, Chua, Ng and Tan (2001) also studied Rogers' definition on the perceived innovation attributes and formulated a linear model to examine the receptivity of Singaporean small and medium-sized enterprises with respect to the adoption of electronic commerce.

Other researchers have used Rogers' Theory of Innovation Diffusion to develop technologies and innovation dissemination plans in different contexts. For instance, Mosley (2005) developed a technology-mentoring program for K-12 instructional environments based on the primary components of Rogers' Theory of Innovation Diffusion, which was subsequently endorsed by K-12 teachers, administrators, technology coordinators, and higher education faculty. Karsh, Escoto, Beasley, and Holden (2006) conducted a study exploring the barriers and facilitators for the design of a medical error reporting system and discussed how Rogers' innovation diffusion model and other theories of technology acceptance fitted with the results of the study. This study enabled Karsh and his colleagues to develop an integrated theoretical model of a medical error reporting system design and its subsequent implementation.

2.2.2. Rogers' Model of Innovation Diffusion

In Rogers' Model of Innovation Diffusion, he defined an innovation as "an idea, practice or object that is perceived as new by an individual or another unit of adoption" (Rogers, 1995, p.12). He also categorized diffusion of innovations as "the process by which an innovation is communicated through certain channels over time among the members of a social

system" (Rogers, p.11). The ultimate result of this process is that an individual or group will either adopt or reject a given innovation. Rogers' Model of Innovation Diffusion consists of three contributing components (illustrated in Figure 2) that require further explication.

- **1. Innovation:** The "innovation" component identifies five attributes of an innovation, which affect how an innovation is perceived by an individual. Typically, a potential adopter evaluates these attributes to determine whether the perceived problem(s) can be solved by an innovation. The evaluation process influences a potential adopter's decisions on the adoption or rejection of an innovation. The five attributes of an innovation are as follows:
 - Relative advantage: The degree to which an innovation is perceived as more advantageous than what it supersedes.
 - Compatibility: The degree to which an innovation is consistent with a potential adopter's existing values, beliefs, and needs.
 - Complexity: The degree to which an innovation is perceived as difficult or easy to use.
 - **Trialability**: The degree to which an innovation can be tested without penalty.
 - **Observability**: The degree to which the positive results of using an innovation are seen by others.

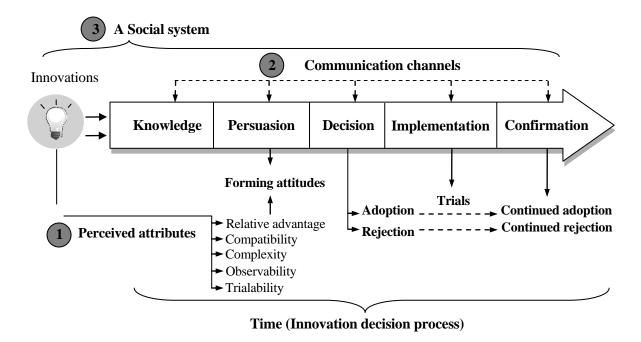


Figure 2: The main components (1- 3) of Rogers' Model of Innovation Diffusion. Adapted from Rogers (1995); Used under fair-use.

- 2. Communication channel: The "communication" component corresponds to the two prevalent means of transmitting information about an innovation to individuals who do not yet have knowledge of, or experience with, the innovation. Those two channels are mass media and interpersonal. Rogers (1995) noted that mass media channels are a more efficient means of reaching a larger audience; while interpersonal channels are more effective in persuading an individual to accept an innovation. The primary difference between the two is how information is transmitted.
 - Mass media channel: Transmits information about an innovation (particularly when first developed) through a mass medium such as posters, radio, television, Internet, newspapers, and so on. Mass media is not considered effective for certain innovations, such as agricultural innovations, where interpersonal channels are viewed as very important for promulgating an innovation.
 - Interpersonal channel: Transmits knowledge of an innovation by sharing information between individuals (e.g., via face-to-face information exchange) who have a similar socioeconomic status, education or cultural background.
- **3.** A social system: The "social system" component features five elements that affect the way an innovation is diffused into a social system.
 - Social structure: Describes the unit arrangements within a social system that regulate the ways people interact to facilitate or limit mutual communications. Social structure, therefore, can also either facilitate or impede the diffusion of innovation. For instance, in a formal (hierarchical) social structure, individuals in positions of greater power have the authority to issue orders to those in lower positions to adopt a particular technology. Conversely, a person of lower authority would be less likely to affect the diffusion of innovation to those with greater power. In an informal social structure, however, individuals communicate with others with whom they are similar.
 - Social norm: Describes the established behavioral patterns among individuals in a social system. An organization with a conservative social norm may resist the introduction of new ideas, whereas one with a more progressive norm may welcome and make use of innovations to resolve problems.
 - Opinion leadership: Describes the degree to which an individual is able to
 influence another individual's attitudes or overt behavior. Opinion leaders are at the
 center of interpersonal communication network and tend to be held in high esteem

- by those that accept their opinions. Another type of an opinion leader is a change agent who represents a change agency external to the system.
- **Types of innovation decisions:** Describes the types of decisions that are made by an individual, a system, or via consensus among the members of a system, to adopt or reject an innovation.
- Consequences of innovation: Describes the changes that can occur within an
 organization due to the adoption or rejection of an innovation. The consequences of
 adopting an innovation may be desirable, direct, and anticipated; conversely, they
 could be undesirable, indirect and unexpected. The consequences of innovation
 provide messages during the confirmation stage in the innovation-decision process,
 which in turn affect the adoption of an innovation.

In addition, Rogers (1995) also indicated that the following three variables could affect the length of time for an individual to adopt an innovation:

- 1) Innovativeness: Corresponds to how soon an individual will adopt an innovation in comparison to other members of an organization. There are five adopter categories associated with this construct: innovators, early adopters, early majority, late majority, and laggards.
- **2) Rate of adoption:** Corresponds to an innovation's rate of adoption within an organization. This rate can be determined by the number of members of an organization who adopt an innovation in a given time period.
- 3) Innovation decision process: Corresponds to the five stages (knowledge, persuasion, decision, implementation, and confirmation) an individual undergoes to adopt an innovation. The process begins with knowledge of the existence of the innovation. This is followed by the persuasion stage, during which potential adopters gather information and determine the use of the innovation based on its perceived attributes. Typically, early adopters (representing people with the highest degree of opinion leadership compared to the other adopter categories) provide advice and information about the innovation to the other members in an organization. If the decision favors adoption, the implementation stage follows. This phase is characterized by actual behavioral change. In other words, once the mental exercise of thinking and deciding has been accomplished, the acceptance of an innovation is actually put into practice. At this stage, the innovation may (a)

become incorporated into the culture of an organization in its original form, (b) be changed or modified during the diffusion process as it moves from adopter to adopter, or (c) be rejected by individuals. During the final stage of the innovation decision process—the confirmation stage—individuals seek supportive messages for the innovation decision they made, and may reverse the decision if they are exposed to conflicting messages about the innovation.

2.3. Participatory Design in Information System Design

PD is an approach in which intended users actively take part in product design throughout the system development process (Kensing & Munk-Madsen, 1993). The approach, initiated in the Scandinavian workplace democracy movement, focuses on collaborating with users rather than designing a system or innovation "for them" (Muller & Kuhn, 1993). This approach departs from the traditional systems-engineering process in that it attempts to thoroughly understand the relationship between human activity and system performance, instead of ignoring or only minimally considering how an innovation or system is impacted by human behavior (Schuler & Namioka, 1993).

Carlsson, Walden, and Bouwman (2006) argued that it is not enough to merely look at user characteristics to understand the meaning of technology in designing an interface. Rather, it is more important to gain insights into the way people learn about technologies and understand how to master and use them. As a domestication research approach, PD helps systems developers understand what users do with systems and how they might do better with different or improved systems. PD provides a way to check the relevance of specification-to-fit user needs and makes eventual acceptance of a system more likely. As noted by Bredies, Chow, and Joost, (2010), PD addresses anticipation of use and how an innovation fits into people's lives.

PD has been used to identify users' requirements and design ideas for domestic ubiquitous computing applications (Schmidt & Terrenghi, 2007). It also has been successfully applied in the design of information systems in different contexts. For instance, Ellis and Kurniawan (2000) reported their PD efforts in renovating an existing World Wide Web (WWW) site for elderly people, especially with respect to display formats. In a later study, Druin et al. (2001) recruited seven children to design a digital library. This PD group came up with a design that provided children a more user-friendly and age-appropriate system for online library queries and searches. Demirbilek and Demirkan (2004) reported a PD model for the design and development of safe and appropriate products with the goal of promoting and

maintaining independent living among the elderly. The validity of the conceptual phase of their PD model was verified by a case study.

In PD, user involvement may take various forms. For example, the "Future Workshop" approach, which was originally developed to assist concerned citizens in presenting their ideas to public policy decision making bodies (Jungk & Mullert, 1987), has been shown to be useful as a way to involve users in systems design (Bodker & Gronback, 1991; Kensing & Madsen, 1991). The Future Workshop concept was reported to enhance the sense of shared responsibility between developers and users because they attempt to better understand design problems, generate a viable approach to design changes and improvements, and create a clearer vision on how to accomplish those future changes/innovations (Ellis & Kurniawan, 2000). The Future Workshop approach consists of three main phases: *critique, fantasy*, and *implementation*.

- The critique workshop consists of a brainstorming session about critical issues/problems between human activity and system performance. Brainstorming is followed by discussion. Participants are encouraged to focus only on problem issues rather than look for solutions to problems.
- The fantasy workshop encourages participants to express their ideas for solutions or
 for improved system design without limitation or constraint. Generally, participants
 begin the fantasy workshop by discussing selected topics identified in the critique
 workshop.
- The implementation workshop continues the process by checking and evaluating the practicality of the ideas put forth during the fantasy workshop. At this point participants are generally aware of all the possibilities, obstacles, and limitations of the various ideas.

The concept of the future workshop continues to evolve, and some differ markedly in both intent and execution. Some of the techniques utilized to facilitate the workshops (Dix, Finlay, Abowd, & Beale, 2003) and help convey information between users and designers include the following two strategies:

- **Brainstorming:** Brainstorming is a group activity designed to creatively generate a large number of ideas for solving a problem. All ideas are recorded without judgment.
- Pencil and paper exercises: Pencil and paper exercises allow designs to be talked through and evaluated. Users can "walk through" typical tasks using paper mock-ups,

which are designed to identify discrepancies between user requirements and a proposed design.

2.4. OHS Problems in the Construction Industry

The construction industry is a hazardous business. According to the Bureau of Labor Statistics (2009b), the construction industry is fifth among all private industries in the incident rate and number of non-fatal occupational injuries. Construction leads all other private industries in the number of fatal injuries and represents about 21 percent of all work-related fatalities (U.S. Bureau of Labor Statistics, 2009a). In addition, during a 15-year period from 1980 through 1995, at least 17,000 construction workers perished from injuries incurred on the job. Construction lost more workers to injury-related deaths than any other major industrial sector during this time period, and continues to rank as one of the highest industries for lost-time injuries (Kisner & Fosbroke, 1994).

Small construction firms represent most of the establishments (about 91 percent in 2008) in this industry (U.S. Census Bureau, 2008). However, the accident rate among smaller firms is disproportionately higher than larger firms. Smaller firms also have limited access to safety resources (e.g., safety training and on-the-job safety programs) on jobsites in comparison to large construction companies (Holmes, Lingard, Yesilyurt, & Munk, 1999; Kines, 2003). They often choose not to have—or cannot afford—health and safety monitoring programs (e.g., safety and health audits and evaluations of workers' hazard exposure level). Therefore, the employees of subcontractors may find themselves in the difficult position of having to work under less safe circumstances in order to continue to receive a paycheck. Most of them are regularly under-employed, do not join labor unions, and are reported to experience increased levels of exposure to hazards without the benefit of relevant OHS information (Methner, McKernan, & Dennison, 2000). Additionally, subcontractors are rarely visited by safety inspectors (Eakin & Weir, 1995), who are challenged to enforce the OHS standards of the many companies doing construction work in this country.

2.5. Subcontracting and Worksite Safety

2.5.1. The Nature and Extent of Subcontracting

In the construction industry, large companies, often headed by a general contractor, typically make their money from large and/or long-term contracts capable of generating significant profits over a longer period. However, large construction companies are also

subject to tighter regulations with respect to deadlines, OHS requirements, wages, and overall working conditions.

Large companies frequently employ smaller firms, which they do via the use of subcontracts, to perform a particular task(s) on a project (McVittie, Banikin, & Brocklebank, 1997). This is done when specialized work is needed, as a means of reducing project costs, and/or in order to meet a mandated completion deadline (Steiger & Form, 1991). Typically, a general contractor performs basic operations and then will subcontract the remainder of a project to various specialty subcontractors (Stanworth & Stanworth, 1995). Hence, specialty subcontractors are often located at the lower end of the inter-organizational "food chain" in a construction.

Subcontracting operates on a payment-by-result basis (Mayhew & Quinlan, 1997). In other words, payment to a subcontractor usually depends on task completion rather than on the amount of time spent on a project. Consequently, this type of contract encourages quicker completion times. Mayhew and Quinlan added that output-based contracts are typically prevalent in the residential building sector, and in times of periodic market downturns it is the subcontractor and his employees who are most negatively impacted. (Note: For simplicity, this study reflects the fact that most general contractors and subcontractors in the construction industry are male and thus will use the "he/him" designation herein.) Specifically, Mayhew and Quinlan noted that in order to stay afloat during building downturns, subcontractors must offset lower returns by completing more jobs in less time and by competing for more contracts. As a result, subcontractors (and those employed by them) are at risk for working harder and longer in order to meet or beat construction deadlines. Contracts that are tied to completion dates are also associated with an increased tendency to overlook safety regulations. Therefore, subcontracting is linked to more hazardous work practices and OHS-related problems (Mayhew, Quinlan, & Ferris, 1997).

2.5.2. OHS Problem Shift in Subcontracting

OSHA requires an employer to be responsible for providing workers with a place of employment that is free from hazards (U.S. Bureau of Labor Statistics, 1999b). However, that general mandate becomes somewhat murky in the construction environment, which is characterized by the frequent use of subcontractors (Arditi & Chotibhongs, 2005). Although a general contractor is responsible for overseeing the OHS needs of his own employees, he may or may not be responsible for the health and safety of the subcontractor and that person's

employees. Nor are federal guidelines clear on that topic. OSHA's "Multi-employer Worksite Policy" (U.S. Department of Labor, 1999a) states the following:

<u>Multi-employer Worksites.</u> On multi-employer worksites (in all industry sectors), more than one employer may be citable for a hazardous condition that violates an OSHA standard. A two-step process must be followed in determining whether more than one employer is to be cited. (Section X.A.)

Step One of that process involves determining whether the employer is a "creating, exposing, correcting, or controlling employer." Once all the parties have agreed on the role of the employer, Step Two involves determining "if the employer's actions were sufficient to meet the obligations" of a safe work environment. Thus, there is no hard-and-fast rule about accountability on a multi-employer construction jobsite, and one could anticipate the reluctance of a contractor or subcontractor to willingly assume the blame for an accident—especially if it were to involve a fatality with the resulting possibility of a lawsuit.

A general contractor who uses a subcontractor has the capability of outsourcing the financial liability and OHS risks to the smaller firm through a variety of contractual arrangements (Uher, 1991). Uher noted that most in-house subcontract documents (mostly prepared by the larger contracting entity) contain terms and conditions unfavorable to subcontractors, and that many non-standard subcontract documents do not treat both the contractual parties as being equal. Three common approaches are taken by general contractors to transfer occupational risks to subcontractors (Arditi & Chotibhongs, 2005):

- 1. **Broad Form Indemnity:** This approach relieves a general contractor from covering losses related to a subcontractor's performance of work, regardless of the cause or type of risk. This approach shifts most of the risk to a subcontractor.
- 2. Additional Insured Endorsement: If a subcontractor agrees to an additional insured endorsement, other parties (owners or general contractors) will be named as insured under the subcontractor's general commercial liability policy. This waiver may create problems for the subcontractor because it usually impacts his workers compensation insurance, resulting in higher premiums.
- 3. Waiver of Subrogation: This makes the subcontractor responsible for any losses or injuries on the jobsite. A general contractor may ask a subcontractor to sign this waiver, which prohibits the subcontractor's insurance carrier from making any claims to recover funds from general contractors that carriers paid out to cover a loss.

Adding to the complexity of maintaining a safe work environment is the fact that not all general contractors or subcontracts are sufficiently trained and/or competent to manage the health and safety of their employees. Therefore, it turns out that contractors often leave the responsibility of safety to individual smaller subcontractors and do not take an active part to ensure that jobsites are safe (Wilson & Koehn, 2000). This adds to the burden of the smaller subcontractor, resulting in the poorer OHS performance of these smaller entities (Lingard & Holmes, 2001). The domino effect of reduced safety standards leads to more fatigue, stress, and burn-out among employees—not to mention accidents and delay, or even failure, to seek treatment for work-related injuries (Mayhew, Quinlan, & Ferris, 1997).

National survey data on occupational injuries and illnesses (U.S. Bureau of Labor Statistics, 2009c) show that specialty trades contractors account for the majority of injury and illness cases (64.7 percent). To sum up, the problem faced by subcontractors is that they may be required to implement a safety program that satisfies the specific requirements of general contractors, as well as the more comprehensive standards mandated by OSHA. However, as already discussed, high worker turnover, the expense incurred in implementing a safety program, and the pressure to complete projects in advance of deadlines can negatively influence a subcontractor's ability and willingness to implement proper safety measures. Thus, the need for research related to enhancing safety awareness in the building sector becomes clear.

2.6. The Roofing Industry and Safety Measures to Prevent Falls

2.6.1. Introduction

Roofing work includes roof construction, removal, repair, and installation of weatherproofing roofing materials, such as shingles, tile and tar paper (U.S. Department of Labor, 1999b). This industry often employs workers who have skills regularly used in plumbing, carpentry, electrical and other fields (National Roofing Contractors Association, 2008b). According to Hsiao and Simeonov (2001), the complexity of the work varies by the construction method, roof style, roofing materials used, and the geometrical configuration of the design (i.e., slope/pitch). Moreover, the very nature of the work requires a roofer to work at elevated heights and handle heavy and bulky materials, such as sheets of plywood, rolls of felt, bundles of singles, and other tools of the trade. The specific tasks associated with residential roofing work include cutting, aligning and attaching plywood sheets, asphalt felt, shingles, flashing, and accessories to the roof structure. The common physical activities of

roofing work include walking, reaching, stooping, crouching, and kneeling on sloped surfaces, on narrow planks, or along the edges of roofs.

2.6.2. Tasks and Activities Leading to Falls

Balance control on a roof is essential for someone in this profession. Not only must a roofer do his job on an elevated and frequently sloped surface, but he must also manually work with heavy, bulky materials, as well as operate equipment. Therefore, the primary cause of injury in the roofing industry is falls. Researchers have examined the tasks and activities leading to falls from roofs. For example, Cloe (1979) reported that 89 percent of falls from roofs occurred while workers were performing their normal job activities, such as installing roofing material, walking from one work surface to another, mobbing materials or equipment, working at the edge of the roof surface or an opening, and backing off the edge. Parsons, Pizatella, and Collins (1986) similarly reported that falls from roofs occurred while workers were walking forwards or backwards, standing, kneeling, climbing, and handling materials. In addition, Hsiao and Simeonov (2001) also investigated the causes of falls in this industry, noting that the most commonly-cited reasons were slips, trips, and loss of balance. Cattledge, Schneiderman, Stanevich, Hendricks, and Greenwood (1996) observed that the leading causes for falls among roofers included the presence of a slippery substance on the surface, a slip or trip, a loss of balance, unsafe equipment, and a ladder slipping/skidding.

2.6.3. Current Measures to Prevent Falls from Roofs

1. OSHA Regulations

(a) Standard 29 CFR, Part 1926.500 ~503 (Subpart M-Fall Protection)

Fall protection regulations for the construction industry were promulgated by OSHA in 1994 (U.S. Bureau of Labor Statistics, 1994a). Residential construction is defined as construction where the work environment, materials, methods and procedures are essentially the same as those used in building a typical single-family home or townhouse. As such, typical materials would include wood (e.g., wood framing, wooden floor joists and roof structures), and involve common framing techniques typified in residential construction.

The regulations under 29 CFR 1926.501 specifies the duties for employers to provide fall protection systems. For example, residential construction employers should provide workers who are exposed to fall hazards of over 6 feet (1.8 m) with adequate fall protection, which involves the installation of either fall-prevention systems (e.g., guardrail systems, safety net system), or personal fall-arrest systems. The regulations under 29 CFR 1926.502 describe

fall protection systems criteria and practices. The regulations under 29 CFR 1926.503 require the employer to provide a training program for each employee who might be exposed to fall hazards. Also, the training program should enable each employee to recognize the hazards of falling and should train each employee in procedures to minimize these hazards.

A training program is required to impart the following information:

- The nature of fall hazards in the work area;
- The correct procedures for erecting, maintaining, disassembling, and inspecting the fall protection systems to be used;
- The use and operation of guardrail systems, personal fall arrest systems, safety net systems, warning line systems, safety monitoring systems, controlled access zones, and other protection to be used;
- The role of each employee in the safety monitoring system of choice;
- The limitations of mechanical equipment used for work on low-sloped roofs;
- The correct procedures for the handling and storage of equipment and materials and the erection of overhead protection.

OSHA also requires the employer to prepare a written certification record. When an employer has reason to believe that any affected employee who has already been trained does not demonstrate an adequate comprehension or skill level, the employer is required to retrain that employee.

(b) OSHA Instruction STD 3.1: Interim Fall Protection Compliance Guidelines for Residential Construction

OSHA Instruction STD 3.1 (U.S. Bureau of Labor Statistics, 1999a) modifies fall-protection requirements for employers engaged in certain residential construction activities—particularly roofing work—to enable them to use alternative procedures if they can demonstrate that conventional protective measure are infeasible, or create an even greater hazards if they are used. In other words, employers have the option of developing and implementing a fall protection plan in lieu of installing conventional fall protection measures only when they can demonstrate the infeasibility or greater hazard created by those established measures.

2. OSHA Free Safety Training Program

OSHA awarded funding to the National Roofing Contractors Association (NRCA) to create and administer roofing safety programs (National Roofing Contractors Association,

2008a). For example, OSHA's 10-hour free safety-training program, which is offered by NRCA every year, is designed specifically to help workers identify and avoid hazards encountered on the job. The class includes video segments of job-site scenarios that show typical hazards and their remedies.

3. NIOSH Recommended Fall Protection Program

NIOSH suggested that building contractors whose jobs involve fall hazards should include the following elements in their fall protection programs (National Institute for Occupational Safety and Health, 2000):

- Addressing all aspects of safety and hazards in the planning phase of projects.
- Identifying all fall hazards at the worksite.
- Training employees in the recognition and avoidance of unsafe conditions and the OSHA regulations applicable to their work environment to control or eliminate hazards. OSHA recommends that fall-protection training include classroom instruction supplemented by hands-on training with the equipment. Training should commence at the time of hire for new employees exposed to fall hazards, and continue periodically thereafter. Involve workers, when feasible, to help identify which tasks create fall hazards, and what methods could be used to eliminate these hazards. Employee participation and acceptance is crucial to implementing an effective fall protection program.
- Performing a job hazard analysis for each task to be performed.
- Providing appropriate fall protection equipment, training workers on the proper use of fall protection equipment and enforcing its use, and daily inspection of equipment.
- Conducting scheduled and unscheduled safety inspections of the worksite.
- Addressing environmental conditions, multi-language differences, alternative methods/equipment to perform assigned tasks, and establishment of medical and rescue programs
- Encouraging workers to actively participate in workplace safety

2.7. Summary

This chapter began with a discussion of the main three research streams of technology adoption: diffusion research, adoption research, and domestication research. Diffusion research studies the aggregate diffusion and adoption of a technology in a group, community, or society.

Adoption research focuses on the attitudinal explanations of intentions in the use of technologies, e.g., how users decide to adopt a particular technology. Domestication research describes how technologies are incorporated into the daily life of users by means of a process of domestication. Basically, diffusion research and adoption research are more concerned with the process of technology diffusion and adoption among individuals, as well as an individual's decision-making process associated with the adoption of an innovation. Domestication research is more concerned with the mutual adaptation of users and innovations in the user environment. To summarize, the technology adoption issues tackled by the three main streams have differing focuses with respect to innovation diffusion and adoption. To lay the groundwork for the development of an innovation analytic and design framework, Rogers' Theory of Innovation Diffusion and Adoption (a representative theory in diffusion research) was also discussed in this chapter—with particular emphasis on the theoretical components for uncovering technology challenges and opportunities (Rogers, 1995). This chapter also illustrates the power of PD methodologies and procedures, as well as how PD has been used in various studies to facilitate traditional systems-engineering processes in designing new interfaces and systems that are more likely to be incorporated into the daily lives of users.

Additionally, this chapter reviewed the various OHS-related challenges in the residential small roofing industry to get a better idea of its worker population and associated research challenges. First, with regard to the shift of OHS problems in subcontracting, production-driven contracts force smaller subcontractors to work harder and longer to beat construction deadlines, which oftentimes results in OHS negligence. The literature also revealed that construction contracts, mostly prepared by general contractors, typically contain terms and conditions unfavorable to subcontractors. These many factors shift the responsibility for safety management (i.e., onsite safety monitoring, safety training, and workers compensation) to smaller subcontractors who are generally ill-equipped with safety resources or unable to manage OHS. Second, with regard to the measures to prevent fall injuries, OSHA consolidated fall protection regulations in 1994 and updated the regulations for residential construction (known as OSHA Instruction STD 3.1) in 1999 to address the disproportionately high level of OHS risk for workers working on heights. In recognition of the importance of enhancing roofers' safety awareness, OSHA also started to provide free safety-training programs to roofing companies every year across the nation. Having the same recognition for improving fall hazard awareness, NIOSH in its published alert listed recommendations for designing fall protection programs. Using the insights revealed through a detailed review of the literature, Chapter 3 describes how the innovation analytic and design framework was

constructed using Rogers' Theory of Innovation Diffusion, Theory of Domestication Research, and PD. Chapter 4, 5, and 6 describe how the framework was applied in designing a more likely adopted fall-protection training intervention. Chapter 7 describes the process by which the intended training intervention and framework were evaluated through expected adoption outcomes and adoption propensity. Chapter 8 summarizes this research and addresses this study's contributions, implications, and limitations.

3. METHOD

The purposes of this research were to (1) construct an analytic and design framework to guide the development of an innovation that has a higher chance of being adopted by users and (2 implement the framework in designing a more likely adopted fall-protection intervention for residential roofing subcontractors to reduce fall accidents. The following addresses the development of the framework:

3.1. Innovation Analytic and Design Framework

The proposed innovation analytic and design framework is built upon the traditional systems-engineering process (Chapanis, 1996): Requirement Analysis, Prototype Development, and Summative Evaluation. This framework was used to address the first research question: *How do designers/engineers design an innovation that has a better chance of being adopted by users?*

Table 2: The innovation analytic and design framework and its theoretical components

Innovation Analytic and Design Framework							
Traditional Systems Requirement Prototype Engineering Process Analysis Development		Prototype Development	Formative/Summative Comparative Evaluation				
Theoretical Component	Rogers' Model of Innovation Diffusion	Innovation Domestication Theory, PD	Adoption propensity, Performance of the contributing factors of adoption, Expected outcome of adoption				

The theoretical components are shown in Table 2. As illustrated in Table 2, Rogers' theoretical components of Innovation Diffusion and Adoption (*perceived attributes of an innovation, communication channel, and social system*) were used for developing the Requirement Analysis element in this study. This theory not only guided the investigation of innovation-decision process at the user level, but also helped to identify the influence of social variables at the systems level (Rogers, 1995).

It was anticipated that utilizing Rogers' Model of Innovation Diffusion in Requirement Analysis would result in richer insights compared to using a method with the adoption research approach (e.g., TAM) because (1) *Perceived attributes of an innovation* (*Relative Advantage, Compatibility, Complexity, Trialability, and Observability*) essentially address similar concepts to two central variables covered in most adoption research—

perceived usefulness and perceived ease of use of a technology (Lai, Chau, & Cui, 2010); and (2) variables related to communication channel and social system have been favored by adoption researchers. To better explain users' adoption behaviors, they have been trying to expand their models by studying contextual or environment factors (e.g., organizational facilitators and social influences) (Schillewaert, Ahearne, Frambach, & Moenaert, 2005). However, their proposed models do not go beyond the scope of Rogers' Model.

Rogers' Model of Innovation Diffusion is, however, limited by the fact that it does not adequately explain how people interact with and use an introduced technology—nor how they become accustomed to it after deciding to adopt it (Peansupap & Walker, 2005). To address this limitation (Schuurman, Courtois, & Marez, 2010, in press), a domestication research method was added to the analytic and design framework used in this research because (1) domestication research typically examines what technologies mean to people, how people experience technologies, and the roles technologies can come to play in people's lives; and (2) an innovation will not be continuously adopted until it finds a place in users' lives and in their social group (Schmidt & Terrenghi, 2007). In fact, domestication research has been shown for providing insufficient insights to encourage the diffusion of an innovation; such limitation, conversely, could be overcome by Rogers' model (Boczkowski, 2004).

As one of the most powerful methods in domestication research, Participatory Design (Schuler & Namioka, 1993) was added to the framework because it aids the researcher in determining (1) how an individual will adapt, perceive, and react to a technological solution more directly than other user centered designed methods (Bredies, Chow, and Joost, 2010), and (2) how to tailor the design to fit an individual's needs, thus enabling continuous adoption. In fact, PD has also been demonstrated to enhance traditional systems-engineering processes (Greenbaum & Kyng, 1991; Schuler & Namioka, 1993), to capture usability issues, and to reinforce the importance of being more responsive to users' cultural and practical needs. For the framework, PD was added to Prototype Development, which provided a viable method for (1) including end users in the technology developmental process, (2) improving knowledge acquisition for better design, and (3) effectively bridging the intent of the developer with the needs of the user (Grenbaek, Kyng, & Mogensen, 1993; Kensing &

Munk-Madsen, 1993).

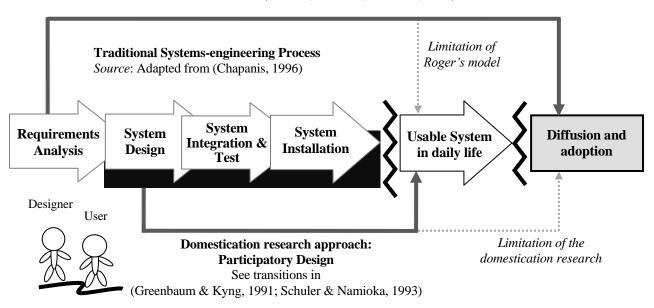
The proposed innovation analytic and design framework is based on a cyclic and iterative process of prototyping, testing, analyzing, and refining an intended innovation. Based on the results of testing the most recent iteration of a particular innovation, changes and refinements can then be made. In the innovation analytic and design framework (Table 2), the Formative/Summative Comparative Evaluation element involved a comparative study that compared the developed innovation against a standard product with regard to (1) adoption propensity, (2) performance of the contributing factors on adoption, and (3) expected outcome of adoption. Results of this comparative study were utilized to shed light on the effectiveness of the developed innovation and to suggest future design modifications.

- (1) Adoption propensity: Studies showed that self-reported behavioral intention to adopt an innovation is positively correlated with the actual adoption of said innovation (F.D. Davis, Bagozzi, & Warshaw, 1989; Liao & Lu, 2008; Szajna, 1996). Thus, understanding intention to adoption helps to infer an individual's actual adoption likelihood (Hsu, Lu, & Hsu, 2007).
- (2) Performance of the contributing factors on adoption: In Requirement Analysis, researchers/designers identify not only users' needs and requirements, but also significant motivators for adopting an intended innovation. In Formative/Summative Evaluation, the performance of the identified contributing factors on the intended innovation and the innovation's counterpart product are compared to infer the likelihood of future adoption of the developed innovation.
- (3) Expected outcome of adoption: Outcome measurement of adoption has been shown to be a valid indicator for actual adoption (Wilson, Ramamurthy, & Nystrom, 1999). Obtaining target users' feedback on expected outcome of adoption could be treated as an intermediate measurement to explain future adoption (Miller, Radcliffe, & Isokangas, 2009).

A conceptual diagram (Figure 3) was developed to illustrate the overall approach of the innovation analytic and design framework. Rogers' Model of Innovation Diffusion is used to disclose factors affecting the diffusion and adoption of an intended innovation. It is also used to identify the design features that make an intended innovation more likely to be adopted. For example, studying *perceived innovation attributes* helps to yield design criteria for designing an innovation that has a better chance of being accepted by users. Studying the *communication channel* and *social system* theoretical components enables researchers/designers to conceive an innovation that has appropriate features for facilitating innovation dissemination.

Rogers' Model of Innovation Diffusion & Adoption

- See transitions in (Iacovou, Benbasat, & Dexter, 1995)



(*Note*: The vertical wavy lines in the diagram represent disconnections between stages)

Figure 3: A conceptual diagram of the approach of the framework

In Figure 3, the limitation of Rogers' model is overcome by PD, which helps to bridge the gap between a user's actual task use and a developer's theoretical model of that task. Concurrently, the limitation of PD is overcome by Rogers' model, which provides a theoretical framework to examine innovation adoption barriers from a global perspective.

3.2. Research Approach

In this research, the innovation analytic and design framework was used to guide the training intervention design. A two-stage mixed methods design (B. Johnson & Christensen, 2004) was employed in Requirement Analysis to obtain quantitative and qualitative data to address the research questions and hypotheses. A mixed methods research design was preferred for the following reasons:

- There is a need for both quantitative and qualitative approaches in construction research (Lin & Mills, 2001), since one approach alone would have been inadequate for obtaining a complete picture of the practices of fall-protection training and safety technology adoption in order to inform the design of a training intervention.
- Safety systems used in the small construction industry tend to be dynamic.
 Quantitative data alone could not capture in-depth knowledge from the perspective

- of users; whereas qualitative data could not generalize or predict trends with respect to use and acceptance of safety systems.
- Quantitative data can be enhanced by qualitative data and vice-versa (Creswell & Clark, 2007). In this study, the use of qualitative information helped to further elucidate any poor fall-protection training practices and technology adoption challenges, while the quantitative data helped to explain the significance of the technology adoption challenges.

Rogers' model (Rogers, 1995) was mainly used in Requirement Analysis to help identify users' fall-protection training needs and the motivators and inhibitors for safety technology adoption. To complement the research insights gleaned from the use of Rogers' model, all the data collected in Requirement Analysis were utilized in a PD workshop to brainstorm a potential fall-protection training intervention. This research believed that, through the use of PD, the developed training intervention would be more appropriate for roofers' actual work environment. In addition, in the Formative/Summative Comparative Evaluation, participants were asked to explain their intention to adopt the developed training intervention. This also helped this research capture how end users might use the intervention in real work settings. In short, through the use of both diffusion and domestication research approaches, it was expected that this research would generate a more likely adopted fall-protection training intervention.

4. REQUIREMENT ANALYSIS: QUESTIONNAIRE

4.1. Introduction

The construction industry in general has been slow to adopt new technologies to promote health and safety. As indicated in Chapter 1, any number of factors (e.g., uncertainty, conservative culture, and highly-entrenched system of bonuses) could come into play to inhibit workers' adoption of technologies. Various studies have targeted the factors that influence the diffusion and adoption of construction technologies. For example, Ahuja, Yang, and Shankar (2009) conducted a survey that examined the extent and the process of the adoption of ICT, as well as the perceived factors affecting the adoption of ICT. They identified two major ICT adoption barriers: (1) the inconsistency of ICT capabilities among construction subcontractors and management, and (2) the cost of updating the ICT infrastructure.

Much of the focus of the construction literature has been on issues pertaining to ICT adoption, such as e-commerce (Kong et al., 2004) and information-sharing system (Nikas, Poulymenakou, & Kriaris, 2007). Few studies, however, have addressed the diffusion and adoption of safety technologies (e.g., safety training programs and equipment), particularly in the small roofing industry. In fact, researchers have argued that ICT adoption is different from other diffusion phenomena (Brancheau & Wetherbe, 1990). Specifically, Chau and Tam (1997) argued that innovation studies must be investigated within appropriate contexts and with variables tailored to the specificity of the innovation. Because safety technologies have been attracting increased attention in recent years, it is important that research examines the phenomena of safety-technology adoption in the small roofing construction industry. Furthermore, there is a lack of research that employs well-defined, robust constructs to globally examine the factors that affect safety technology diffusion and adoption in the small roofing industry.

Typically, most construction studies have used the following two approaches to study technology adoption:

1) The use of a portion of the Innovation Diffusion and Adoption Theory Model Kendall et al. (2001) utilized a portion of Rogers' model of Innovation Diffusion (Rogers, 1995) (perceived attributes of an innovation) as a framework to identify the factors affecting workers' willingness to adopt e-commerce. They formulated a survey and distributed it to 350 workers in small construction firms in Singapore.

Their results showed that out of the five attributes assumed to affect the adoption of e-commerce, only *relative advantage*, *compatibility*, and *trialability* appeared to be significant. In addition, Kramer et al. (2009) studied the role of opinion leader—an important construct in Rogers' model of Innovation Diffusion—in the dissemination process for a novel hydraulic ladder lift in the construction industry. Kramer et al. conducted interviews with 27 management representatives on their innovation decision processes. Results showed that four elements impacted this cohort's construction innovation adoption decisions: (1) the relevance and usefulness of the innovation, (2) the characteristics of the adopting construction company, (3) the credibility of the opinion leaders as promoters of the innovation, and (4) the barriers and/or facilitators associated with the adoption of a given innovation in the construction sector.

2) The integration of different variables/models of adoption and diffusion of innovations to formulate an analysis framework

Peansupap and Walker (2005) integrated the factors that affect construction ICT adoption according to the concepts of (1) innovation diffusion, (2) change management, and (3) learning and sharing knowledge. They then used these concepts to form a framework for identifying ICT adoption factors. The framework categorized the factors as being either static or dynamic. On the one hand, the theoretical components of Rogers' Theory of Innovation Diffusion and Adoption (Rogers, 1995) were used to address static factors. Dynamic factors, on the other hand, were collected from the literature, which included motivation, training and technical support, supervisor support, open discussion environment, and sharing and learning ICT knowledge with others. From their survey with three large construction firms, Peansupap and Walker found that management, individual, and technology and workplace environment affected adoption and implementation of ICT. In addition, Aranda-Mena, Wakefield, and Lombardo (2006) used Wejnert's framework (Wejnert, 2002) (derived by grouping the variables in Rogers' Theory of Innovation Diffusion and Adoption) to analyze the incorporation of e-business technologies in small building enterprises. Through interviewing 20 small construction firms, they identified that the major adoption barriers to e-business were resistance to change and perceived inefficiencies of ICT.

The problem with the first approach is its lack of explainability for studying technology diffusion and adoption because of the use of limited construct(s). Therefore, it would produce insufficient results for extrapolation to the construction worker population. The problem with the second approach is that it usually ends up with constructs that are similar to those associated with Rogers' Innovation Diffusion and Adoption Theory. Some studies might include more variables in explaining technology diffusion and adoption. However, there appears to be no obvious justifications for why these variables were included. Moreover, the resulting research models are different from each other, and only apply to the specific technology they investigated.

To summarize, Rogers' Theory of Innovation Diffusion and Adoption is the most widely accepted theory in the field of ICT and sociology. As such, it could provide researchers and designers with a ready framework for obtaining a global understanding of the barriers and facilitators of safety technology adoption. For this study, a questionnaire was developed to identify significant facilitators using the main components of the Innovation Diffusion and Adoption Theory.

4.2. Method

4.2.1. Instrument Development Process

To answer the research question: What are the contributing factors to the adoption of safety technologies (i.e., safety training programs and equipment) in the small roofing industry?, the questionnaire contained multiple close-ended items to examine three major constructs in Rogers' model of Innovation Diffusion and Adoption: perceived attributes of an innovation, communication channel, and social system. In addition, to understand how these constructs might influence the adoption of safety technologies in small construction firms, the questionnaire included items to examine the rate of adoption. The questionnaire also included questionnaire items to understand workers' perceived fall-protection training needs. The response categories for the questionnaire items used a Likert scale format with anchors from 1 (strongly disagree) to 5 (strongly agree).

The development of the questionnaire was carried out through pre- (i.e., content validity) and post-data collection assessment of reliability and construct validity, which were noted as requirements for creating a reliable instrument (Straub, Boudreau, & Gefen, 2004). Table 3 illustrates the constructs examined in the questionnaire.

Table 3: List of constructs examined in the questionnaire

	Construct	Sub-construct	# of items
1	Perceived attributes of an innovation	Relative advantage, Compatibility, Complexity, Trialability, and Observability	5
2	Communication channel	Inter-personal channel, and Mass media	6
3	Social system	Type of innovation decision in organization, Opinion leader, Social norm/structure	8
4	Rate of adoption	Rate of adoption	1
5	Perceived fall-protection training needs	OSHA fall-protection training requirements	10

To address the likelihood of non-English speaking participants, a Spanish language version of the questionnaire (Appendix A2) was created by an undergraduate student in Industrial and Systems Engineering with research experience in construction safety and Spanish fluency. Both the English and Spanish language versions were then given to a professional Spanish translator for proofreading. The original English questionnaire and the Spanish questionnaire were then sent to two SMEs (subject matter experts) separately for proofreading. One SME had the same background as the developer of the Spanish questionnaire. Another SME was a specialist in construction health and safety and human factors theory. After reviewing the questionnaire, the two SMEs met with the principal investigator to finalize the Spanish-version questionnaire. Item finalization was based on group consensus.

4.2.2. Item Creation and Selection

With regard to **perceived attributes of an innovation**, its questionnaire items were developed by adapting prior studies (Hsu, Lu, and Hsu, 2007; Moore & Benbasat, 1991) because it is the most commonly-used construct in Rogers' model of Innovation Diffusion and Adoption (Rogers, 1995) for studying innovation diffusion and adoption. *Perceived attributes of an innovation* contains five sub-constructs: *relative advantage*, *compatibility*, *ease of use*, *trialability*, *and observability*.

With regard to **communication channel** and **social system**, their questionnaire items were developed from scratch. This novel approach was needed because few published studies were available that measured users' perceptions on their performance on innovation adoption

using a pre-determined scale. The principal construct under *communication channel* is *diffusion network* (i.e., mass media and inter-personal channels) that normally disseminates the information of safety technologies in the organization. The constructs under *social system* included all possible social forces (i.e., social norms, social structures, opinion leaders, types of innovation decision in organization) that could influence a worker's adoption of a safety technology.

With regard to **rate of adoption**, it too was a stand-alone construct created from scratch, which was treated as a response variable *for perceived attributes of an innovation*, *communication channel, and social system*.

With regard to **perceived fall-protection training needs**, the questionnaire items were derived from OSHA's six fall-protection training requirements (as illustrated in Section 2.6.3). The total number of questionnaire items created to measure the five constructs was 30.

4.2.3. Face and Content Validity

Face validity of the questionnaire was performed at the beginning by four SMEs with expertise in Industrial and Systems Engineering, Education, Construction Health and Safety, and Psychology—each of whom reviewed and commented on the wording of the questionnaire items. Based on the SMEs' comments, improvements were made to better reflect this study's constructs.

Content validity was performed by a quantitative approach to understand the extent to which a questionnaire item measures its given construct (Lawshe, 1975). First, a content validity questionnaire was generated which included questionnaire items on a three-point scale: 1 = not necessary; 2 = useful but not essential; 3 = essential. Second, a total of 11 SMEs was identified on the basis of their broad involvement with the research subject area, including experts in the field of Industrial and Systems Engineering, Psychology, Industrial Management, Education, Design, Construction Health and Safety, and Computer Science. After agreeing to participate in the study, the SMEs were given the instructions, a reference document explaining the constructs, and the content validity questionnaire. For each questionnaire item, the SMEs' responses indicating "Essential" were calculated.

The content validity ratio (CVR) for each item was estimated and evaluated with a significance level of 0.05. Items that were not significant were either removed or modified for re-evaluation based on the SMEs' comments. Items that were not removed or reworded were considered to be effective in measuring their given constructs. All questions items were re-evaluated and modified until their CVR value was significant, which meant that its value

was greater than 0.818—i.e., a questionnaire item was rated 'Essential' by at least 10 SMEs. The summary of the content validity assessment is shown in Table 4.

The process of content validity evaluation kicked out two items. The average CVR value for each main construct ranged between 0.82 and 0.96, which suggested good content validity of the questionnaire. In addition, the Flesch–Kincaid readability test of the questionnaire was performed in Microsoft Word. The results showed that the reading level of the questionnaire was 7, meaning that the questionnaire could be easily understood by a seventh grader. To ensure the questionnaire was understood by every roofing worker, this study also featured an informal pilot test, whereby a roofing manager checked the wording of the questionnaire items.

Table 4: Summary of content validity

Construct	Sub-construct (Questionnaire items)	Total # of Items	Significant Items	CVR or Mean CVR (SD)
Perceived attributes of an innovation	Relative advantage (Q1.1), Compatibility (Q1.2), Complexity (Q1.3), Trialability (Q1.4), and Observability (Q1.5)	5	5	0.89 (0.10)
Communication channel	Inter-personal channel (Q2.1 - 2.5), Mass media (Q2.6)	6	6	0.94 (0.09)
Social system	Type of decision (Q3.1 - 3.3), Opinion leader (Q4.1 - 4.2), Social norm/structure (Q6)	8	6	0.94 (0.09)
Rate of adoption	Rate of adoption (Q5)	1	1	0.82
Perceived fall-protection training needs	OSHA fall-protection training requirements (Q7.1-7.10)	10	10	0.96 (0.08)
	Total	30	28	

4.2.4. Participants and Data Collection

Purposeful sampling (Patton, 1990), a non-probability sampling method used to select information-rich cases for in-depth studies, was employed to recruit participants. The sampling techniques included criterion sampling (picking all cases that meet the specified criteria) and

convenience sampling (selecting participants based on their availability) (Patton). The sampling criteria were as follows:

- Participants were required to be roofers working in a construction firm with less than 20 employees.
- One half of the participants were required to be managerial personnel (including owners, supervisors, and foremen). The other half of the participants was required to be employees.
- Participants had to be 18 years or older and had at least one year work experience in the residential roofing industry.

The contact information of small roofing contractors was obtained through local business yellow pages and the phone book directory, the Center for Innovation in Construction Safety and Health (CICSH) at Virginia Tech, as well as via information on local building permits. Roofing contractors were contacted and screened regarding their qualifications for this research. Appointments were made once roofing contractors agreed to participate in this study.

Depending on participants' preferences, the questionnaire was either administered during the work day (primarily during participants' lunch break) or was mailed. Before administering the questionnaire, however, the researcher provided guidance on how to complete the questionnaire, as well as how to fill out the informed consent forms (Appendix B1 and B2). It should also be noted that a research facilitator whose first language is Spanish was recruited and trained in advance to administer the questionnaire with Hispanic workers. (Note: The term "Hispanic" is used herein to include all individuals of Latino/Hispanic origin.) In summary, a total of 128 participants from 29 small roofing companies in the rural and urban geographic regions in Virginia and North Carolina participated in this study. Of those 128 completed questionnaires, 24 of them were not used due to incomplete responses. Thus, 104 questionnaires were considered to be valid for data analysis.

4.3. Results and Discussion

Table 5 provides a demographic overview of the participants in the study. The majority of the participants were European-American workers (76%). Twenty-three percent were Hispanic workers and 1% were Asian workers. Thirty-seven percent of the participants were managerial personnel; 63% were employees. Most of the participants received at least a junior high school degree, and 20% of the participants had an undergraduate or post-graduate degree. In general, the managerial personnel was more experienced and better educated than the workers.

Table 5: Sample demographics of the questionnaire

Job # Title	#	Ethnicity			Education Level			Work Experience (yr)			
		European American	Hispanic	Asian	Elem.	Junior High	Senior High	≥ College	1-5	6-10	>10
Owner	18	18	0	0	0	0	9	9	1	3	14
Supervisor	11	8	3	0	2	1	4	4	1	5	5
Foreman	10	6	4	0	2	3	5	0	1	3	6
Worker	65	47	17	1	10	24	23	8	32	19	14
Total	104	79	24	1	14	28	41	21	35	30	39

4.3.1. Reliability and Construct Validity

A correlation analysis was performed to assess the reliability of the questionnaire items. Items were removed when the Cronbach coefficient alpha of a construct had a lower than acceptable level of reliability (i.e., 0.7) (Nunnally, 1978). Results of the analysis are as follows:

- (1) The Cronbach coefficient alpha of perceived attributes of an innovation was $r_{alpha} = 0.81$, with an inter-item correlation ranging from an r of 0.30 to 0.63, p < 0.05.
- (2) The Cronbach coefficient alpha of *communication channel* was $r_{alpha} = 0.75$ (after removing 2 questionnaire items), with an inter-item correlation ranging from an r of 0.22 to 0.59, p < 0.05. The removed questionnaire items were:
 - (Q2.2) Who shows you new safety equipment? Option Managers (ex. owner, supervisors or foremen).
 - (Q2.6) Who shows you new safety equipment? Option Mass media (ex. Internet, TV, newspapers, posters, or magazines).
- (3) The Cronbach coefficient alpha of *social system* was $r_{alpha} = 0.79$ (after removing 4 questionnaire items), with an inter-item correlation r of 0.65, p < 0.05. The removed questionnaire items were:
 - (Q3.1) In my company, the adoption of new safety equipment is often decided by the managers (ex. owner, supervisors or foremen).
 - (Q4.1) At least one person among my co-workers can influence other individuals' decisions to adopt new safety equipment.

- (Q4.2) At least one person from outside my company (ex. equipment manufacturers, retailers) can influence the workers' decisions to adopt new safety equipment.
- (Q6) Generally speaking, my company does not like to adopt new safety equipment.
- (4) The Cronbach coefficient alpha of *perceived fall-protection training needs* was $r_{alpha} = 0.96$, with an inter-item correlation ranging from an r of 0.54 to 0.88, p < 0.05.

All the r_{alpha} values were greater than 0.7, including those for the constructs examined by ethnicity (Table 6), showing that the questionnaire was effective in eliciting participants' responses in a consistent (reliable) manner. The final questionnaire was a 22-item instrument, which is presented in Appendix A1 (along with the demographic questions).

Table 6: Cronbach's alphas for the constructs in different ethnic groups

Construct	Cronbach's alpha – European American Participant Group	Cronbach's alpha — Hispanic Participant Group
Perceived Attributes of an Innovation	0.76	0.86
Communication Channel	0.70	0.76
Social Influence	0.75	0.81
Perceived Fall-Protection Training Needs	0.94	0.98

The construct validity of the questionnaire was accessed by Factor Analysis in SAS utilizing principal component analysis with varimax rotation method. The results, which are shown in Table 7, yielded four factors with eigen values greater than 1 (a commonly used cut-off value to determine the number of factors) (Straub, Boudreau, & Gefen, 2004). The four factors accounted for approximately 70% of the variance in the data set. The criterion used to identify which questionnaire item (sub-construct) belonged to which factor was a factor loading score of 0.5, which is above the minimum recommended value (0.4) in information systems research (Straub et al., 2004).

All expected factors emerged fairly clearly. The items for *perceived attributes of an innovation* converged into two factors. The first factor was *perceived compatibility with safety needs*, which was accounted for by "relative advantage and compatibility." The second factor was *perceived ease of use*, which was accounted for by "complexity, trialability, and observability." These two factors addressed an individual's perception on an innovation, which confirmed the existence of construct validity.

Table 7: Construct validity Evaluation: Factor loadings with varimax rotation method

		Rotated Fac	ctor Loading	
Sub-construct (Questionnaire item)	1	2	3	4
Perceived Attributes of an Innovation (Q1.1)				0.80399
Perceived Attributes of an Innovation (Q1.2)				0.67717
Perceived Attributes of an Innovation (Q1.3)			0.69626	
Perceived Attributes of an Innovation (Q1.4)			0.79486	
Perceived Attributes of an Innovation (Q1.5)			0.77450	
Communication channel (Q2.1)		0.62454		
Communication channel (Q2.3)		0.78494		
Communication channel (Q2.4)		0.65166		
Communication channel (Q2.5)		0.77324		
Social system (Q3.2)		0.80381		
Social system (Q3.3)		0.71257		
Perceived training need (Q7.1)	0.73909			
Perceived training need (Q7.2)	0.74167			
Perceived training need (Q7.3)	0.84937			
Perceived training need (Q7.4)	0.75874			
Perceived training need (Q7.5)	0.88857			
Perceived training need (Q7.6)	0.88951			
Perceived training need (Q7.7)	0.86750			
Perceived training need (Q7.8)	0.80364			
Perceived training need (Q7.9)	0.85483			
Perceived training need (Q7.10)	0.85070			
Eigen values	9.019	2.785	1.975	1.051
Percentage of variance explained	42.95	13.26	9.41	5.00
Cumulative percentage	42.95	56.21	65.62	70.62

Note: Factor loadings below 0.50 are not shown.

The items for *social system* loaded with *communication channel* items as one factor. In other words, the two constructs were either viewed by respondents as being identical, or there was a perceived relationship between the two constructs. For example, it would be unlikely that a safety technology would be diffused in a small construction work setting by a communication channel if said channel was not socially empowered or appreciated to distribute that information efficiently or plausibly. In fact, the relationship between *communication channel* and *social system* was positively correlated with r(102) = 0.68, p < 0.001 from a correlation analysis on these questionnaire items. It should be noted that this positive relationship also held when examining the European-American participants' responses, with r(77) = 0.56, p < 0.001, and Hispanic participants' responses, with with r(22) = 0.80, p < 0.001.

The items for *perceived fall-protection training needs* all loaded on their corresponding factor. Findings from the factor analysis showed that all items used to operationalize particular constructs loaded onto the desired factor(s). The results satisfied the criteria of construct validity, including both the discriminant validity (loading of at least 0.5, no cross-loading of items above 0.5) and convergent validity (eigen values of 1, loading of at least 0.5, items that load on posited constructs).

4.3.2. Descriptive Statistics

Frequency analysis was performed on important demographic questions. The results are illustrated in Figure 4.

- About one half of the participants (46%) specialized solely in roofing, whereas the others specialized in multiple fields, including roofing.
- Most of the fall protection training that participants received was done informally (60%). Twelve percent of the participants did not know if their companies provided safety training.
- Most of the participants (60%) preferred informal training.
- A relatively higher number of participants preferred training materials to be
 delivered through hard copies, such as documents created by lecturers, MSDSs
 (material safety data sheets) (e.g., adding information to the sheets for debris
 removal, single-ply roof system adhesives, and elastomeric coating materials), and
 note-cards; whereas some of them preferred the materials to be delivered through
 technologies (e.g., computers and mobile devices). Participants who checked
 'Other' (13%) explained that they preferred in-person safety training.

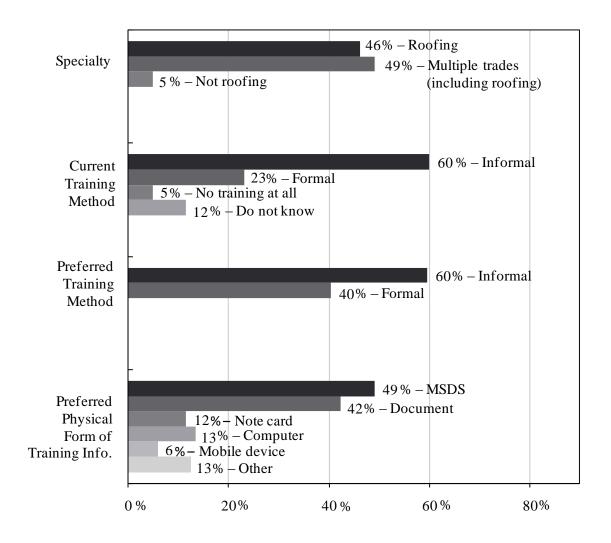


Figure 4: Percentage distribution of participants' responses

Table 8 encapsulates the descriptive statistics of the questionnaire items regarding the adoption of safety technology. In general, the participants agreed that the perceived attributes of safety technologies influenced their willingness to adopt that particular technology (M = 4.13, SD = 0.66). There were no obvious tendencies among the participants to think that their decisions to adopt safety equipment were driven by *communication channel* (M = 3.00, SD = 0.94) or *social system* (M = 2.95, SD = 1.08). The participants stayed neutral about their rate (neither quick nor slow) of adopting new safety equipment (M = 3.09, SD = 1.03).

Figure 5 illustrates the descriptive statistics with respect to which piece of information (from Q7.1 to Q7.10) should be added to company's training program to avoid falls. Results showed that the average ratings for the ten training need items were all above Neutral (3) and close to Agree (4). This suggests that participants wanted to receive more fall-protection training in every aspect required by OSHA, such as knowledge of minimizing and identifying

fall hazards, limitations of mechanical fall-protection systems, and standard procedures for using, maintaining, and handling fall-protection systems.

Table 8: Descriptive statistics: Questionnaire items associated with safety technology adoption

Construct	Sub-construct	Questionnaire item	Mear	n (SD)
	Relative advantage	Q1.1	4.13 (0.93)	
Perceived	Compatibility	Q1.2	4.28 (0.78)	
attributes of an	Complexity	Q1.3	4.26 (0.78)	4.13 (0.66)
innovation	Trialability	Q1.4	3.87 (0.97)	
	Observability	Q1.5	4.11 (0.92)	
	Co-workers	Q2.1	2.97 (1.28)	
Communication	General/Sub contractor	Q2.3	2.95 (1.23)	3.00 (0.94)
Channel	Equipment Mfr./Retailers	Q2.4	3.22 (1.12)	3.00 (0.94)
	Relative advantage Q1.1 4.13 (0.93) Compatibility Q1.2 4.28 (0.78) Complexity Q1.3 4.26 (0.78) Trialability Q1.4 3.87 (0.97) Observability Q1.5 4.11 (0.92) Co-workers Q2.1 2.97 (1.28) General/Sub contractor Q2.3 2.95 (1.23) Equipment Mfr./Retailers Q2.4 3.22 (1.12) Professional Association Q2.5 2.84 (1.32) Type of decision – Individual Q3.2 2.76 (1.14) Type of decision – Consensus Q3.3 3.05 (1.22)			
Cocial avatam	Type of decision – Individual	Q3.2	2.76 (1.14)	2.05 (1.09)
Social system	Type of decision – Consensus	Q3.3	3.05 (1.22)	2.95 (1.08)
Rate of adoption	Rate of adoption	Q5	3.09 (1.03)	

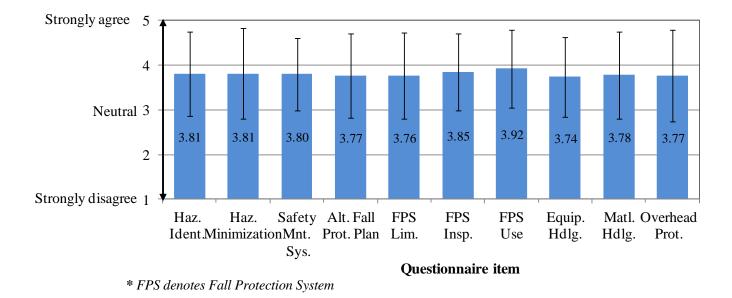


Figure 5: Participants' perceived fall-protection training needs

4.3.3. Hypothesis Testing

Logistic regression, a nonparametric statistical analysis, was conducted in SAS (with the backward elimination method) to test the second research hypothesis: *The theoretical components in the proposed innovation analytic and design framework predict the rate of the adoption of safety technologies*. The reason that this study used logistic regression analysis was

twofold: (1) the error terms (residuals) in the multiple regression analysis (the dependent variable = rate of adoption, the independent variables = perceived attributes of an innovation, communication channel, and social system) had non-constant variance – i.e., non-randomly scattered residuals in Figure 6; (2) the error terms were not normally distributed – the Shapiro-Wilk Normality Test with p=0.04. The backward elimination method was employed because it has been generally used for exploratory analyses (Sierpina, Levine, Astin, & Tan, 2007), where the analysis begins with a full or saturated model and variables are eliminated from the model in an iterative process.

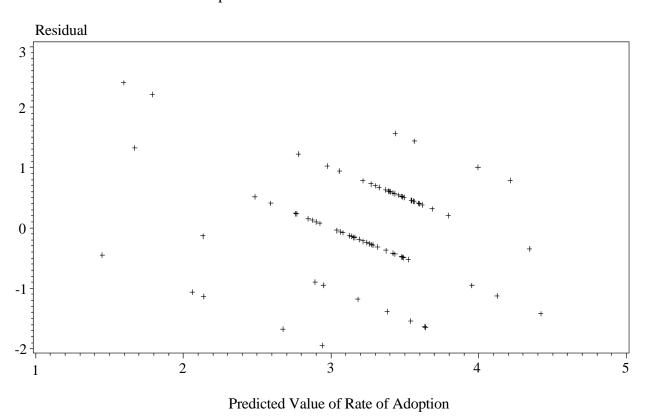


Figure 6: Residual plot illustrating nonconsistent error variance

The following sections describe the dependent and independent variables used for the hypothesis testing:

• The dependent variable was **rate of adoption**. The rating scores for Q5 (*The average worker in my company can adopt new safety equipment more quickly than expected.*) were used for the logistic regression analysis. For easy interpretation of the results, rating scores greater than 3 were coded 1 to denote *quick adoption*, while rating scores equal or less than 3 were coded 0 to denote *slow adoption*. Thus, in the logistic regression model, **rate of adoption** was a binary variable.

• The independent variables were **perceived compatibility with safety needs**, **perceived ease of use**, **and inter-social influences**, which were obtained from factor analysis of the questionnaire items related to safety technology adoption (illustrated in Table 9, where all items converged into the same factors as described previously). It should be noted that this study did not 'directly' use the theoretical components of Rogers' model as independent variables because the noises and the dependencies among the theoretical constructs in the field were generally hard to clearly isolate from the data. If all possible interactions among the constructs were also included in this study's statistical model, the data analysis and resulting interpretation would be difficult. Therefore, in order to have independency among the independent variables (Johnson, 1998), this study employed each participant's factor scores (under the three factors) as the data points for the logistic regression model.

Table 9: Factors used for the logistic regression analysis

Sub-constant (Ougstionneins to)	Rotateo	To do		
Sub-construct (Questionnaire item)	1	2	3	Factor name
Perceived Attributes of an Innovation (Q1.1)			0.835	Perceived
Perceived Attributes of an Innovation (Q1.2)			0.786	to safety needs
Perceived Attributes of an Innovation (Q1.3)		0.744		- D ' 1
Perceived Attributes of an Innovation (Q1.4)		0.783		Perceived ease of use
Perceived Attributes of an Innovation (Q1.5)		0.788		ease of use
Communication channel (Q2.1)	0.701			_
Communication channel (Q2.3)	0.813			_
Communication channel (Q2.4)	0.641			Inter-social
Communication channel (Q2.5)	0.754			influences
Social system (Q3.2)	0.822			_
Social system (Q3.3)	0.691			
Eigen values	3.824	2.548	1.015	
Percentage of variance explained	34.77	23.17	9.23	
Cumulative percentage	34.77	57.94	67.17	

Note: Factor loadings below 0.50 are not shown.

Results of the logistic regression analysis confirmed the second research hypothesis, which showed that *inter-social influence* was statistically significant in predicting *rate of adoption*, with p = 0.002 (Table 10). The odds ratio estimate for *inter-social influences* was 2.20 (with 95% confidence interval from 1.34 to 3.61), suggesting that for a one unit increase in inter-social influence, the odds of quick adoption for a safety technology would increase 1.20 times. The measure c (i.e., ROC) for the model in predicting the response showed that the model had good predictive ability, with a c value equaling 0.714. The classification table also showed that the model had good predictive accuracy, with a probability level equaling 0.38 (where sensitivity=71.8% and specificity=67.7%). For the analysis, the selected probability level was based on nearly equal values of sensitivity and specificity in the classification table. To ensure that the chosen probability level was optimal, a series of model development and testing was performed. As shown in Table 11, a small portion of the data (14 random observations) was used to evaluate every regression model developed from the data set (90 random observations). The results showed balanced performance of the models (with higher and lower numbers of hits), confirming the robustness of the probability level.

Table 10: Logistic Regression: Analysis of maximum likelihood estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	P value
Intercept	1	-0.596	0.221	7.260	0.007
Inter-social influences	1	0.789	0.252	9.777	0.002

^{*} The logistic regression equation is logit (p) = -0.596 + 0.789*Inter-social influences.

Table 11: Probability level verification process

Data Selection Method	# of Observations	# of Hits for the Tested Observations	Prob. Level	
All participants	104		0.38	
1 st random selection	MD: 90	4	0.36	
1 Tandom selection	MT: 14	4	0.30	
2 nd random selection	MD: 90	2	0.38	
2 Tandom selection	MT: 14	2		
3 rd random selection	MD: 90	2	0.40	
3 Tandom selection	MT: 14	2	0.40	
4 th random selection	MD: 90	6	0.26	
4 random selection	MT: 14	6	0.36	
5 th random selection	MD: 90	1	0.36	
5 Tandom selection	MT: 14	4		

^{*} MD denotes model development

^{*} MT denotes model testing

4.4. Conclusions

This study featured the development of a questionnaire to understand the practices of safety technology adoption and fall-protection training. To develop a reliable instrument, the study carried out pre- and post-data collection assessment of validities, including face validity, content validity, reliability and construct validity. Results showed that the content validity ratios of the questionnaire items were high (above 0.8), and that the Cronbach coefficient alphas of the constructs (including those for European American and Hispanic participants) were all above the acceptable level of 0.7. The questionnaire items also converged into three desired factors in factor analysis: *perceived compatibility with safety needs, perceived ease of use, and inter-social influences.* The study demonstrated that the questionnaire was reliable and measured what it was designed to measure.

Results of the study provided quantitative insights toward the design of a fall-protection training intervention, as well as how to facilitate the adoption of workers' adoption of new safety technologies. The descriptive statistics showed that the participants were neutral about their rate of adoption of safety equipment. This finding means that despite the fact that the rate of adoption of safety technology was not considered high in the small residential roofing industry, neither could it be considered to be at a markedly low level—which would mean that any introduced safety technology would likely be rejected. Therefore, distributing a new safety technology among workers to reduce falls is not an unreachable goal. To further explore this issue, methods for improving workers' rate of adoption of new safety equipment were further explored in the semi-structured interview.

In addition, the participants agreed that *perceived attributes of an innovation* influenced their adoption of safety equipment, but responded in a neutral way on the influences of *communication channel* and *social system*. However, from the logistic regression analysis, the factor that affected workers' safety technology adoption significantly was *inter-social influences*, which consisted of the concepts of *communication channel* and *social system*. This suggests that the effects of these two constructs with respect to the adoption of safety technology were hard to isolate. In fact, the relationship between *communication channel* and *social system* has been discussed in the literature. For example, small construction contractors typically operate within a small number of inter-organizational networks, which they utilize to facilitate the development of knowledge needed to encourage learning and innovation (Sexton, Barrett, & Aouad, 2006). Most of them, however, do not always know where to go or who can help facilitate that acquisition of knowledge and resources (Hassink, 1996). Therefore, the diffusion and adoption of a safety technology is very likely attributed to a joint outcome of

existing social norms (which, as discussed in the Introduction of this report, tend to be conservative) and interpersonal communication channels. In this study, therefore, the factor that contains these two constructs is referred to as *inter-social influence*.

Results of the questionnaire also showed that most of the fall protection training that participants received was done informally, with most participants favoring informal training and training materials to be delivered through hard copies. Additionally, the participants generally desired to receive more fall-protection training. These findings suggest that there is a mismatch between OSHA's recommended and used fall-protection training method (i.e., formalized training in a classroom setting) (U.S. Bureau of Labor Statistics, 1994b) and workers' safety training needs and current safety training practices.

The above quantitative results were further explored and explained via the use of the semi-structured interviews.

4.5. Limitations

The main area of concern for the final instrument was the fact that the questionnaire items removed from the item reliability test represented sub-constructs under the main constructs. Despite the fact that this study was concerned with the contributions of the "main" constructs in safety technology adoption, removing these items could have lowered the accountability and predictability of the main constructs in the logistic regression model if the deleted items were "important" to safety-technology adoption. Further research is needed to understand whether the deleted questionnaire items poorly measured their designated constructs or did not have any effect whatsoever on safety technology adoption.

This study used purposeful sampling to recruit participants. It should be stressed that we did not expect the results of this study to provide a comprehensive analysis of OHS problem-solving trends that employ innovative technologies in the construction industry as a whole. Rather, we anticipated that this study's findings would be sufficient for designing a fall-protection training intervention for OHS problem solving in small roofing companies.

In addition, the reading level of this questionnaire was a 7, meaning that the 14 participants who had only completed elementary education may have had problems reading the questionnaire items. This limitation could have influenced the reliability of the participants' responses. However, this potential drawback was overcome by the researcher's and research facilitator's assistance when participants filled out their questionnaires.

5. REQUIREMENT ANALYSIS: SEMI-STRUCTURED INTERVIEWS

5.1. Introduction

In residential construction, falls remain the leading cause of injuries and fatalities. According to Lipscomb et al. (2003), the majority of falls are associated with the following three fall hazards: working on roofs, ladders, and scaffolds. Two of the three sources are directly related to the job of roofing workers. This fact suggests that the likelihood of roofing workers getting injured is higher than other trades workers. And indeed, the accident rate of roofing workers has been documented to be higher than the average construction trades worker. Therefore, developing safety measures to reduce fall injuries and accidents in the roofing industry is imperative.

Research has confirmed that current fall-prevention training is not adequate. According to Lipscomb et al. (2004), most fall accidents occur in situations where standard prevention practices and use of personal protective equipment are not in place. Huang and Hinze (2003) concluded from their analysis of 10-year construction accidents that the severity of fall hazards tends to be misjudged by workers—nor do workers' direct experiences with fall hazards seem to diminish accident occurrence. These studies suggest that more training is needed to prevent falls, especially with respect to increased safety awareness. Additionally, Wojcik, Kidd, Parshall, and Struttmann (2003) recommended that training intervention content should be linked to specific trades rather than aimed at generality across all construction trades. This study, therefore, was based on the notion that because the safety standards and fall-protection training practices in small roofing companies are different from many ways from other construction trades (e.g., siding, framing, and carpentry) due to job-specific work conditions and environmental constraints (Lipscomb et al., 2004), training interventions should be industry-specific. This study also embraced the notion that *understanding* roofing workers' training needs for developing an effective training intervention was more important than having training programs in place.

Understanding roofing workers' training needs does not guarantee successful implementation of fall-protection training interventions. As noted in Chapter 1, the construction industry has been notorious in resisting new ideas and technologies. Typically, companies in this industry are conservative and view innovations with skepticism (Doherty, 1997; Toole,

1998). Therefore, to facilitate the adoption of a fall protection training program or intervention (the purpose of this study), developers need information not only on workers' needs, but also on the adoption practices of safety technologies—which cannot always be obtained through quantitative means. In this study, the semi-structured interview was employed to enhance questionnaire results.

5.2. Method

5.2.1. Participants

Participants who were interviewed in the semi-structured format were recruited from those who responded to the questionnaire. A total of 29 participants volunteered to receive the follow-up interview directly after they completed their questionnaires, which was considered sufficient to discover the underlying structure of work practices when designing customer-centered systems (Beyer & Holtzblatt, 1998).

5.2.2. Interview Questions

The questions in the semi-structured interview were developed to answer the following two research questions: *How do safety practitioners improve roofing workers' adoption of a fall-protection training intervention?* What is a fall-protection training intervention that improves OHS performance among small residential roofing contractors?

Answering the first research question involved investigating when and how new safety safety equipment was introduced and used among roofing subcontractors, as well as identifying specific programmatic aspects that could potentially influence workers' willingness to use/implement fall-protection training. The following open-ended questions were developed:

- (1) Normally, how often does your company introduce new safety equipment?
- (2) What's your attitude when the company introduces new safety equipment? What are your co-workers' attitudes?
- (3) How do you typically find out about new safety equipment?
- (4) How would you ensure that every worker would use a fall-protection training program? Please elaborate on what you think people like and dislike about fall-protection training programs.
- (5) If presented with new safety equipment, what can be done to ensure you'll use it and continue to use it?
- (6) Do you prefer safety training to be done formally, like in a classroom, or informally, like on site from a supervisor? Why?

(7) What form of physical information about fall protection would be the most effective way to share the information? Examples are in MSDS, personal computer, pocket-size note cards, or mobile devices. Why?

Answering the second research question and understanding roofing workers' training needs required investigating when and how fall-protection training programs were done, as well as what aspects of the programs were appreciated by workers. The following open-ended questions were developed:

- (1) Can you talk about your company's fall-protection practices? Please elaborate on who covers it and what, when, where and how the information is covered.
- (2) Do you think you received adequate fall-protection training from your company? Is there any training information that should be added to your company's training?
- (3) If I did develop a fall-protection training program or materials, which areas are the most important and what should I focus on the most?
- (4) When working from heights, what information or advice would you want to know or keep in mind, from a safety perspective?

5.2.3. Procedure

This study was conducted principally during the participants' lunch break since it was their only private time in a work day. Before receiving the interview, participants signed an informed consent form (Appendix C1 and C2), which included an assurance of confidentiality and anonymity. To prevent response bias, prior to the interview the interviewer talked with the participants to put them at ease. The interviewer also ensured that participants understood the goals of the study and were comfortable with the process. This protocol helped the interviewer attain a certain level of trust and openness so that he could be accepted as nonjudgmental and nonthreatening. In addition to asking the participants the prepared questions, the interviewer also asked supplementary questions for clarification and to provide greater detail where necessary. All interviews with Hispanic workers were conducted in Spanish by the research facilitator recruited in connection with the development of the Spanish-language questionnaire. All interviews were tape-recorded and transcribed to provide a protocol for data analysis. The participants who participated in the interview sessions were reimbursed a nominal fee (or lunch) for their time and inconvenience.

5.2.4. Content Analysis

The audio files of the interview (English and Spanish) were transcribed and translated into English by a professional transcription service company. Content analysis (Downe-Wamboldt, 1992) was carried out on the transcripts of the interview. Each piece of information (including participants' phrases, sentences, and paragraphs) related to the research questions was coded by two independent coders separately and without consultation. The independent coders had expertise in construction health and safety and human factors research. They created codes based on a Grounded Theory approach (Charmaz, 1995; Glaser & Strauss, 1977) where no presumptions were made on the participants' responses. Atlas.ti (ATLAS.ti Scientific Software Development GmbH, 2008), a qualitative data analysis software, was used to store text documents and support information coding. The following described how the content analysis was performed:

- The independent coders reviewed the transcripts of all the interviews before
 creating codes. After the first-pass review, the coders made codes for the
 information they believed was meaningful or included concepts that were relevant
 to the research questions.
- 2. After coding all the interviews, the coders met together and discussed the codes they created. Different codes were marked and similar codes were identified. Once they examined how each code was used to interpret differing sections of verbiage in the transcripts, the two coders came to agreement on which codes were to be kept and which codes were to be merged. The purpose of the meeting was to generate a master list of codes and frequencies for the codes. The frequency of a code represented the number of times a code occurred across all transcripts.
- 3. Once the coders agreed on a finalized list of codes, each created a list of themes that either summarized the codes or captured the insights/phenomena in addressing the research questions (e.g., the practices of safety training and safety technology adoption). The coders met again and discussed the themes and by mutual agreement created a final list of themes.

During content analysis, codes were disregarded if the coders could not reach consensus. However, this rarely occurred in the analysis because, in most cases, the participants' verbiage was used by one coder to refer to certain concepts that were not captured by the other coder. Therefore, after explanation and discussion the codes were typically either kept or reworded to better address their constructs. In this study, the final inter-coder reliability

score (i.e., percent agreement on the codes) was 98%, showing a high degree of consistency between the coders on data interpretations.

5.3. Results

As noted above, a total of 29 participants completed the semi-structured interviews, and the sampling structure is shown in Table 12. Fourty-five percent of the participants (13) were European-American workers, while 55% were Hispanic workers (16). Sixty-two percent of the participants (18) did not have a senior high school degree. Most of the participants had more than 10 years of work experience. In general, the managerial personnel tended to be more educated and have more work experience.

Table 12: Sample demographics of the semi-structured interview

Job Title	#	Ethnicity Education Level		el	Work Experience (yr)					
		European American	Hispanic	Elem.	Junior High	Senior High	≥ College	1-5	6-10	>10
Owner	2	2	0	0	0	0	2	0	0	2
Supervisor	6	4	2	1	1	2	2	1	1	4
Foreman	5	0	5	3	2	0	0	0	1	4
Worker	16	7	9	3	8	4	1	5	2	9
Total	29	13	16	7	11	6	5	6	4	19

The following section describes the set of themes that resulted from the content analysis to address the research questions. The insights were used for designing a more likely adopted fall-protection training intervention.

5.3.1. Results: Adoption Practices of New Safety Technologies

Three themes were identified to answer the following research question: *How do* safety practitioners improve roofing workers' adoption of a fall-protection training intervention?

- The first theme was social influence, which describes the entities, channels, and social
 forces that influenced the adoption or diffusion of a safety technology or training
 program.
- The second theme was *barriers for safety training*, which describes the barriers among workers that hindered them from receiving safety training.
- The third was *recommendations for adoption*, which describes from participants' perspectives how to make sure every worker adopted an introduced safety technology.

(1) Social Influence

Social influence consisted of 2 subthemes (as illustrated in Figure 7) that were used to describe the data: *communication channel* and *social system*.

Communication channel includes all possible channels that provide roofing workers with information about new safety technologies. As shown in Figure 7, "managerial personnel," "retailer," and "colleague" encompass the three main sources that disseminate new safety technology information. Take "managerial personnel" as an example, a European-American supervisor said, "We have a lot of turnovers in this business, umm so, I'll take training and then I train the people that work under me." As an example of "retailer," a Hispanic worker commented: "The salesperson shows us how to use it and it also shows the boss." With respect to the "colleague" answer, a European-American company owner mentioned: "If something new was out there, I guess just by word of mouth more than anything else."

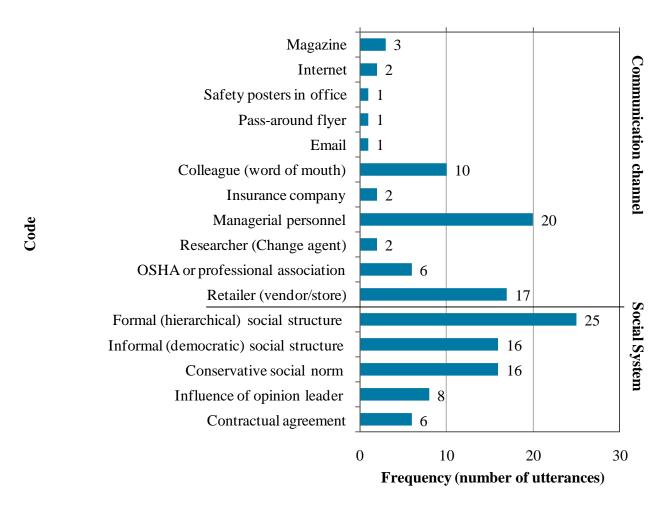


Figure 7: Social influence: Summary of sub-themes, codes, and frequencies

Social system describes the social norms and structures that frame workers' safety technology adoption behaviors. From Figure 7, formal social structure, informal social structure, and conservative social norm were the three main codes that described the attitudes and behaviors of workers when they faced a new safety technology.

- Formal social structure refers to situations when individuals in positions of greater power (e.g., managerial personnel) have the authority to issue orders to those in lower positions to adopt a safety technology. As commented by a Hispanic supervisor on his company's safety technology adoption practices: "Most of the time, the company had some rules, you know, how to do this, this is not like a program, it's rules. You have to do this, and you don't have any choice, you know."
- Informal social structure refers to how members in an organization communicate with others to decide on the adoption of a safety technology. For example, as a Hispanic worker talked about his company's equipment adoption practices, he commented: "If they showed us a new security equipment, I would tell them afterwards if I didn't understand one thing or if I think they missed something."
- Conservative social norm means that an organization is satisfied with its methods for preventing falls and typically resists the introduction of new ideas. For example, when a European-American supervisor talked about receiving safety training, he commented: "I don't really see anything new that would be new about a roof, you know, of course safety. Like I said, it's pretty much everybody knows what they need to do."

From Figure 7, it can be concluded that *managerial personnel*, *retailers*, and *word of mouth* are the three main channels for a roofing worker to learn new safety training or equipment information. In addition, since roofing subcontractors tend to be conservative when facing new safety technologies, their decisions for adopting new safety technology were found to be mainly driven by either management pressure or mutual discussions. These results explained the finding from the questionnaire that *inter-social influence* affects the rate of adoption.

(2) Barriers for Safety Training

According to participants, the major barrier for safety training was associated with workers feeling significantly knowledgeable (i.e., they felt they already knew safety procedures) (Figure 8). As illustrated by a European-American company owner: "I have the

advantage of having learned it over the years. I don't have to go learn it now." A European-American worker had the same opinion on receiving safety training: "Well, I mean I don't really look at them, because I've been through it and I know a lot of safety." A Hispanic worker echoed similar perspectives on safety training: "We know it all and we use it all. We use everything now so that's why I don't need."

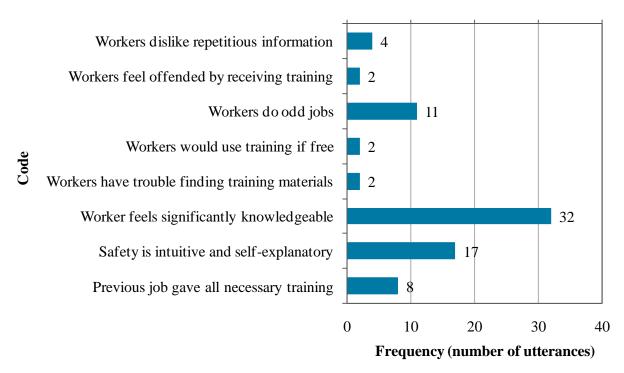


Figure 8: Barriers for safety training – codes and frequencies

The second major barrier for safety training was workers thinking that safety was intuitive and self-explanatory. In keeping with this notion, this study found that many workers were overconfident about their past work experiences/safety record, contributing to the belief that they did not think they needed safety training. For example, when a Hispanic supervisor was asked whether or not providing safety training to his work crew was important, he commented: "When the employees are, you know, they have worked for long time, uh, they know what to do." Another European-American supervisor commented: It's pretty much self-explanatory, it's pretty much what - you know, we just do whatever, you know, what we're going to do for the day and what needs to be done. Workers also expressed overconfidence in their roofing skills. For example, as European-American worker said, "You know what I'm saying, it's just common sense stuff."

The third major barrier for safety training was the inconsistency in employment roles (i.e., doing "odd jobs"). In fact, a roofing contractor (worker) could be either a subcontractor

or a general contractor on a construction project. If acting as a subcontractor, it tends to be inherently unclear who is responsible for safety training. A European-American supervisor, for example, clarified why he did not conduct safety training for the work crew: *I work at another company.... And usually, there ain't this many people here either. Like I said, I'll just do this on the site. They all work for another man that's up there.* In addition, because workers frequently change their worksites and have shorter periods of employment, safety training may be sacrificed (Lingard & Holmes, 2001). A European-American worker explained why he did not receive safety training: "Roofing is not something I do every day, tomorrow I might be somewhere else."

The fourth major barrier for safety training was the belief that previous jobs provided all necessary training, which was illustrated by the responses of two European-American workers: "I learned the craft before I come here, uh, another company I worked for." "The companies I've worked for, yeah. I've had several trainings, harness training and all that."

Therefore, from Figure 8, it can be concluded that the main barriers for safety training included workers doing odd jobs, and workers' confidence/overconfidence in their roofing skills, knowledge, and the training they received from previous companies.

(3) Recommendations for Adoption

The "recommendations for adoption" theme included 11 codes to address participants' recommendations for promoting technology adoption. From Figure 9, most participants thought that management's confirmation of the need for adoption facilitated workers' compliant behavior, followed by showing injury and illness consequences, punishment, and showing benefits.

As an example, of "check by management," a European-American owner explained how he made sure the supervisor/foreman delivered safety training: "You have to, a week later review it again and make sure that it's being followed. And uh, and then keep record of the fact that you did that." A Hispanic supervisor commented on the importance of showing the injury and illness consequences of compliance failure: I convince them like, you know... you have a family, and if you don't know how to do it, I mean, this is difficult, it is going to cost you life. With respect to the code, "punish workers for a low rate of adoption," several participants agreed that punishment may be the best way to induce workers to adopt a given safety technology. For example, a Hispanic worker recommended: "If the employee doesn't listen, doesn't obey, he'll be relieved." With respect to "show benefits," several participants believed it could be a good way to convince workers to adopt a technology or training program. As a

Hispanic worker insisted, "If they told me something else and I knew it was for my own good, I would do it for my safety."

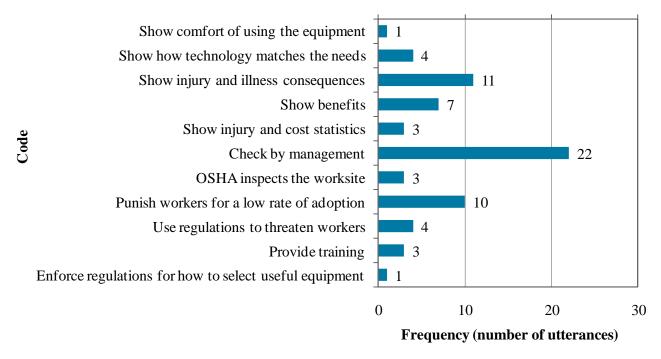


Figure 9: Recommendations for adoption – codes and frequencies

Several recommendations were also made by participants to facilitate workers' adoption of safety technologies, such as using established regulations to threaten workers, showing injury and cost statistics, and demonstrating how adoption matches the needs of the company. From Figure 9, the most mentioned strategies for facilitating workers' adoption of safety technologies were having management's commitment, and showing positive/ negative consequences and punishments.

5.3.2. Results: Fall-protection Training Design

Five themes were identified to answer the following research question: What is a fall-protection training intervention that improves OHS performance among small residential roofing contractors?

- The first was *problems of formal safety training programs*, which describes the problems of safety training programs and how they fall short of workers' expectations.
- The second was *recommendations for training implementation*, which describes workers' expectations on how fall-protection training should be implemented.
- The third was *important areas for fall-protection training*, which describes participants' desired knowledge areas to be included in fall-protection training.

- The fourth was *physical form of training intervention*, which describes participants' preferred physical forms for a fall-protection training intervention.
- The fifth was *design guidelines of training intervention*, which describes the design guidelines that could be used to present the training intervention.

(1) Problems of Formal Safety Training Programs

Figure 10 shows seven problems (codes) associated with safety training programs that participants experienced previously.

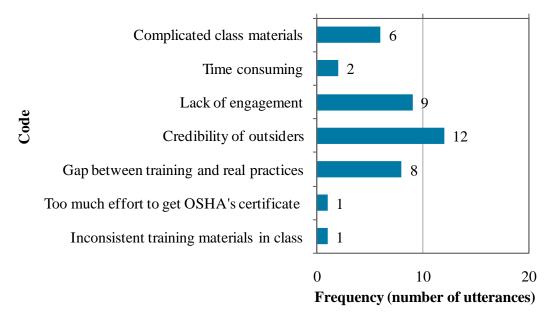


Figure 10: Problems of safety training programs – codes and frequencies

The most mentioned problem was "credibility of outsiders," meaning that participants did not believe they could learn from a safety training lecturer who did not have any on the job roofing experiences. The following is an example of a European-American company owner describing what happened in an OSHA seminar:

One of the contractor people locally, uh, was asking if he should help himself to setup fall protection in the building where he hadn't put the trusses up yet. And the OSHA instructor said, well that's - I have that material, but I don't have it with me. And the guy that was from the audience said, "Well, how is that going to help me?" He said, "I'll bring it next time." He said, "But in the meantime, I might be able to do job, and you guys will come around and give me a fine...

The problem of credibility was also raised by a number of Hispanic participants. For example, a Hispanic supervisor commented: *I don't know how to explain this stuff, but*

normally uh, if someone come and told us like uh, I'm going to laugh...because I have been roofing for long time, and I know exactly what to do.

Among the 12 utterances for "credibility of outsiders," 8 were from the European American participants and 4 were from the Hispanic participants, suggesting that the problem of trainer credibility may have impacted both groups on their willingness to receive formal safety training. Overall, if the credibility issue is not addressed in safety training, the effectiveness of safety training will be low.

The second and third major problems of safety training programs were "lack of engagement," and "gap between training and practices"—both of which had similar frequencies. With regard to "lack of engagement," most participants generally did not like to learn from talks and lectures. Participants also said they oftentimes felt bored in training sessions because of the typical top-down training approach. For instance, a European-American worker commented: "If it's like a classroom, you just kind of seem like you're kind of getting told, you're not getting showed." A Hispanic worker talked about the trainer in his company's training program: "Uh, the person. It's always the person that makes the training boring. I think that would be it." Among the 9 utterances, 5 were from the European American participants and 4 were from the Hispanic participants, which indicated that the lack of engagement influenced the intentions of both groups of ethnic workers in receiving formalized safety training.

With regard to "gap between training and practices," most participants said what they received in the training did not reflect what they needed or what happened in the field. A Hispanic worker complained what the trainer did in safety training: "It is very easy to say, 'Do this, this, and this,' but it's not the same going up there and actually doing it. They should know how does it feel up there." Participant also felt disconnected in the training sessions. A European-American worker commented:

The way fall protection is going on in roof, it's like water being sheeted. It's pretty lacking. I don't know if somebody has better answers, but the answer that we get from OSHA and our company are just not real, they are kind of vague.

Among the 8 utterances for "gap between training and practices," 6 were from the European American participants and 2 were from the Hispanic participants. Therefore, the gap between training and work practices had a greater impact on the European American workers' willingness to receive formalized safety training in comparison to the Hispanic workers.

In addition to the above-stated problems with current safety training programs, other problematic issues were associated with complicated training materials, and unwarranted

time/effort considerations. To summarize, the problem of current safety training programs principally lies in the design of the training program and the materials. Most participants stated that they felt bored and disconnected in formal safety-training sessions. To enable effective learning in safety training, the way training is delivered needs to be changed to address trainees' needs.

(2) Recommendations for Training Implementation

Participants made a number of recommendations with respect to safety training implementation. The recommendations were coded and shown in Figure 11.

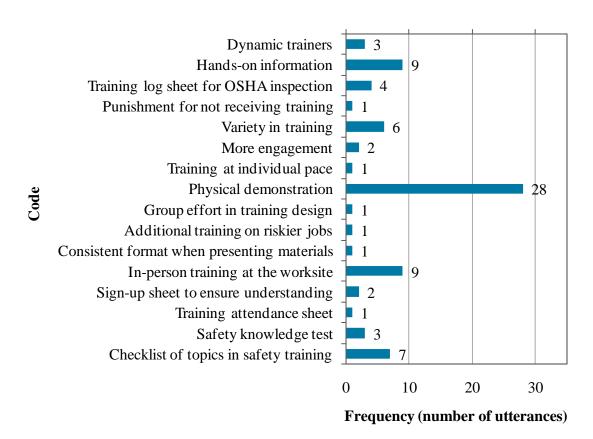


Figure 11: Recommendations for training implementation – codes and frequencies

The most common recommended approach to implement safety training was via a physical demonstration of the safety technique or device. This recommendation stemmed from the fact that participants did not like safety training to be conducted verbally in an indoor environment. As commented by a Hispanic worker: "With words, sometimes people don't understand. They give you a paper or a book, and you see it and you realize, it's not the same doing it than seeing it in a drawing." In fact, physical demonstration seemed to be especially important for the growing Hispanic population in the roofing industry. As a Hispanic worker

commented, "Sometimes if you read stuff is not enough. There are also many Hispanics [that] cannot read."

As also shown in Figure 11, "hands-on information" and "in-person training at the worksite" got higher frequencies than most other codes, suggesting that participants preferred to receive hands-on safety training from a trainer on the worksite. One European-American worker commented: "I think classes are useless... you're better off just to go out there, you get with somebody who knows what they're doing and they can show you a whole lot more ..." More specifically, another European-American worker commented: "I do think that if somebody who actually came out and showed, you know, this is how you do this, this is how you do that, I think that would be really good, probably the best way." Additionally, to highlight the importance of delivering hands-on information in safety training, a Hispanic worker also commented: "We like to hear the things that can help you learn. We don't like when they talk about things we don't understand."

During the interviews, participants also recommended including a topical checklist for managing training sessions. Variety was also considered important in safety training. As commented by a European-American worker: "A lot of times, videos, they get really kind of boring to be honest, and they would be like the same thing as reading a... you kind of just skim through stuff, even though it's important stuff." Other recommendations with low numbers of occurrences in the interview included: "training log sheet for OSHA inspection," "safety knowledge test," "dynamic trainers," and "more engagement."

To summarize, participants recommended safety training to be delivered physically and informally through a trainer on the site using a variety of hands-on demonstration methods.

(3) Important Areas for Fall-protection Training

A fall-protection training program typically covers a wide range of areas, such as ladder safety, fall-arrest systems, balance control, and fall hazard identification. In the interviews, participants targeted certain important areas for preventing fall accidents. These areas were coded and grouped into three categories (i.e., subthemes) and are shown in Figure 12.

The first category was *Equipment*, which included seven safety-related use codes—three of which received the highest frequencies: "safety issues with ropes," "harness use" and "ladder safety." According to participants, ropes can become a fall hazard when they are old and rotten, are tied improperly, or are not stored properly, thereby causing workers to trip on the roof. The second on their list of equipment-related concerns was improper use of a safety harness, which could prove to be fatal. For example, a Hispanic worker highlighted the

pressing need to train workers in harness use: "To show us how to use it very well. A very detailed training on how to use it so that we are conscious that the way you showed us is the correct method and not make any errors." Third, ladder safety should be emphasized as well. As indicated by a European-American worker, "Falls have got a lot to do with ladder, because that's the first thing you're going up to get there."

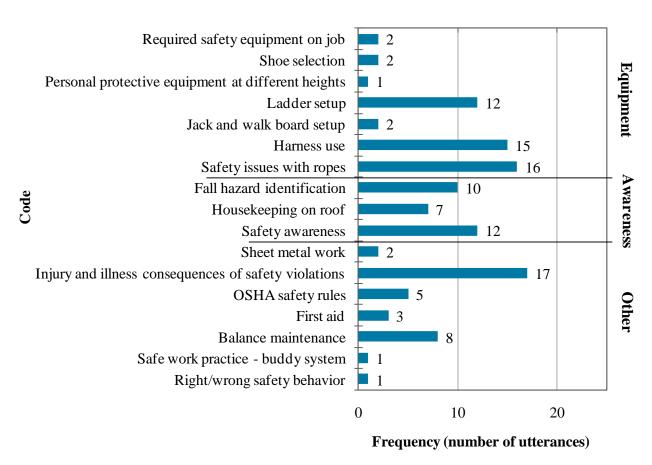


Figure 12: Important areas of fall-protection training – codes and frequencies

The second category was *Awareness*, which encompassed the following three codes: "fall hazard identification," "housekeeping on roof," and "safety awareness." As shown in Figure 12, the frequencies of these codes tended to be high. These areas were considered important because once a worker becomes aware of or has the ability to identify fall risks and hazards, he/she would develop safer work behaviors, such as wearing required equipment at work, and ensuring that ropes were not tangled or frayed.

The third category was *Other*, which contained seven training areas codes including "sheet metal work," "bad consequences of safety violations," "OSHA safety rules," and "first aid." In this category—in fact, across *all* categories—the most-mentioned training area by participants was "bad consequences of safety violations." The frequency of 17 that this

category received means that participants generally thought that workers needed additional training to understand all possible injury and illness consequences of safety violations in order to better prevent fall accidents. As indicated by a Hispanic worker:

We have ...we have plenty of communication regarding to that. We are like, 'See, this happened to this person,' and many people don't want to believe, but after seeing that it was the truth indeed, then they try to avoid those situations.

To summarize, to reduce fall injuries and accidents, participants recommended conducting fall-protection training specifically in harness and rope use, safety and hazard awareness improvement, as well as injury and illness consequences of safety violations.

(4) Physical Form of Training Intervention

As documented in Figure 13, the results for the recommended physical form of training interventions as noted in the semi-structured interviews were very close to those obtained via the questionnaire. In other words, participants preferred receiving hard copies of training information from roofing subcontractors. In the interview, most participants believed that workers would read the training information if they were presented with hard copies. Some of them also stated that they would keep hard copies in their trucks or trailers so that they routinely refer back to safety information if necessary.

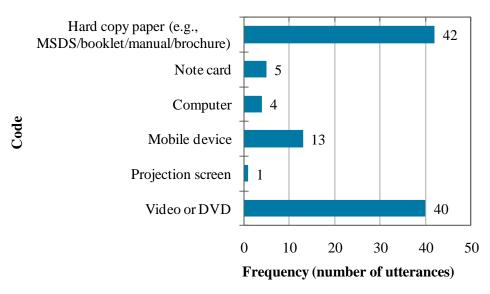


Figure 13: Physical form of training intervention – codes and frequencies

However, Figure 13 also shows a high frequency for "DVD or Video." This result could be explained by the fact that most participants stated that they had access to TVs or DVD players, and that videos presented training information both audibly and visually. As

commented by a Hispanic worker: "I think if they get to see videos or something like that. If they could see what could happen, it would make an impact in their lives." Only a few participants preferred to receive training information through mobile devices because mobile devices were generally considered to be a distraction, possibly leading to fall hazard on the jobsite. Some roofing companies even prohibited the use of mobile phones during work. The fact that some participants chose mobile devices as training delivery systems suggested that some workers were aware of the as yet largely unexplored potential (i.e., playing videos) that mobile technology could bring to roofing safety training.

To sum up, the preferred physical form of training intervention was either hard copies of safety information or training delivered via readily available media system that workers could easily access.

(5) Design Guidelines of Training Intervention

Figure 14 lists the design guidelines recommended by participants. In general, participants preferred to see more pictures in safety training.

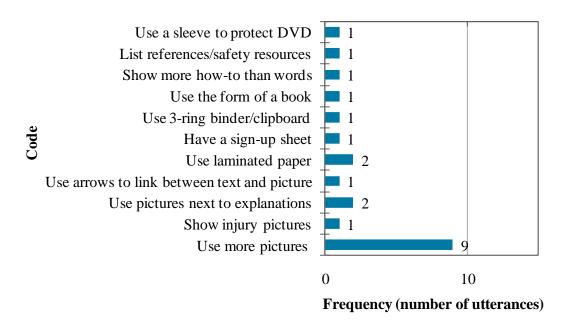


Figure 14: Design guidelines of training intervention – codes and frequencies

One European-American supervisor said pictures would work even better than words in the roofing industry, especially in communicating with Hispanic workers. In fact, most Hispanic workers commented that pictures would motivate them to read the training materials (providing they were literate). One Hispanic worker even recommended: You can also teach a person through images, it could be a manual with illustrations and very thorough. I mean, not only saying, put this and put that, no! It should show all the parts, how things are built and how things are done.

Although the frequencies of the remaining recommended guidelines were much lower, they were still considered to be valuable for the design of the training intervention—for example, showing injury pictures, using pictures to enhance written explanations, using laminated paper to preserve materials, showing more "how-to" illustrations than words, and so forth.

To summarize, participants overwhelmingly recommended that training interventions should include as many pictures as possible for better communication and engagement.

5.4. Discussion

Semi-structured interviews were used to complement the results of the questionnaire for identifying requirements for designing a fall-protection training intervention. The open-ended questions were developed to uncover safety technology adoption issues and fall-protection training practices to answer the stated research questions. Participants' responses to the questions were analyzed using content analysis, whereby themes were created utilizing a grounded theory approach. Results revealed three themes that provided insights on design factors that could improve roofing workers' adoption of a fall-protection training intervention. An additional five themes were related to design factors that could improve OHS performance among small residential roofing contractors.

With respect to the three themes related to promoting safety technology adoption, the first theme that emerged was "social influence." Its underlying codes (Figure 7) addressed Rogers' (1995) constructs for communication channel and social system (Table 8) and explained how safety technology was diffused among roofing subcontractors. Our results confirmed that small construction firms generally do not have the knowledge and resources needed to obtain information about new technologies (Ahuja, 2000). The results also demonstrated the importance of inter-organizational networks in promoting safety technology diffusion and adoption (Sexton, Barrett, & Aouad, 2006). Therefore, the "social influence" theme pointed to the importance of good communication strategies and jobsite networks for facilitating the adoption of a fall-protection training intervention in the small roofing industry.

The second theme that emerged was "barriers for safety training," which helped to elucidate why roofing workers refused to receive safety training. Its underlying codes demonstrated that participants were satisfied with the "safety status quo," as well as their

current knowledge and customary methods for preventing falls (e.g., being attentive). These findings reinforce literature reports concerning the conservative change-making process among small roofing firms (Acar, Koçak, Sey, & Arditi, 2005) and general poor safety awareness (Lipscomb, Dale, Kaskutas, Sherman-Voellinger, & Evanoff, 2008) in the small construction industry.

The third theme, "recommendations for adoption," provided insights for overcoming barriers to safety training—for example, enlisting management support and showing the negative consequences and associated punishments for unsafe work practices. The underlying codes addressed actions to be taken on the industry's network system and on the unsafe work practices to improve safety technology adoption.

As noted, this study also produced five themes related to promoting OHS through fall-protection training. These themes addressed the shortcomings of formal safety training programs, as well as roofing workers' needs regarding fall-protection training design. This study revealed that some of these problems could be addressed through redesign approaches (e.g., making training materials more consistent and less complicated), and possibly by improving credibility issues with outsiders, and increasing opportunities for engagement. However, problems concerning the gap between training and actual safety practices was shown to be hard to "fix" solely via indoor (i.e., formal) educational settings. This item speaks to the need for informal jobsite safety training (preferred by most participants in the questionnaire) to complement what had been covered in formal safety training.

This study also highlighted the importance of trainer credibility in fall-protection training. The gap between training and actual work practices in most formal safety programs could have potentially damaged trainers' credibility. In fact, building trust is critical in construction safety training, as evidenced by the fact that trusting relationships have been shown to lead to greater knowledge exchange (Dirks & Ferrin, 2001). Although there are many ways to establish trust and trainer credibility in safety training program, Hilyer et al. (2000) found from a union-initiated safety training program that workers functioned effectively as trainers because they spoke directly to worker interests and experiences. In their research, Hilyer et al. demonstrated the positive impact of joint labor-management health and safety programs in training program design.

The importance of informal training has been verified in the literature. Marsick and Watkins (1990) confirmed that employees tend to rely on personal strategies to question, listen, observe, read and reflect on their work environment. Conlon (2004) noted that a great deal of informal learning results when more experienced workers share their knowledge and

experience with their juniors, which explains why apprenticeships became an important part of the unionized construction industry (Lipscomb et al., 2008). However, informal training cannot be the only source of training in the work place, since as noted by (Sorohan, 1993), a small percentage of what employees learn *does* result from formalized and structured training. Furthermore, learning cannot effectively take place without an institutionalized combination of formal schooling and informal experience (Crossan, Lane, & White, 1999).

Thus, in assessing what was judged to be most valued by participants via the semi-structured interviews (namely, improved design guidelines and on-the-job forms of safety training), the intended fall-protection training intervention should be informal, and its design should address the problems of formalized safety training programs and the needs of workers in order to facilitate worker adoption.

5.5. Conclusions

To conclude, participants' verbal responses in the semi-structured interviews confirmed questionnaire findings that social influence affects the rate of adoption of safety interventions. Particularly, the codes with high frequencies matched almost all the sub-constructs included in the questionnaire (as illustrated in Table 8), which demonstrates the validity of the logistic regression model we used in this research.

As discussed earlier, the small roofing industry is conservative in adopting new safety technologies. Decisions in this regard are primarily affected by the relationships between management and employees. For example, a company with low power distance may make adoption decisions by mutual discussion across all levels of employees; a company with high power distance may make adoption decisions by management alone. One important barrier to safety training noted in this study was when workers felt knowledgeable of and overconfident about their roofing skills, meaning that workers were satisfied with the status quo of their safety performance. The nature of the subcontracting roofing business in general also hindered workers from receiving safety training on a regular basis. To facilitate the rate of adoption, participants recommended using punitive measures for non-compliance, involving management, and showing good/bad consequences.

Participants' interview responses also provided insights in designing a fall-protection training intervention fitting their needs. For example, participants indicated that they felt disconnected and a lack of engagement in most training sessions. They preferred receiving hands-on safety training on the jobsite from a trainer with actual roofing experience. Regarding training areas needing particular focus, participants voiced their preference for receiving safety

training related to safety equipment, safety awareness, and consequences of safety violations. Additionally, participants preferred safety training to be delivered through hard copy materials, pictures, and via any media that they could easily access in their lives.

In summary, this study confirmed the effects of social influence on safety technology adoption and identified the design guidelines (which have not yet been specified in the literature) (Table 13) for a more likely adopted and effective fall-protection training intervention for small residential roofing subcontractors. The guidelines were used as important references for developing the intended training intervention in the Participatory Design study.

5.6. Limitations

This study used purposeful sampling to recruit participants, who were from Virginia and North Carolina. Their ethnicities were mainly European-American and Hispanic. Because of the relatively small sample size (n=29) and the narrow geographic/ethnic distribution of participants, the findings described herein may not represent OHS problems and technology adoption practices in the residential roofing industry as a whole. However, we believe our results shed light on what a more likely adopted fall-protection training intervention would be like because of the amount of the data we collected and its representative sampling structure.

Another possible limitation concerned the semi-structured interviews, which were conducted primarily during the participants' lunch break. In several cases, the interviews went longer than expected. In such instances participants were not able to pay full attention to the last few questions because of work conflicts. This could have affected the frequency counts of the codes in the data analysis.

Table 13: Design guidelines for an easy-adopted and effective fall-protection training intervention

Categ.	Design Guideline	Source/Rationale			
A1	A training intervention should not employ a technology that is beyond the capabilities of a roofing subcontractor. It should feature a technology that could be easily implemented in the company and communicated among roofing professionals.	Figure 7 (Socail influence); Table 10 (Analysis of the questionnaire items –Logistic regression analysis)			
A2	The systems features of a training intervention should be highly visible and easily identified. Therefore, when it is presented to workers, they should know immediately how to implement to improve their job site safety.	Figure 7 (Socail influence); Table 10 (Analysis of the questionnaire items –Logistic regression analysis)			
A3	Preferred methods for enhancing the adoption of a training intervention should include management follow-up, showing good/bad consequences, and use of punitive penalties.	Figure 9 (Recommendations for adoption)			
A4, B1	Training information should be delivered through hard copies with pictures and/or via easily accessible media systems.	Figure 4 (Analysis of demographic questions); Figure 13 (Physical form of training intervention); Figure 14 (Design guidelines for training intervention)			
B2	A training intervention should focus on structuring workers' experiences rather than transmitting safety knowledge.	Figure 8 (Barriers for safety training)			
В3	A training intervention should be designed to encourage workers to learn to talk, not to learn <i>from</i> talk.	Figure 10 (Problems of safety training programs)			
B4	A training intervention should encourage worker participation.	Figure 10 (Problems of safety training programs)			
В5	A training intervention should engage workers through the use of frequent talks/discussions about fall-protection and safety issues, preferably on-the-job during breaks.	Figure 11 (Recommendations for training implementation)			
B6	The principal areas on which to focus during fall-protection training are safety awareness, the proper use of fall prevention equipment, and the consequences of safety violations.	Figure 12 (Importance areas of fall-protection training)			

Category A: Guidelines for designing a more likely adopted fall-protection training intervention

Category B: Guidelines for designing an effective fall-protection training intervention

6. PROTOTYPE DEVELOPMENT: PARTICIPATORY DESIGN

6.1. Introduction

Participatory Design (PD) is a user-centered methodology that focuses on collaborating with intended users in planning and designing a system or interface. Its philosophy is expressed via the following three premises (Ellis & Kurniawan, 2000): (1) the goal of PD is to improve quality of life, rather than demonstrate the capabilities of a particular technology; (2) the orientation of PD is collaborative and cooperative, rather than patriarchal, and (3) PD values interactive evaluation to gather feedback from users.

The success of PD is dependent on how designers collaborate and cooperate with users. Research shows that one of the most common challenges in PD is the difference between the vocabularies of designers and users (Go, Takahashi, & Imamiya, 2000). For example, designers are interested in what can be done to resolve an interface problem, while users reiterate what they dislike in a system. To address the challenge of disparate interests, a number of PD techniques have been proposed. They are described in the following section; they provided important insights into the design of this study's PD workshop:

Muller (1991) developed PICTIVE (or Plastic Interface for Collaborative Technology Initiatives through Video Exploration) to enhance user participation in the PD process. This technique involves the use of simple office materials, plastic design components (e.g., menu bars, query fields, and command line) and video recording facilities to improve knowledge acquisition for design. Furthermore, Halskov and Dalsgård (2006) stressed the importance of inspiring materials by introducing two types of inspiration cards, the "domain" cards (containing findings from domain studies) and the "technology" cards (containing sources of inspiration from applications of technology). They proposed a collaborative PD method, called "Inspiration Card Workshop," which uses these two sets of cards to trigger participants' ideas to form design concepts. In a similar vein, Beck, Obrist, Bernhaupt and Tscheligi (2008) proposed "Instant Card Technique" by using a typology of instant cards (e.g., cards of user cards, time, location, technology, and activity) to formulate usage scenarios for an intended interface. Additionally, Scenario Building is one of the key tools for conducting PD. According to (Go et al., 2000), scenario building features a shared vocabulary between designers and users in the systems development process and is an excellent medium for designer-user communication.

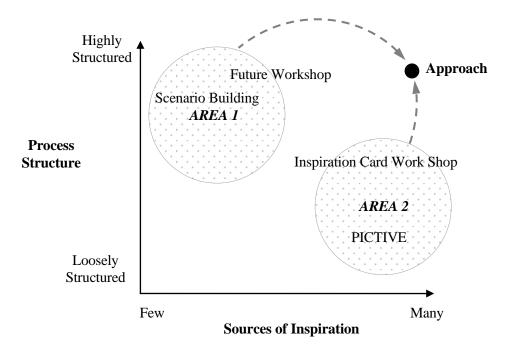
Therefore, in order to guide effective discussions among the researchers and the worker participants in this study, we employed a series of scenarios in the PD sessions. The scenarios were developed from findings in the questionnaire and semi-structured interviews and were presented via Microsoft PowerPoint in the PD workshop. Additionally, inspired by PICITVE (Muller, 1991) and Inspiration Card Workshop (Halskov & Dalsgård, 2006), the study used a variety of color-coded Post-it notes and design materials to facilitate PD discussions and the generation of training intervention ideas. For this study, the workshop sessions followed the structure of the "Future Workshop" (Jungk & Mullert, 1987; Schuler & Namioka, 1993) to develop the training intervention.

6.2. Method

6.2.1. Approach

PD is a design approach that actively involves users in the design process to ensure that the product meets users' stated needs. In the literature, a variety of techniques have been proposed to facilitate the PD process. Some are designed for idea generation via a loosely-structured process, such as Lateral Thinking (De Bono, 1993) and PICTIVE. Conversely, some are highly structured with less of an emphasis on inspiration as a source for ideas, such as Future Workshop.

Figure 15 (inspired from Halskov & Dalsgård, 2006) shows this study's PD approach in a taxonomic space of PD practices, with "Sources of Inspiration" on the x axis and "Process Structure" on the y axis. The specific approach used in this study was to encourage idea inspiration via a structured (systematic) design process for developing a fall-protection training intervention. Therefore, this study adopted the concepts of the PD techniques from Area 1 and 2 in Figure 15 to conduct the PD workshop, which included Future Workshop, Scenario Building, PICTIVE, and Inspiration Card Workshop.



(**Note:** Area 1 encompasses more highly-structured techniques with fewer sources of inspiration; Area 2 includes more loosely-structured techniques with higher sources of inspiration)

Figure 15: Taxonomy of PD practices and the approach of this study's PD

6.2.1. Participants

The study used two purposeful sampling techniques, criterion sampling and convenience sampling, to identify participants. A total of six participants participated in this portion of study, including two investigative researchers from the study, and four roofing professionals from construction subcontractors. The expertise of the investigative researchers included Construction Health and Safety, Human Factors, Industrial Design, and Computer Engineering. Among the four roofing professionals, two were managerial personnel (a company owner and a supervisor) and two were employees from different companies. The ethnicity of the roofing professionals was European-American. One worker had completed middle school education; the remaining three had senior high school diplomas. The roofing professionals were recruited through the assistance of a worker participant who participated in Study 1 and 2. All of them have at least five years work experience in the residential roofing industry.

6.2.2. Apparatus

To guide the PD team in generating effective design ideas from the results of the questionnaires and semi-structured interviews, the study adopted the concepts of domain cards and technology cards from the Inspiration Card Workshop (Halskov & Dalsgård, 2006) and the

concept of shared design surface as described in PICITVE (Muller, 1991) to develop the following apparatus for the PD workshop (Figure 16):





Design materials and three sets of color-coded Post-it notes

Shared design space (the white board behind the Post-it notes)

Figure 16: The setting for and materials used in the PD sessions (photos by author, 2010)

- **Design Materials**: The design materials included a collection of safety training materials (e.g., MSDSs, safety manual, fall-protection training brochure, safety booklet, safety newspaper, and safety note cards), safety training technologies (e.g., pseudo mobile device, computer, DVD, projector, three-ring binder, and poster stands), and markers (green, red, and blue). The design materials represented the codes for two themes identified from analyzing the semi-structured interviews: (1) Design guidelines of training intervention, and (2) Physical form of training intervention.
- Color-coded Post-it Notes: The Post-it notes were grouped by color into three categories, which represented three themes identified from the analysis of the semi-structured interviews: (1) Important areas of fall-protection training, (2) Recommendations for training implementation, and (3) Recommendations for adoption. Every Post-it note included three types of information: a code, a code frequency (number of utterances) and a graphic/picture illustrating a code. Blank Post-it notes were also provided for any new ideas that emerged in the PD sessions.
- Shared design space: The shared design space was represented by a wide white board that allowed the PD members to draw and write down ideas with markers, and place Post-it notes to conceptualize the design features for the intended fall-protection training intervention.

6.2.3. Procedure

The PD workshop was held in a conference room in the Department of Industrial and Systems Engineering at Virginia Tech on two consecutive days. To systematically guide the group discussions and design activities, this study employed the design process encompassed in the Future Workshop (Jungk & Mullert, 1987; Schuler & Namioka, 1993) to structure the PD sessions. The two PD sessions featured: (1) Day 1: the Introductory and Critique Sessions, and (2) Day 2: the Fantasy Session. The overall PD design process is shown in Figure 17. In the workshop, the two investigative researchers acted as impartial moderators and facilitators. Their roles were not to decide the design of the training intervention, but to make suggestions and collaborate with the worker participants.

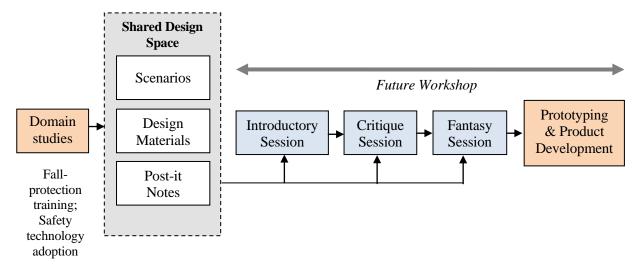


Figure 17: The PD workshop: Prototype development process

(1) Day 1: Introductory and Critique Sessions

Refreshments were provided at the beginning of the session, which allowed participants to get to know the investigative researchers on a more informal basis. During the introductory session, the scope and the purpose of the research study were explained to participants. Informed consent forms (Appendix D) were given to the participants. Issues of confidentiality and anonymity and the risks of participation were addressed by the investigative researchers. The participants were also informed that the PD sessions would be audio-recorded for later transcription. Finally, they were told that they could freely withdraw from the study at any time and for any reason.

The critique session began after a ten-minute break once the introductory session had concluded. To enable a more complete understanding of the research, this research's

background information was presented with a scenario, which described who performed the research, who were selected as participants, when and how the research was conducted, and what had been found quantitatively (e.g., demographic and descriptive statistics). The purpose of presenting the background information with a scenario was to inform participants of the context of performing research on current safety training practices in the roofing industry. Additionally, the scenario-based presentation helped the PD members stay focused on the research goal.

During the critique session, cases of participants' fall injuries as reported in the semi-structured interviews were also presented with scenarios. Each injury and its causes were represented by figures, illustrations, and videos (using Microsoft PowerPoint) to direct the members' thoughts and discussions to the solution space for reducing safety challenges related to falls.

The findings from the semi-structured interviews (i.e., themes, codes, and code frequencies) were also presented to the PD members. In response to the presented findings, members shared their ideas and discussed how they could overcome adoption barriers, mitigate OHS problems, and increase fall-hazard awareness through training.

(2) Day 2: Fantasy Session

The purpose of this session was to use the design materials and Post-it notes to conceptualize an effective and more likely adopted fall-protection training intervention utilizing the shared design space. Upon arrival, the PD members were introduced to the apparatus associated with this study. They were particularly encouraged to express their ideas in the collaborative design process, during which interruptions and complementary ideas were welcomed.

The codes and themes resulting from the semi-structured interviews and the questionnaire findings were important resources for the PD team in their goal of identifying the design features of the intended training intervention. The PD members discussed which codes or findings were to be implemented in the design of the training intervention. They also shared their thoughts on emerging ideas. The discussed topics ranged from the various form of available technology to the best methods for delivering training, as well as design elements for presenting training information and facilitating adoption.

During the session, the PD members put together Post-it notes and design materials on the design space if the ideas were related. The members placed Post-it notes separately to illustrate differing features of the intended training intervention. New ideas were either written on blank Post-it notes or on the design space with markers. At the end of the fantasy session, the design features, specifications, and system requirements for the intended training intervention were all displayed on the design space, which formed a single unified design.

6.3. Results

It should be noted that while fall-protection training could have covered a number of areas (e.g., personal fall-arrest systems, ladder safety, safety regulations, jack and walk board setup), due to the limited availability of the participants and the timeframe, the PD team was not able to develop a full fall-protection training package to cover all topical areas. However, after the discussions the team decided to develop a safety training intervention for a "Personal Fall Arrest System (PFAS)," because it covered two most important training areas identified in the semi-structured interviews—"harness use" and "safety issues with ropes" (Figure 12). The features and requirements of this PFAS training intervention is shown in Figure 18, which were outlined by colored Post-it notes, a poster stand, a three ring binder, and complementary ideas and descriptions on the shared design space.

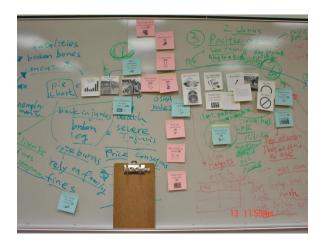




Figure 18: Outcome of the PD workshop - Design features and systems requirements (photos by author, 2010)

The following description details the features and requirements of the PFAS training intervention:

The physical form of the intervention should be low-tech to improve adoption. The
intervention should use a three-ring panel board with double-sided laminated training
sheets (instructions on the back). The back of the panel board should be a white board
so that the instructor could write and draw safety-related information to facilitate
training. The panel board should be light and easily carried across work sites. The size

- of the panel board should be larger than a regular B4 paper, making the training information large enough to be seen among a small group of workers.
- The training information should be delivered through visual representations/objects
 (e.g., pictures, graphs, figures, pie/bar charts, and/or arrows) to increase users'
 acceptance of the intervention. The training information should have a Spanish version
 for Hispanic workers.
- The aim of the intervention had two main purposes: (1) to provide supplement formal (classroom) safety training; (2) to facilitate informal training on the worksite via "toolbox talks" on areas of importance.
- Five areas were considered to be sufficiently important for the development of an effective PFAS training systems that could reduce fall injury and accidents:
 - (1) **Fall injuries and citation statistics:** Providing a general overview of what could result from the lack of fall-protection training);
 - (2) **Negative consequences of falls:** For example, death, disability, license suspension, unemployment, increase in insurance premiums, monetary losses resulting from OSHA citations, and personal injury monetary losses;
 - (3) **Instructions on prompt fall rescue:** Demonstrating crew-rescue options and self-rescue options;
 - (4) **Do's and don'ts regarding the use of a PFAS**: For example, do keep the buddy system in mind, don't bring a bad attitude to the job; don't rush; don't be embarrassed by fear; don't be afraid to ask questions or request help; don't drink alcoholic beverages before or during work; don't use drugs of any kind before or during work);
 - (5) **Safe working behaviors and their benefits**: For example, staying employed and making money; decreased insurance premiums; improved safety record; decreased company losses; staying physically healthy; being able to be there for family members; seeing supervisors and OSHA officers smile);
- Any PFAS training should be implemented on the jobsite with physical demonstrations
 of apparatus components and use. Graphical illustrations of the components of a PFAS
 should be provided to facilitate instructors' physical demonstrations. The ideal
 personnel for delivering the training should be either a worker or managerial personnel.
 Workers should take turns conducting the training.

- The PFAS training intervention should include a laminated fall hazard warning sign, which could be placed on a stand near the ladder or on the wall behind the ladder, making it easy to be seen by workers every time they climb up/down the ladder.
- The intervention should include a DVD (containing the files for the training sheets) so that a contractor could either update information on the training sheets or add training sheets that correspond to specific needs.

6.3.1. Prototype Development and Finalization

The investigative researcher in the PD team developed the prototype in Microsoft Word, Photoshop, and Illustrator following the design features and systems requirements specified in the PD workshop. (It should be noted that due to the lack of research resources, i.e., time and funding, a Spanish PFAS training intervention was not developed.) Representative components of the English PFAS training intervention are shown in Figure 19 (also see Appendix G). The investigative researcher designed a cover sheet for the training intervention. On the back of the cover sheet is an overview of the training intervention. The warning sign was designed following ANSI Z35.1-68 (Specifications for Accident Prevention Signs) and OSHA Standard 29 CFR, Part 1926.200 (U.S. Bureau of Labor Statistics, 2002) and to be stored on panel board. The training sheets address the five training areas recommended by the PD team and contain graphical illustrations of the components of a PFAS. The templates for the training sheets (front and back) are shown in Figure 20, which illustrate the rubrics for placing the design elements.

To verify whether the developed PFAS training intervention followed the design features and systems requirements specified in the PD workshop, two SMEs were recruited—one with expertise in Construction Health and Safety and Human Factors, while the other was a roofing company manager with more than 30 years of work experience in the roofing industry. They were given the transcripts of the PD workshop and the developed training intervention. They were told to review the transcripts before evaluating the training intervention. There were no time constraints associated with this evaluation process, although the two SMEs completed their evaluation within three and half hours. Results of the evaluation showed that the developed training intervention addressed the insights brought forth during the PD workshop. The only suggested change was to lower the roof pitch of a house in training sheet illustration of when to wear the PFAS. The final training sheets and their instructions of the PFAS training intervention are presented in Appendix E. The reading level for the training instructions in the Flesch–Kincaid readability test is 9.5.

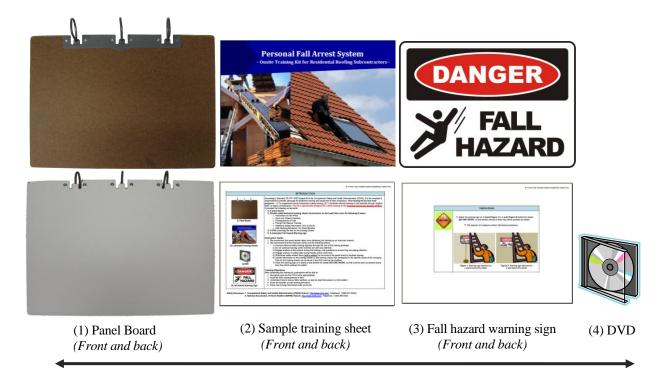


Figure 19: Components of the fall-protection training intervention (photos and graphics obtained from Microsoft Clipart; Warning sign designed by author, 2010)

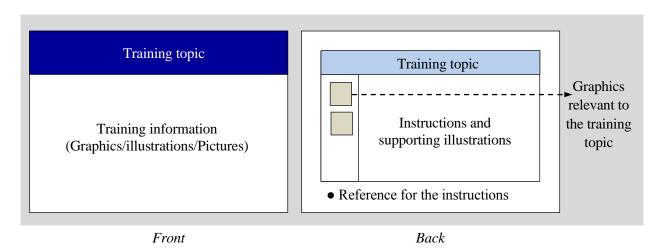


Figure 20: Design templetes for the fall-protection training sheets (front and back)

6.4. Conclusions and Discussion

The goal of the study was to work with roofing professionals to develop a more likely adopted fall-protection training intervention. To achieve this goal, the study conducted a PD workshop using these established protocols: the use of PICTIVE, Inspiration Card Work Shop, Scenario Building, and Future Workshop. Findings obtained from the questionnaire and

the semi-structured interviews were provided to PD members as important reference materials for brainstorming ideas.

The researcher found it beneficial to use the design process of Future Workshop to guide the design activities because it made discussions centered on the goal of each session. The study also observed that the use of scenarios to describe the background of this research and participants' injury cases effectively involved PD members in problem of context. It attracted the member' attention and made them try to join the discussions to enhance the understanding of a problem. In addition, the study found the design materials and Post-it notes facilitated member communications and brainstorming ideas. For instance, when discussing how to make workers keep safety in mind all the time, a Post-it note (attached with a warning sign) was put on a poster stand to illustrate one member's idea, which inspired the later ideas of placing a warning sign on a poster stand behind a ladder and on a wall behind a ladder. In this study, the use of the shared design space facilitated forming ideas among the PD members. For example, when discussing how to show the costs of common fall injuries, some participants suggested using the bar chart idea on the design space (which was previously agreed upon for displaying OSHA citation statistics), while others preferred using pie charts. Overall, the PD approach in this study-encouraging idea generation through a systematic collaboration process- has contributed to the area of construction safety training design, where training designs and insights came mostly from either focus groups (Brunette, 2005; Kaskutas et al., 2010) or participatory research with unspecified levels of member participation and collaboration (Ochsner et al., 2008; Williams Jr, Ochsner, Marshall, Kimmel, & Martino, 2010).

The outcome of the workshop was a PFAS training intervention that included the following features to facilitate its diffusion and adoption among roofing subcontractors:

- 1. The panel board, paper training sheets, and warning sign should use low-tech materials known by every roofer. Implementing and using the developed intervention should not require technical knowledge. The safety training information should be implemented on paper sheets which are highly accessible without the support of an electronic device (e.g., a DVD player or mobile phone).
- 2. The developed training intervention should be portable. Its use should not be restricted to an indoor environment. It should be able to be used anywhere on the jobsite to better engage workers in safety training—thereby increasing workers' acceptance of safety training.

- 3. The features of the developed training intervention should be highly visible and accessible, making the intervention easy to be disseminated through a variety of communication channels (e.g., managerial personnel, co-workers, or retailers) and the social system (e.g., organizational culture and social norm). Moreover, when the developed training intervention is presented users, they should know immediately how to implement it to promote jobsite safety.
- 4. The training sheets should show negative consequences for not implementing fall-protection training (e.g., high possibility of receiving OSHA citations and high personal and/or corporate monetary losses due to citations), which would enable/accelerate workers' adoption of fall-protection training programs, such as the developed training intervention.

In addition to the above features to enable workers' adoption, the developed training intervention should also include the following features to reduce the likelihood of fall injuries and accidents:

- 1. The use of the developed training intervention should not be restricted to managerial personnel. In fact, the training intervention should be structured in such a way that all workers could take turns delivering training. Therefore, workers would be encouraged to learn by talking, not to learning *from* talking. In order to conduct safety training, workers would have to digest safety training information and/or demonstrate best safety practices, which could result in improving their safe working behaviors.
- 2. The developed training intervention should also focus on structuring workers' safety experience rather than transmitting safety knowledge. Therefore, the intervention should stress the importance of engaging in frequent talks and discussions with workers about fall-protection and safety issues during break. In fact, this type of engagement in ongoing safety talks frequently helps to develop and imbed an organizational safety culture.
- 3. The developed training intervention should demonstrate concrete examples of the bad consequences of safety violations (e.g., monetary losses associated with citations and injuries) and falls (e.g., death, disability, license suspension, unemployment, and increases in insurance premiums). As indicated by participants in the semi-structured interviews, to improve worker safety awareness, it is necessary to educate workers about the real consequences of their unsafe work practices.

In general, the PD workshop was successful. The coffee and refreshments helped to relax the PD members, making everyone more willing to share their perspectives. All the

members enjoyed the presentation flow of the research findings and the scenarios. Most of the discussions were positive and were directed toward the design issues of the intended training intervention. The roofing professionals appreciated the goals of this research and tried to help as much as they could in the PD sessions. Every member was satisfied with the outcome and believed that it had a better chance of overcoming the conservative technology-adoption culture in the roofing industry. The results of this PD study demonstrated the effectiveness of using a variety of PD techniques in designing an innovation.

6.5. Limitations

The construction industry has been significantly impacted by the growth of the Hispanic population. Thus, the development of any effective safety intervention in the roofing industry would require the input of Hispanic workers. Although the composition of the PD team in this study did not include Hispanic workers, a significant portion of the data (obtained from the questionnaire and the semi-structured interviews) discussed in the PD sessions were from Hispanic workers, which helped to overcome this suggested limitation and reduced the bias of the PD participants.

The success of PD is driven by the participation level of team members. Thus, one limitation is that any design outcome could be negatively impacted by participants' mindsets, knowledge and work experiences—especially if participants are from the same ethnic group and geographic area. This study, therefore, utilized criterion sampling to exclude inappropriate participants, which could have negatively impacted PD outcomes.

Effective PD sessions are known to be time-consuming because typically they are iterative, whereby the suggested design is subjected to continuous evaluations and revisions. The limited budget and timeframe associated with this study did not allow the investigative team to carry out a full-blown PD. Nonetheless, even with just one PD iteration, the results of the study were expected to identify major needs and adoption preferences for a fall-protection training intervention.

Another obstacle that is frequently cited in the PD literature (Blomberg & Henderson, 1990) is the unequal power relationship between participants and researchers. Blomberg and Henderson indicated that participants in PD might feel a tendency to show more positivity than they actually feel toward the discussion topics in order to help the researchers complete their study. To overcome this limitation, the research team encouraged workers to express their opinions without reservation, stressing that their true opinions could ultimately help to reduce OHS problems and improve safety technology adoption in the roofing industry.

7. SUMMATIVE EVALUATION: A COMPARATIVE RESEARCH STUDY

7.1. Introduction

The purpose of this research was to develop a more likely adopted and effective fall-protection training intervention. To understand whether a particular developed training intervention is capable of being adopted by users, it is necessary to measure their adoption behaviors. The following are the main measures typically described in the literature for analyzing innovation adoption:

The first is *time measure*. This component has to do with the time needed to adopt an innovation, or the number of innovation adoptions during a specific time period. For example, Subramanian and Nilakanta (1996) used this measure to classify banks into adopters and non-adopters of technical innovations, such as the use of a new ATM. In order to classify the innovation adoption behavior among different sizes of libraries, Damanpour and Evan (1984) surveyed how many innovations (technological and administrative) from an innovation list were adopted by librarians between 1970 and 1982. Although it did provide some baseline information, the shortcoming of this approach, however, was the lack of depth and richness for the evaluation of adoption behaviors (Wilson, Ramamurthy, & Nystrom., 1999).

The second is *binary adoption measure*. This approach uses a binary variable to classify innovation adoption, where 1= Adoption (Yes) and 0 = Rejection (No). For instance, in their study of integrated pest management practices among Texas cotton growers, Thomas, Ladewig, and McIntosh (1990) used a dichotomous adoption measure for each of the three practices associated with this study: scouting, use of information from pheromone traps to determine insect trends, and preservation of beneficial insects by selectively using insecticides. They combined the adoption variables to produce a scale of adoption ranging from zero to three. However, McDonald and Glynn (1994) noted that this approach is limited in assessing the extent of adoption. In other words, researchers would not know the actual adoption level of an innovation, especially if the data are to be interpreted in relation to environmental impacts.

The third is *multi-component measure*. This approach combines more than one measure to produce a scale to explain an individual's innovation adoption behavior. For example, Wilson et al. (1999) proposed the use of "radicalness" and "relative advantage" to

measure the adoption of imaging technology innovations in hospitals. In a later study, Al-Gahtani (2003) used a five-attribute scale (*frequency of use, time duration of use, number of application systems use, number of needs and purposes used for, and intention of future usage*) to measure the adoption of computer technology in public and private organizations in Saudi Arabia. This approach is probably the most robust measure commonly used in the literature to understand users' adoption behaviors.

The fourth is *outcome measure*. Outcome measure of adoption has been shown to be a valid indicator for actual adoption (Wilson, Ramamurthy, & Nystrom, 1999). This approach is concerned with any outcome that a proposed innovation adoption would be expected to influence. One such example was reported by (Donaldson, Rutledge, & Ashley, 2004), where fall incident rates, the effectiveness of fall risk preventive strategies, and evolution of adoption were used to measure the adoption of a practice intended to reduce patient falls in hospitals. In addition, obtaining target users' feedback on expected outcomes of adoption could be treated as an intermediate measurement to explain future adoption. For example, one study proposed a perception-influence model that described the predictability of perceptions with respect to technology implementations in construction projects on workers' adoption behavior.(Miller, Radcliffe, & Isokangas, 2009).

The fifth is *proxy measure*. This approach uses intermediate measures (such as willingness of adoption, perception/intention of adoption, or adoption propensity) to infer users' future adoption behaviors. For example, Kendall, Tung, Chua, Ng and Tan (2001) investigated construction workers' willingness to adopt E-commerce to explain the receptivity and adoption of E-commerce in the small construction industry. In fact, a number of studies have demonstrated a positive correlation between intention to adoption and actual adoption of an innovation (Davis et al., 1989; Hsu, Lu, and Hsu, 2007; Szajna, 1996). Despite its predictive power under certain circumstances, this approach for predicting adoption behavior is limited when changes to social technical systems (such as innovation adoption culture and practices and competitive innovations) are rapid.

Conversely, other researchers have shown that measuring users' adoption of an innovation is difficult, especially when the adoption is confounded by other effects (McDonald & Glynn, 1994). For example, assessing the results of a new pesticide on crop yields cannot ignore the consequences of droughts, flooding, or other weather extremes. Rogers (1995) indicated that the major challenge of measuring adoption is that the consequences are often complicated and occur over extended periods of time. He recommended a long-range research approach where consequences are analyzed as they

unfold over a period of time (which could be several years).

The reader must be reminded that this research was exploratory in nature and lacked certain research resources associated with longer-range and/or well-funded research. In other words, this study did not take a long-range research approach to study roofers' adoption of the developed PFAS training intervention. Rather, it used a multi-component approach, including measuring adoption propensity (inspired from the proxy measure approach) and assessing expected outcome of adoption (inspired from the outcome measure approach) to achieve its intended goals. The expected outcome in this study was safety performance improvement for reducing falls. Thus, gauging this outcome also provided insights on the effectiveness of the developed training intervention and the efficacy of the proposed innovation analytic and design framework. In addition, the performance of the contributing factor—namely, *social influence* (from the questionnaire)—on technology adoption was used as another measure to understand the likelihood of workers' adoption of the training intervention.

7.2. Method

7.2.1. Research Design

To evaluate the efficacy of the proposed innovation design framework and the effectiveness of the training intervention in improving safety performance, a summative comparative evaluation was conducted in this study. It compared the developed PFAS training intervention against a standard PFAS training intervention with respect to (1) users' adoption propensity, (2) expected adoption outcome, and (3) results demonstrability (i.e., an indicator of the performance of the contributing factor, *social influence*, on technology adoption). Formative evaluation was not conducted due to a lack of research resources (time and money).

According to results from the semi-structured interviews, fall-protection training practices varied by company. In other words, training took place frequently/infrequently and formally/informally. Therefore, to remove the influence of individual difference in explaining the adoption measures, a within-subject research design was used. The following describes how threats to internal validity were removed from the experimental design:

First, to remove the testing threat to internal validity, this study counterbalanced the presentation order of the treatments (i.e., the developed and a standard PFAS training intervention). This means that half the participants reviewed the developed PFAS training intervention prior to evaluating a standard PFAS training intervention, and the other half did

the reverse. Second, to prevent participants from rating the developed training intervention higher than the standard training intervention in order to please the researchers, the study's designers informed participants that the two designs were developed by two roofing associations in different states. Third, the study required participants to have experiences in both formal and informal safety training in the past to remove selection threat to internal validity. Fourth, to remove the social interaction threat to internal validity, the study asked participants not to talk about the experiment in front of those who had not yet participated in the experiment.

7.2.2. Independent and Dependent Variables

The independent variable was *PFAS training intervention*, which had two treatments: the developed PFAS training intervention, and a standard PFAS training intervention. The dependent variables were *adoption propensity, results demonstrability*, and *expected outcome of adoption*. The three dependent variables represent intermediate measures for workers' adoption and were used to test the following two stated research hypotheses:

- (H1) The developed PFAS is more likely to be adopted by residential roofing subcontractors than a standard fall-protection training program.
- (H2) The developed PFAS will improve safety performance in small roofing companies more than a standard fall-protection training program.

7.2.3. Apparatus

The apparatus for this portion of the study included a questionnaire for adoption evaluation, the developed PFAS training intervention, and a standard PFAS training intervention. The following describes the development of the questionnaire and a standard PFAS training intervention:

(1) Questionnaire

The purpose of the questionnaire was to measure three constructs, namely the three dependent variables: adoption propensity, results demonstrability, and expected outcome of adoption. The questionnaire along with the demographic questions is shown in Appendix F. Adoption propensity was measured with three items (Q1-Q3), adapted from Hsu, Lu, and Hsu (2007). Results demonstrability (i.e., an indicator of the performance of the contributing factor, *social influence*, on technology adoption) was measured with four items (Q4-Q7), adapted from Moore and Benbasat (1991) and Hsu, Lu, and Hsu (2007). Expected outcome of adoption was

associated with the company's perceived safety performance after adopting the training intervention. This construct was measured with three items (Q8.1-8.3), adapted from Wu, Chen, and Li (2008). To accommodate the questionnaire items within the context of this research, the wording of the items in the questionnaire was reviewed and modified by three SMEs with expertise in construction health and safety. The response categories ranged from 1 to 5 (1 = strongly disagree, and 5 = strongly agree). Participants' responses to the questionnaire items under each construct were summed and averaged. A higher mean rating for *adoption propensity* indicated that a training intervention would be more likely to be adopted. A higher mean rating for *results demonstrability* indicated that a training intervention would be easier to diffuse in the roofing social system. A higher mean rating for *expected outcome of adoption* indicated that a training intervention would be more effective in improving company's safety performance. The questionnaire, along with demographic information, is presented in Appendix F.

(2) Development of a Standard PFAS Training Intervention

As revealed by the semi-structured interviews, most roofing subcontractors did not have their own documented safety-training programs. Some of the companies either occasionally invited safety-training vendors to their company to deliver safety training, or purchased safety training materials from these vendors—mainly to document their safety compliance to OSHA officers in order to avoid citations. It should also be noted that when we examined the various safety training packages available online from government agencies or professional worker associations (e.g., National Association of Home Builders, the National Institute for Occupational Safety and Health, as well as the United Union of Roofers, Water-proofers and Allied Workers), we found that most fall-protection training programs were designed for workers working on heights (e.g., framers, siding workers, roofers, carpenters, and electricians). There were no safety training programs or materials tailored to meet the needs of the small residential roofing industry. Therefore, from our mixed-measures results, there appears to be no "standard" safety training program designed for residential roofing subcontractors. For the purpose of this summative comparative evaluation study, developing a standard PFAS training intervention to be compared with this research's novel training intervention appeared to be necessary.

a) Participants – SMEs

Two SMEs were recruited. One SME was a graduate student majoring Construction Safety and Health and Industrial Management. The other SME was a roofing company's owner who had been working in the roofing industry for 15 years. The standard PFAS training intervention was designed using a safety manual (NRCA, 2009) developed by the National Roofing Contractor Association (NRCA). The NRCA's safety manual was used as the design reference for the following reasons:

- Unlike other safety training programs in the market, the NRCA safety manual
 contains a complete and wide range of critical topics related to roofing safety (e.g.,
 fall protection, asbestos, fire safety, hazardous materials, and driver safety). It is
 especially suitable for roofing contractors who wish to customize a written
 company safety program (NRCA, 2009).
- NRCA is the most respected professional association in the roofing industry with a
 designated staff responsible for safety training, education, and technology
 advocacy.
- NRCA delivers the latest roofing information and best practices on a regular basis and is assigned by OSHA to conduct OSHA's yearly free training courses across the nation.

b) Intervention Development Procedures

Before developing a standard PFAS training intervention, the two SMEs were instructed to review the NRCA's safety manual. Both SMEs then met at the roofing company's owner's office on an agreed date. First, the two SMEs were encouraged to get to know each other on a more personal basis. They were then given the following directions for designing the PFAS training intervention: (1) The intended training intervention was for smaller contractors' safety training, specifically with respect to the use of PFAS; (2) The intended training intervention was to supplement formal (classroom) safety training; (3) The intended training intervention was to facilitate informal training on the worksite via "toolbox talks" on topics of importance.

There were no time constraints for the SMEs to complete their design. Moreover, they were told to take whatever time they needed (within reason) to specify the design features and systems requirements, such as the physical form of the training and the topics or information to be included in the training intervention. The overall design process took three hours and was audio-recorded for future reference.

c) Prototype Development and Finalization

The design features and systems requirements developed by the SMEs are listed below:

- The physical form of the training intervention should be a B4-sized spiral-bound manual with a transparent cover sheet.
- The training intervention should be delivered by managerial personnel. The manual should include an instructions page at the front for the trainer, which contains these sections: Introduction, Instructors' Guide, and Training Objectives.
- Managerial personnel should review all training sheets with new employees and with all employees every three months.
- The training intervention should either be conducted on the worksite or in the company's office. Every trainee should get one copy of the manual during training.
- Every company should have multiple safety training manuals and store them in the
 office. When safety training is required, managerial personnel should have
 sufficient copies on hand to distribute to every worker.
- The training intervention should include training sheets covering the following topical areas:
 - PFAS: Identification of each implement (describing the components of a PFAS and tips and reminders for using it at work)
 - Problems related to safety equipment (describing what to do when witnessing misuse of a PFAS)
 - What to do if there is a fall accident (describing the steps for reacting to a fall incident)
 - Weekly safety meetings (describing company's safety meeting rubrics, e.g., safety training areas, the role of the safety monitor, established penalties for unsafe work practices, and the benefits of participating in safety meeting)

Following these specific design features and systems requirements, the SMEs developed the standard PFAS training intervention in Microsoft Word. The design is shown in Figure 21. All the training sheets can be found in Appendix G. For this study, in order to prevent participants' adoption evaluations being affected by the esthetics of the two compared training interventions, the investigative researcher recommended to the SMEs that they use the same cover page and page template (the blue bars on the top and the bottom) during training intervention in the participatory design phase.

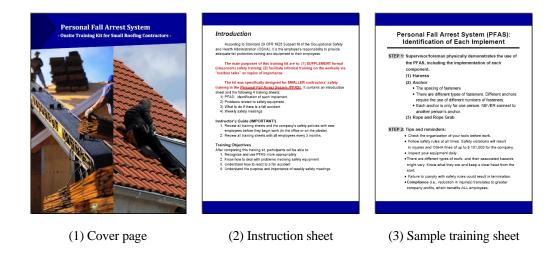


Figure 21: The standard PFAS training intervention (photos obtained from Microsoft Clipart)

7.2.4. Participants

The study used two purposeful sampling techniques, criterion sampling and convenience sampling, to recruit participants. The employed sampling criteria were as follows:

- Participants were required to be roofers working in a construction firm with less than
 20 employees.
- Participants had to be 18 years or older with at least one year of work experience in the residential roofing industry.
- Participants were required to have received both formal and informal safety training in the past.
- Participants were not limited to be managerial personnel.

A total of 18 participants in both rural and urban geographic regions in Virginia participated in this study, including 11 construction managerial personnel (foremen, supervisors, and company owners) and seven workers—all of whom responded to the questionnaire on the worksite. Among the 18 participants, 16 were European-American workers and two were Hispanic workers. Only two participants did not have at least a senior high school degree. The managerial personnel were generally better educated and had more work experience. Twelve of the participants preferred informal safety training, whereas six preferred formal safety training.

7.2.5. Procedure

Before taking the questionnaire, participants signed an informed consent form (Appendix H), which included an assurance of confidentiality and anonymity. The

questionnaire was administered during the participants' lunch break. Before administering the questionnaire, the researcher provided instructions to the participants and guided then on completing the informed consent forms. Participants were told that they could freely withdraw from the study at any time and for any reason.

To control any undesired practice effects, participants were randomly assigned to a control group or the experimental group. Participants in the control group evaluated a standard PFAS training intervention prior to evaluating the developed training intervention, whereas those in the experimental group reviewed the training interventions in the reverse order. Participants completed the questionnaire after each adoption evaluation. They were told to take their time on the evaluations, and were reimbursed a nominal fee for their time and inconvenience.

7.3. Results

A correlation analysis was performed to assess the internal reliability of the questionnaire items for the investigated constructs. Results of the analysis are shown in Table 14. Most of the constructs had a Cronbach's alpha above 0.7, indicating good internal consistency of the questionnaire items. Only one item (*results demonstrability* in the control group) had a Cronbach's alpha below 0.7. To improve the internal consistency of these items, Q7 was removed, which brought up the Cronbach's alpha to 0.79. A possible explanation for the lack of inter-item correlation for Q7 is that some participants may have been confused it with Q4 because both questions began with the same subjects, verbs, objects, and had similar sentence structure.

Table 14: Cronbach's alpha for the constructs in the questionnaire

Construct	Cronbach's alpha – Control group questionnaire items	Cronbach's alpha – Experimental group questionnaire items
Adoption propensity	0.91	0.87
Results demonstrability	$0.68 \rightarrow 0.79$ (after removing Q7)	0.85
Expected outcome of adoption	0.90	0.90

The construct validity of the questionnaire was accessed by a correlation analysis on the mean ratings of *adoption propensity* and *results demonstrability*. Results showed that the mean ratings of these two constructs were correlated, with r(16) = 0.91, p < 0.001 in the control group and r(16) = 0.79, p = 0.001 in the experimental group. These results confirmed the validity of the two constructs' items in measuring the innovation adoption construct.

Figure 22 shows the descriptive statistics associated with this study. From the figure, it can be seen that participants had a tendency to agree to adopt both PFAS training interventions, with the average rating scores above 3. Participants also believed that the training interventions were effective in improving their company's safety performance. Generally, participants rated the developed PFSA training intervention higher than the standard PFAS training intervention across the three investigated constructs.

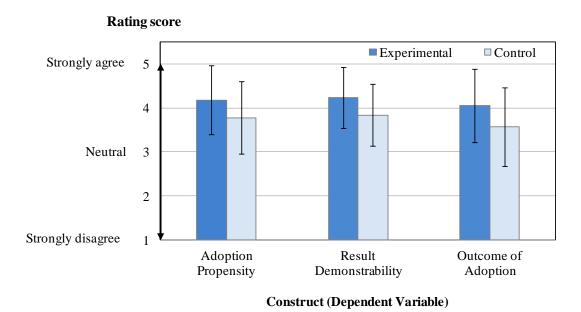


Figure 22: Participants' responses on the two PFAS training intervention

A paired-t test was conducted on participant responses to the developed and standard PFAS training interventions. Results showed that the ratings for all three constructs (dependent variables) were significantly higher on the developed PFAS training intervention, with p < 0.05 (Table 15). The results confirmed the three stated research hypotheses, which suggest that (1) the developed PFAS training intervention is more likely to be adopted and easier to diffuse among roofing subcontractors than a standard PFAS training intervention developed by experts and roofing managerial personnel; (2) using the developed PFAS training intervention can better improve a company's safety performance than using a standard PFAS training intervention; (3) the proposed innovation analytic and design framework is effective in designing a more likely adopted innovation.

Table 15: Results of the paired-t test of the dependent variables

	N	Control	Experimental	Mean difference (SD)	df	t value	P value
Measure		Mean (SD)	Mean (SD)				
Adoption propensity	18	3.78 (0.82)	4.18 (0.79)	0.40 (0.73)	17	2.30	0.034
Results demonstrability	18	3.83 (0.71)	4.23 (0.69)	0.40 (0.52)	17	3.25	0.005
Expected outcome of adoption	18	3.57 (0.90)	4.05 (0.84)	0.48 (0.86)	17	2.35	0.031

^{*} SD denotes Standard Deviation

From participant responses with respect to their intentions for using the two training interventions, this study found that the standard training intervention was perceived to be beneficial to supervisors, whereas this developed training intervention was perceived to be beneficial for *all* workers. Specifically, some participants indicated that the illustrations/pictures in the developed training intervention could facilitate trainer-trainee communications, especially when their jobs included Hispanic workers. Some participants thought that the training information in the standard training intervention was too general and lacked illustrations, making it somewhat less effective for new employees. In addition, most participants liked the design of this study's developed training intervention because it provided training flexibility and concrete examples of unsafe work practices.

7.4. Conclusions and Discussion

As shown in Figure 22, the mean ratings for the three constructs were above 3 for both of the training interventions. This outcome suggested that the investigated interventions were considered effective in improving company's safety performance and were accepted for future adoption. In fact, from the participants' open-ended responses, this study found some fundamental differences between the two training interventions (the novel training intervention developed by the researchers and the standard training intervention), which led to participants preferring this study's developed training intervention. These differences are documented in Table 16, which are divided into the following training approach categories: training approach, user, design, customizability, and package component.

Table 16: Comparison of this study's investigated training interventions and current training packages

	Type of Training Package					
	PFAS Training Intervention (developed by this research)	Standard PFAS Training Intervention (designed by a SME and a roofing company's owner)	Fall Protection Training guides/handbook/packages (developed by government agencies)			
Targeted Worker Population	Residential roofing workers	Residential roofing workers	Workers working on heights			
Training Approach	Bottom-up/top-down Top-down		Top-down			
Usage of Location	Indoor/outdoor environment	Indoor/outdoor environment	Indoor environment			
Training Focus	Safety awareness Safety awareness		Safety knowledge			
Office Equipment	Not required	Not required	Projector			
Package Component	Panel board, laminated training sheets, Warning sign, DVD	Manual	Manual, Brochure, Booklet, DVD			
User	Managerial personnel /worker	Managerial personnel	Managerial personnel /worker			
Design	Image-based	Text-based	Text-based			
Customizability	Yes	No	Yes			

With respect to the intervention's training approach and user, the developed training intervention was designed to be conducted through a two-way (bottom-up and top-down) approach. In other words, all workers (including managerial personnel and employee) would be encouraged to participate in safety training. Therefore, safety training would no longer be ruled by the voice of one person alone—every worker could be the user (i.e., trainer) and present his/her views of how to prevent falls on the worksite. Safety training would be effective through this approach because as noted by Marsick and Watkins (1990), learning,

problem definition, problem solving and reflection could be shaped in the workplace via natural opportunities that workers encounter (Cseh, Watkins, & Marsick, 1998). The standard training intervention, conversely, is designed to be conducted through a top-down traditional approach, that is, by managerial personnel. This means that the safety information workers receive results from what is thought to be beneficial for them by others, which may or may not fit their actual training needs.

With respect to the design of the intervention, the developed training intervention mainly uses pictures, graphics, and illustrations to present safety information. As commented by most participants in this study, this design approach tends to enhance trainer-trainee communications during safety training. Conversely, the standard text-based training intervention for transmitting safety information may be challenging for workers with reading difficulties. And as documented by a significant body of research, images and pictures have been shown to be more effective than text alone in transmitting and communicating safety and health information (Bust, Gibb, & Pink, 2008; Leiner, Handal, & Williams, 2004). It comes as no surprise, then, that the developed training intervention received higher mean ratings across all measurements.

With respect to customizability (i.e., the ability for an intervention to be changed by its user) and package components, the developed training intervention allows roofing subcontractors to add, remove, and update the training sheets using the files in the DVD. The panel board also allows trainers to write and draw additional safety information. As commented by participants, this design feature adds training flexibility, improves its mobility to different jobsites, and improves communications with Hispanic workers. In contrast, the standard training intervention does not enable trainers to update training information. Instead, it was designed for the purpose of easily delivering safety policy, rubrics, and work procedures on a regular basis.

It should be stressed that customizability is very important for implementing safety training in the small residential construction industry because of its high worker turnover and typical subcontracting business patterns. Subcontractors generally employ workers with differing work skills and experiences, making safety training more challenging than that in larger construction firms. In addition, modifying a fall protection plan is sometimes required by "higher-ups." According to OSHA Instruction STD 3.1 (U.S. Bureau of Labor Statistics, 1999a), employers need to train workers to know the procedures the company chooses to implement for preventing falls should they find that conventional fall protection is not feasible on a particular worksite. Therefore, a fixed safety-training package will not satisfy

the training needs for all residential construction projects.

Table 16 also illustrates the differences between the developed PFAS training interventions and the fall-protection training packages developed by government agencies, such as the National Association of Home Builders (2007) or Oregon's OSHA (2010). In general, these training packages are designed for any worker working on heights. The training information is organized by various topics around fall protection, but not by trade. In addition, these packages are heavily text-driven and are published on the Internet—making it hard for computer-illiterate and low-educated workers to get the full benefit of such training.

Moreover, despite the fact that most of these packages claim that they are designed for both managerial personnel and workers, their information seems to target managerial personnel, instructing them what to train and how to do it. Another focus of these training packages is that they seem to focus on delivering safety knowledge in formal classroom settings rather than enhancing safety awareness on the worksite. Overall, such unbalanced top-down training approaches should be considered substandard for improving workers' health and safety.

From comparisons shown in Table 16, the design of this research's developed training intervention is valuable to roofing subcontractors. It should be noted, however, that the mean ratings this intervention received from participants were above four—but not close to five. This lower composite score may have resulted from two possible reasons: (1) some participants' companies might have already had effective training programs in place for their employees, and (2) some participants voiced their desire for *more* training areas to be included in the intervention. Therefore, a future study is needed to obtain a deeper understanding of the shortcomings of this research's developed training intervention.

7.5. Limitations

The limitation of this study is that this study adopted a proxy measure approach for workers' adoption of the developed training intervention. Although this approach has been validated for predicting actual adoption outcomes, it was not a direct measurement, thus limiting a fuller picture of workers' adoption behaviors. As noted by Rogers (1995), measuring innovation adoption is complicated. A future study is required for obtaining a richer assessment of workers' adoption of a specific training intervention—for example, by measuring long-term changes in safety behaviors and organizational safety culture.

In addition, this study used an open-ended question at the end of the questionnaire to investigate participants' intention of adoption, which may only capture the likes and dislikes

of certain features of the given training interventions. This data collection technique could not reveal much open-ended information about what led to those likes and dislikes, as well as how and whether the intervention design facilitated the intervention's diffusion and adoption. Despite that the amount of data was not abundant to draw a full picture of participants' adoption intention, the data was sufficient to highlight some key features of the two training interventions that influenced participants' adoption propensity.

8. CONCLUSIONS

8.1. Summary of the Research

With advances in a variety of information technology systems, research efforts were initiated to broadly study the diffusion and adoption of information and communication technology (ICT), and then apply that knowledge to a particular domain, namely the small residential roofing industry. A variety of research approaches were used to study ICT use and adoption, such as adoption, diffusion, and domestication. Although these approaches differ in their approaches—such as studying adoption challenges at the individual level versus the global level—they do have much in common. For example, the perceived innovation attributes used in diffusion research include commonly-used constructs from adoption research—i.e., perceived usefulness and ease of use.

The purpose of this research was to propose an innovation analytic and design framework that synthesizes current research approaches in ICT adoption in designing an innovation that not only has good product usability, but also has a higher chance of being adopted by users. The proposed innovation analytic and design framework is built upon the traditional systems design process: Requirement Analysis, Prototype Development, and Summative Evaluation. Rogers' Theory of Innovation Diffusion and Adoption was used to enhance Requirement Analysis to capture the design features and systems requirements that could lead to users' adoption. Participatory design (PD) was used to enhance Prototype Development to capture the design features and systems requirements that would facilitate the users' adaptation and adoption process of the proposed innovation. For this study, the described framework was used to design a fall-protection training intervention to help address a long-standing problem in the small residential roofing industry. The following sections summarize the developmental process of the intervention and the validation of the framework.

8.1.1. Requirement Analysis

Our use of requirement analysis employed a mixed-methods research approach (consisting of a questionnaire and semi-structured interviews) to obtain different but complementary insights on user needs, systems requirements, and factors affecting the adoption of safety technology among roofing subcontractors.

(1) Questionnaire

The questionnaire used in Requirement Analysis was developed through pre- (i.e., face and content validity) and post-data collection assessments of validities (i.e., reliability and construct validity). It included 5 constructs and 23 questionnaire items. Four of the 5 constructs (perceived attributes of an innovation, communication channel, social system, rate of adoption) reflect the major components of Rogers' Theory of Innovation Diffusion and Adoption. They were used to identify significant contributors for workers' adoption of a particular safety technology. The remaining construct—perceived fall-protection training needs—reflected OSHA's training requirements. It was used to identify user needs and systems requirements.

The face validity of the questionnaire was gauged by 4 subject matter experts (SMEs) with related subject matter expertise—each of whom reviewed and commented on the wording of the questionnaire items. Content validity was assessed by 11 SMEs who rated the essential level of every questionnaire item in addressing the designated construct. The reliability of the questionnaire items was assessed through the Cronbach coefficient alpha via correlation analysis. Twenty-three questionnaire items were retained once the reliability assessment had been concluded. The construct validity of the 23 items was assessed through factor analysis, which yielded 4 factors (perceived compatibility with safety needs, perceived ease of use, social influence, and perceived fall-protection training needs) accounting for approximately 70% of the variance in the data set. Among the 4 factors, "perceived compatibility with safety needs" and "perceived ease of use" reflected Rogers' (1995) "perceived attributes of an innovation" construct, while "social influence" encompassed Rogers' "communication channel" and "social system" constructs. The items for "perceived fall-protection training needs" all loaded on the same factor addressing OSHA's training requirements. Results of the factor analysis showed high construct validity of the questionnaire.

Using the purposeful sampling approach, the validated questionnaire was then mailed to 128 participants from 29 small roofing companies in Virginia and North Carolina. Among those returned, 104 were considered to be useful for data collection. Overall, results showed that most participants preferred informal training and desired to receive more fall-protection training in every aspect required by OSHA. In addition, to verify the research hypothesis—namely, that the theoretical components of the proposed innovation analytic and design framework could predict the rate of the adoption of safety technologies—a logistic regression analysis was conducted. Results of the analysis concluded that the construct "inter-social influence" was effective in predicting "rate of adoption."

(2) Semi-structured Interviews

The purpose of the semi-structured interviews was to develop a deeper understanding of the findings from the questionnaire, as well as to get a better grasp the practices of safety technology adoption and fall-protection training among roofing subcontractors. Twenty nine participants who completed the questionnaire volunteered to play a part in the semi-structured interviews. Content analysis with a grounded theory approach was conducted to analyze participants' responses.

Results of the analysis showed that the influence of various communication channels (primarily managerial personnel, word of mouth, and retailers) on safety technology adoption cannot be separated from the influence of the social system (such as the conservative culture of innovation adoption and the workers' inability or reluctance to obtain safety technology information). These results explained the convergence of "communication channel" and "social system" in the factor analysis and suggested that, to improve workers' adoption of a fall-protection training intervention, the features and the use of the intervention should be obvious for easier acceptance. For example, the training intervention should use a technology that can be easily understood and communicated among roofing professionals.

The content analysis also revealed the barriers to receiving safety training, which included satisfaction with the status quo of safety performance, as well as frequent job rotation. From participants' responses, these barriers could be overcome by (1) management mandate, (2) demonstration of negative consequences of unsafe work practices and positive consequences of safe work practices, and (3) punitive measures. Among the three recommendations, management mandate and punishment were argued to have a somewhat transitory effect on construction health and safety (Yee, 2000). Conversely, demonstrations of positive/negative consequences of safe/unsafe behaviors were linked with enhanced safety awareness and prolonged good safety behaviors (Lingard, 2002). This feature, therefore, was considered to be essential in the development of a fall-protection training intervention. In fact, during the interviews participants stated that through awareness of consequences, workers would better appreciate and accept a company's introduced safety programs.

The analysis also identified two troublesome problems of formalized safety training programs: (1) instructors were not always considered knowledgeable, and (2) safety training that was taught in class was often different from what was practiced on site. According to participants, these problems made them feel disengaged in safety training. This problem of disengagement suggested that the study's intended fall-protection training intervention should

encourage engagement or even participation in safety training—such as giving workers opportunities *to* talk in order to learn, not to learn *from* talk.

In addition, with respect to workers' fall-protection training needs, this research found that participants preferred safety training to be implemented on the site with knowledgeable personnel, physical demonstrations, and hand-on materials. This study also found that participants wanted to receive training on PFAS, safety awareness, as well as the consequences of safety violations. Additionally, they wanted to see graphical presentations of training information—either in hard copies or via any nedia they could easily access in their lives (e.g., DVDs).

8.1.2. Prototype Development

The purpose of Prototype Development was to work with users to develop a fall-protection training intervention that better fit their work culture and context. This study conducted a PD workshop with two SMEs and four roofing professionals. The workshop was held on two consecutive days, comprising three sessions: Introductory Session, Critique and Fantasy Session, and Design Session. To encourage idea inspiration and generation in a structured and systematic manner, key features of the following PD techniques were utilized to organize the PD workshop:

- (1) **Future Workshop**: The highly-structured design process of Future Workshop was used to provide a roadmap regarding what to do in every session.
- (2) **Scenario Building**: Scenario Building was used to quickly involve all PD members in every investigated problem domain.
- (3) **PICTIVE**: The idea of "shared design surface" in PICTIVE was used to create a design space on a whiteboard to facilitate shared communication and design activities.
- (4) **Inspiration Card Workshop**: The concepts of domain cards and technology cards in Inspiration Card Workshop were used to develop thematic color-coded Post-it notes and design materials to inspire the generation of ideas.

The apparatus used in the workshop featured the following components: design materials (e.g., a collection of safety training materials and instantiations of safety training technologies), color-coded Post-it notes (for categorizing design recommendations and ideas from the semi-structured interviews), and a shared design space on a whiteboard. During the

Introductory Session of the PD workshop, the PD members were "warmed up" with an explanation of the study and a review of sample injury cases. The findings from the questionnaire and the semi-structured interviews (e.g., themes, codes, and code frequencies) were presented to participants during the Critique and Fantasy Session to make sure everyone had the same level of understanding of the problem domain. These findings were converted into Post-it notes categories and treated as design materials to be used during the Design Session. In this final session, the PD members decided to focus on designing a PFAS training intervention because of the limited availability of participants. Using all provided design materials, members explored design possibilities on the shared design space. At the end of the workshop, the design features, elements and systems requirements of a PFAS training intervention were specified and laid out on the design space. The intervention was later designed by this study's principal investigator and then evaluated by 2 SMEs based on transcripts of the PD workshop. The following items describe how the features of the proposed PFAS training intervention could improve diffusion/adoption and enhance safety awareness:

- The panel board and laminated paper sheets are low-tech materials known by most workers, enhancing its ease of use. Its maintenance and diffusion is straightforward and does not require any technical skills and knowledge.
- The use of the training package is not restricted by the environment. Its size works in any setting—especially for safety "toolbox talks" with a small group of workers on the jobsite.
- The safety information is presented with charts, images, and pictures. Therefore, they
 can be easily understood and communicated in safety training and among roofing
 subcontractors and workers, some of whom may be Spanish-speaking.
- The safety information emphasizes the monetary losses associated with unsafe work practices—e.g., loss of pay from injuries or serious citations (very important to roofing workers), OSHA fines, and increased insurance premiums. Interestingly, according to the roofing professionals in the PD workshop, they did not feel they knew enough about specific monetary consequences of dangerous work behaviors, but wanted to know more to prevent unsafe work practices.
- The training intervention encourages worker participation. It recommends that workers
 take turns presenting this information to coworkers by demonstrating PFAS use and the
 negative consequences of unsafe work practices. According to the roofing professionals

in the PD workshop, workers' safety awareness will increase by participating in safety talks and presentations.

8.1.3. Summative Evaluation

The goal of the summative evaluation was to verify the efficacy of the proposed innovation design framework in designing an effective and more likely adopted innovation. A within-subjects summative comparative evaluation was conducted to compare the developed PFAS training intervention against a standard PFAS training intervention with respect to (1) adoption propensity, (2) expected adoption outcome, and (3) results demonstrability. A questionnaire was developed to measure these three constructs. For this study, a standard PFAS training intervention was developed by an SME and a roofing company owner using the safety manual developed by the NRCA. Eighteen participants were recruited to answer a questionnaire concerning the two interventions. The resulting descriptive statistics showed that both safety training interventions were considered helpful in reducing fall injuries and acceptable for future use. A paired- t test was conducted to compare the ratings of the two interventions with respect to the investigated constructs, as well as to test the following hypotheses:

- The developed fall-protection training intervention is more likely to be adopted by residential roofing subcontractors than a standard fall-protection training program.
- The developed fall-protection training intervention will improve safety performance in small roofing companies more than a standard fall-protection training program.

Results of the paired-t test confirmed the hypotheses and the efficacy of the proposed innovation design framework. They confirmed that with respect to adoption propensity, participants had a greater intention to adopt the developed training intervention over the standard model. Regarding results demonstrability, participants felt that this study's developed training intervention would be easier to diffuse in the roofing social system. In addition, with respect to the expected outcome of adoption, participants agreed that this study's developed training intervention was more effective in improving their company's safety performance. Based on participants' open-ended responses, the following summarizes what could have contributed to the rating differences.

First, the training approaches are different. The standard training intervention features a top-down training approach as opposed to the two-way training approach used by its

counterpart. This was considered to be more beneficial to both managerial personnel and workers in their ongoing training efforts. Second, with respect to training information design, the standard training intervention employs text-based training information as opposed to the image-based training information used by its counterpart. According to participants, images did help communicate safety training information, especially for Hispanic trainees. Moreover, several participants noted that the information in the standard training intervention was presented with bullet point guidelines, leading them to comment that the standard intervention might be better as a review for current employees and/or an overview for new employees. Third, with respect to intervention customizability, the standard training intervention is not designed for customization. Its use is not as flexible as its counterpart, which can be tailored to fit the training needs of different skilled staff on different roofing projects.

8.2. Research Contributions and Implications

The research has contributed to the existing research on technology diffusion/adoption and OHS issues—especially in small-scale construction—as discussed in the following two assertions. The implications of this research are also addressed.

First, with regard to contributions related to technology diffusion/adoption, the proposed innovation analytic and design framework synthesizes differing research approaches in the field of technology diffusion and adoption. The framework provides researchers a holistic approach for studying technology adoption challenges and opportunities. The framework also provides engineers and designers a road map for designing an interface that not only has good usability, but also has a better chance of being adopted by users. In addition, the developed questionnaire could be used by researchers and practitioners to investigate the adoption challenges of any applicable technologies (such as mobile technology) in construction trades other than roofing. The questionnaire can also be modified to study innovation diffusion and adoption challenges in other research domains (e.g., healthcare, business, agriculture, and the military). Furthermore, the PD workshop in this research was conducted with the use of four PD techniques, which successfully engaged the PD members in various design and idea-generating activities in a structural and systematic manner. This approach—which used a combination of the strengths of various PD techniques—could be leveraged by other construction safety practitioners to design job-specific safety innovations to promote worksite safety. It also has implications for product designers to design a PD workshop that is tailored to satisfy their project goals.

In addition, this research reveals the impact of 'social influence' on the diffusion and adoption of safety technology in the small roofing industry. The result can be used by construction safety practitioners to design strategies to successfully disseminate safety-related measures, programs, and equipment to reduce fall injuries and accidents. This study's results have implications with respect to a reexamination of the impact of the perceived attributes of an innovation in innovation diffusion and adoption. This claim is associated with the fact that a good number of ICT studies are based on the assumption that perceived attributes of an innovation explains 80% of its rate of adoption (Rogers, 1995). Socio-technical factors are often excluded from research models.

Second, with regard to OHS-related contributions (especially in small-scale construction), this research addresses five strategic goals of the NORA (NIOSH, 2008)–Falls, Construction Health and Safety Culture, Construction Health and Safety Management, Safety and Health Training and Education in Construction, and Construction Hazards Prevention through Design. This research also identifies the safety-training needs of the residential roofing subcontractors, which has not been explicitly addressed in the construction literature, and illustrates how these safety training needs are different from OSHA's safety training requirements. The insight has implications for a reexamination of safety-training needs and safety policies in construction and other small high-risk industries in health care and manufacturing.

In addition, this research identifies the material data safety sheet a potential tool for communicating roofing safety training information (e.g., a quick guide for OSHA's safety regulations or even self-rescue procedures), which provides just-in-time assistance in safety training and in resolving safety challenges. Putting safety information in the MSDS is a practicable approach because construction employers are required to have a MSDS in the workplace for each hazardous chemical that they use (e.g., single-ply roof system adhesive) (OSHA 29 CFR 1910.1200).

This research also identifies the value and importance of informal safety training in small construction safety training and why formalized safety training has had a hard time penetrating the small roofing community in effective ways. It also identifies how informal safety training is different from formalized safety training, and why informal safety training should complement formalize safety training to improve safety performance. This insight has implications in designing effective safety training programs in other occupation domains.

The outcome of this research (our PFAS training intervention) represents an important initiative in small construction safety training, which demonstrates the value of informal safety training. The design features of the intervention (e.g., worker participation, pictorial information, and two-way training approach) provide construction safety practitioners insights in designing more likely adopted safety programs for other trades. This research has implications for the design of safety training and educational programs in other settings, such as healthcare, the military or human resource development interventions in the global workplace.

8.3. Limitations

The purpose of this research was to propose an innovation analytic and design framework and validate its efficacy in designing a more likely adopted innovation. This research did not perform multiple design iterations (including formative evaluations and several PD workshops) to develop a flawless PFAS training intervention. However, its design outcome was expected to capture key design features through one design iteration (Nielsen, 1993), which was used to verify the proposed innovation design framework.

This research was primarily conducted at construction worksites. Thus, the collected data might have been influenced by environmental noise (people, machinery, phone calls, and weather). The data's validity could have also been impacted by the participants' timeframe for completing the questionnaire/interviews, and participants' mood and mental concentration at the time of the exercises. It should also be stressed that this research did not try to provide a comprehensive analysis of fall-protection training practices and safety technology adoption challenges across all construction trades. Rather, it was designed to investigate significant phenomena with respect to fall-protection training and safety technology adoption typically seen in the small residential roofing industry. Furthermore, the participants in this research study (from North Carolina and Virginia—i.e., the Appalachian region) were not randomly drawn from every ethnic worker group on a national basis. The regional effect (Scott, 2009) and the fact that smaller contractors (typically family-owned firms) enjoy the benefits of family ties in the workplace (Marshall et al., 2006) made it difficult for the PI to recruit African-American workers.

An additional limitation concerned the reading level of participants. Since the reading level of the training instructions was determined to be a 9.5 (meaning that a ninth-grader should be able to understand them), this level might have imposed reading challenges for workers with literacy difficulties. Thus, the developed training intervention may not work for every worker.

It should be stressed that this research defined a "safety technology" as a piece of safety equipment or a safety training program. Thus, insights gained from studying safety technology adoption practices could also inform the design of safety and fall prevention innovations (e.g., a personal fall-arrest system, or a self-rescue landyard/ladder) that would be more likely to be adopted by residential roofing subcontractors. However, it cannot be assumed that these same insights could then be used to design safety innovations for other construction trades because of the disparate job-specific work conditions and environmental constraints (Parshall & Struttmann, 2003).

Another limitation concerns the differences between the interviewer and the participants with respect to ethnicity, language, occupation, and work experiences. These discrepancies could have caused participants to consider the interviewer as a construction health and safety "outsider," which might have negatively impacted their willingness to address actual technology adoption and safety training challenges. With this limitation in mind, the PI tried to minimize the impact of any differences by talking with participants to put them at ease, highlighting the importance of their candid responses in reducing OHS challenges in the roofing industry, as well as providing contact information for research follow-ups.

Another important limitation related to this research is that, generally, it could take one year or even several years to determine whether a user voluntarily or mandatorily adopts an innovation—or completely rejects all or part of a suggested innovation. However, given the limited resources and time constraints associated with this research, the investigative team could not track the workers' adoption of the investigated training interventions over a long period of time. Therefore, in the future—and if time and resources allow—longitudinal adoption research should be performed to confirm the efficacy of the developed training intervention in OHS problem solving.

8.4. Future Research

Product development is an iterative process that involves repetitive design, testing, evaluation and refinement (Norman, 2002). Future research should include an iterative design process to make sure whether the proposed design framework is effective in designing a more likely adopted innovation, as well as to verify whether the developed PFAS training intervention consists of all necessary features to facilitate users' adaptation and adoption progress after the intervention is distributed. The iterative design process might include more PD workshops and formative evaluations with end users to improve the design of the training intervention. In addition, more participants should be recruited to contribute to future studies,

especially African American and other ethnic workers—as well as those in other geographic areas—to refine the research findings and outcomes. Further research should also consider developing a complete informal fall-protection training program that includes other topics such as fall-hazard identification, ladder use, and safety-regulation comprehension.

As documented herein, this research identified the importance of informal safety training in the small roofing industry. This finding is in accordance with the informal-learning literature in different occupational contexts (Conlon, 2004; Cseh, Watkins, & Marsick, 1998). In the context of construction health and safety training, future research should investigate how to implement informal safety training effectively, how to use informal training to enhance formalized safety training, and even how to structure an informal learning philosophy that improves a worker's aptitude for protecting him/herself when working at heights.

As argued byAnumba (1998), poor dissemination of research results epitomizes a persistent barrier to the adoption of innovations in the construction industry. Therefore, in addition to disseminating the research results through the conventional academic outlets (e.g., publication in journals and conference proceedings), this research should investigate how to leverage the power of social influence to effectively distribute the research outcome to industry practitioners, as well as how to deploy the research outcome within construction roofing organizations. Possible industry-focused dissemination conduits to be studied include demonstration workshops, provision of demonstration disks, retail advertising, as well as promotions of industry organizations and professional bodies.

According to the demographic information provided by participants in this study, construction roofing workers tend to be less educated. To ensure that an assigned trainer has no difficulty using the developed training intervention, the training instructions should be written in a way that can be easily understood by and accessible to low literacy workers so that they will not encounger any comprehension difficulties. In the case of small companies with limited resources, the cost for training the instructors could be reduced as well.

In addition, the advancement and popularity of electronic papers (Genuth, 2007) and mobile device platforms might change the way people read and write in the near future. Intervention research in fall-protection training and workers' preferred physical form of training materials should also be re-evaluated on a constant basis. To sum up, the overarching purpose of this research was to present a method to researchers and designers for developing a more likely adopted innovation to improve the health and safety of workers. The test bed was a fall-protection training intervention intended to reduce the notoriously-persistent rate of fall injuries and accidents in the roofing industry. It is the hope of this researcher that government

agencies (especially NIOSH and OSHA) will benefit from this study's results in order to better understand the safety training needs of construction subcontractors in their attempt to design and deploy more effective and widespread safety training interventions.

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APPENDIX A1: SAFETY TECHNOLOGY DIFFUSION AND ADOPTION QUESTIONNAIRE (ENGLISH)

e	purposes of this rese	arch are to gain infor	mation on:				
			tion safety tools or equip ning is conducted in you		and whethe	r there is room for imp	rovement).
	Age:	Gender: □ Male □	Female				
•	Job Title: Constru	uction Owner	onstruction Supervisor	\square Foreman		□ Worker	
	Ethnicity: African	n American/Black	ispanic/ Latino	□ Caucasiar	n/white	□ Other:	
•	Education (Highest A	ttended):					
	□ Elementary		liddle/Junior High School	□ Senior Hi			
	□ Community		our-year College	□ Beyond 4	year degree		
.		eld do you work in? (Ch	eck all that apply)				
	□ Roofing	□ Painting	□ Wood Framing		Siding		uttering
	□ Masonry)	□ Water & damp pr	-	Steel Erecting	g/ Sheet-Metal Work	Other
•	= -	-	ing industry?	year(s)			
•		workers) of your compa	•				
		□ 6-10 □ 11-2			not know		
3.	-		pically done in your comp	any?			
		s not provide fall-protect					
	-	-	(ex. senior workers guide/te	ach others on	the sites)		
	•	aining is done formally (e	ex. presentations)				
	□ I do not know						
•			rograms for you? (check al	ll that apply)	a :	-	
	□ Do not have	□ Owner	= 1.141145¢1		□ Supervisor		
	□ Senior worker	☐ Insurance company	•	l association		ent agency – OSHA, NIOS	
	□ Equipment manuf		☐ Private consultant		□ Other:	□ I de	o not know
).	I prefer fall-protection	=					
			thers) \Box Formally (with pro-				
۱.	•	· ·	be delivered through: (che		•		
	□ MSDS (Material	•	□ Documents created	·		My personal computer	
	□ My daily-used mo	obile device (ex. cell pho	ne, blackberry, or palm pilot) Drock	ket-sized note (cards Other:	

<u>Safety equipment</u> in the questionnaire can be referred to any of the following. Please check the box that best fits your response.

















Safety training materials Guardrails Harnesses Lifelines/lanyards with hooks Gloves Hard hats Steel toed shoes/boots Face shields/masks

Safety training materials Guardrails Harnesses Lifelines/lanyards with hooks Gloves Hard hats Steel toed shoes/book	ts Face	shields/ma	sks		
1. I am more likely to adopt new construction safety equipment if:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
■ It is better than the one I am using.					
■ It is compatible with my work					
■ It is easy for me to use, access, and/or operate					
■ I have the opportunity to try it out multiple times.					
■ I can see positive results from other people's use (ex. productivity gains, safety record improvements)					
2. Who shows you new safety equipment?	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
■ Co-workers.					
■ Managers (ex. owner, supervisors or foremen).					
■ General contractors, subcontractors.					
■ Construction equipment manufacturers or retailers.					
■ Professional work associations and/or organizations, educational institutions, government agencies, or insurance companies.					
■ Mass media (ex. Internet, TV, newspapers, posters, or magazines).					
3. In my company, the adoption of new safety equipment is often decided by:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
■ the managers (ex. owner, supervisors or foremen)					
■ every individual worker					
■ the general agreement of 'every' member from the owner to the employees.					
4. At least one person:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
■ among my co-workers can influence other individuals' decisions to adopt new safety equipment					
■ from outside my company (ex. equipment manufacturers, retailers) can influence the workers' decisions to adopt new safety equipment					
5. The average worker in my company can adopt new safety equipment more quickly than expected.					
6. Generally speaking, my company does not like to adopt new safety equipment.					

In the following, <u>Fall Protection Systems</u> refer to: (1) Guardrails, (2) Fall arrest systems, (3) Safety nets, (4) Warning lines, (5) Safety monitors, and (6) Controlled access zones, etc. Please check the box that best fits your response.

7. Which piece of information should be added to your company's training program to avoid falls?	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
■ Identification of possible onsite fall hazards.					
■ Ways to minimize fall hazards for OSHA compliance.					
■ What to do when a safety monitoring system is in place.					
■ What to do in my company's alternative fall protection plan when the use of traditional fall protection systems is not feasible					
■ Limitations of mechanical fall-protection systems used for roof work					
■ Standard procedures for ■ Maintaining, disassembling, and inspecting fall protection systems					
■ Using fall protection systems.					
■ Handling and storing mechanical equipment used for work on low-sloped roofs					
■ Handling and storing roofing materials					
■ Putting up overhead protection systems					

APPENDIX A2: SAFETY TECHNOLOGY DIFFUSION AND ADOPTION QUESTIONNAIRE (SPANISH)

-	ropósito de esta investigación es reunir información sobre:
	Que factores influencian su decisión de usar herramientas o equipo de seguridad para construcción.
(2) P	rácticas de entrenamiento para protección de caídas (Como son llevados a cabo los entrenamientos en su lugar de trabajo y si hay cosas que se pueden mejorar).
1.	Edad: Género: Masculino Femenino
2.	Puesto de trabajo: □ Dueño de la compañía de construcción □ Supervisor de la construcción □ Capataz □ Trabajador general
3.	Etnicidad: Afro americano/Negro Hispano/ Latino Caucásico/blanco Otro:
4.	Educación (Nivel más alto alcanzado):
	□ Escuela primaria (de primer a sexto curso/grado) □ Escuela Secundaria □ Bachillerato o Instituto
	□ Primeros dos años de Universidad □ Cuatro años de Universidad □ Posgrado Universitario
5.	¿En que campo de la construcción trabaja? (Marque todos los que apliquen)
	□ Techos □ Pintor □ Estructuras de madera □ Revestimiento externo (apartadero) □ Concreto (cemento) □ Canaletas o Canalones externos
	□ Albañilería □ Revestimiento de paredes internas □ Impermeabilización contra agua y humedad □ Revestir de concreto □ Rejillas y alcantarillado □ Otros
6.	¿Cuánto tiempo ha estado trabajando en la industria de los techos? años (s)
7.	¿Cuántos trabajadores hay en su compañ ía (# de trabajadores)?
	□ 1-5 □ 6-10 □ 11-20 □ Más de 20 □ No sé
	□ Comunicar situaciones de trabajo □ Uso personal □ Buscar información □ Entretenimiento (juegos, películas, etc.) □ Otro:
8.	¿Cómo se llevan a cabo típicamente los programas de entrenamiento para la protección de ca ídas en su compañ ía?
	□ Mi compañía no nos da entrenamiento para la protección de caídas.
	□ Los entrenamientos para la protección de caídas son hechos <u>informalmente</u> (ejemplo. enseñados por trabajadores experimentados)
	□ Los entrenamientos para la protección de caídas son hechos formalmente (ejemplo: presentaciones, cursos cortos)
	□ No sé
9.	¿Quién o quiénes generalmente organizan los programas de entrenamiento para protección de caídas ? (Marque todas las opciones que apliquen)
	□ No recibo entrenamiento □ Dueño □ Gerente □ Supervisor □ Capataz
	□ Trabajador experimentado □ Compañía de seguros □ Asociación profesional de trabajadores □ Agencia de gobierno OSHA, NIOSH
	□ Fabricante del equipo de seguridad □ Consultor privado □ Otro: □ No sé
10.	Prefiero que los entrenamientos para protección de caídas sean hechos:
	□ <u>Informalmente</u> (ej. Enseñados por trabajadores experimentados) □ <u>Formalmente</u> (ej. Presentaciones, cursos cortos)
11.	Prefiero que los materiales didácticos de los entrenamientos sean presentados a través de: (marque todos los que apliquen)
	□ MSDS (Hoja de datos de materiales de seguridad) □ Documentos creados por el conferencista □ Computadora personal o laptop
	☐ Mi aparato móvil de uso diario (ej: teléfono celular, blackberry, o palm pilot) ☐ Tarjetitas informativas (tamaño bolsillo) ☐ Otros:

Los siguientes equipos de seguridad pueden ser a los que nos referimos en el cuestionario son los siguientes.. Por favor marque la casilla que mejor exprese su respuesta.

















Materiales de entrenamiento de seguridad Barandillas Arnés Cuerda de salvamento /cordón de seguridad Guantes Cascos duros Zapatos con punta metálica Mascarillas de seguridad y cubre bocas

Mascarillas de seguridad y cubre bocas					
1.Es más probable que me adapte a nuevos equipos de seguridad para construcción si:	Completa- mente en desacuerdo	Estoy en desacuerdo	Neutral	Estoy de acuerdo	Completa mente de acuerdo
■ El nuevo equipo de seguridad es mejor que el que estoy ocupando actualmente					
■ Es compatible con mi trabajo					
■ Es fácil para mi de usar, accesar y/o operar					
■ Tengo la oportunidad de probarlo varias veces.					
■ Puedo ver resultados positivos de otras personas que lo usaron (ej. Mejoras en productividad, mejor historical de seguridad)					
2. ¿Quién le muestra los nuevos equipos de seguridad?	Completa- mente en desacuerdo	Estoy en desacuerdo	Neutral	Estoy de acuerdo	Completa mente de acuerdo
■ Compañeros de trabajo					
■ Gerentes (ej. Dueños, supervisores o capataz)					
■ Contratistas generales, subcontratistas					
■ Fabricantes o vendedores de los equipos de seguridad					
■ Asociaciones profesionales de trabajo y/o organizaciones, instituciones educacionales, agencias gubernamentales o compañías de seguros.					
■ Medios de comunicación (Ej. Internet, TV, periódicos, pósters, o revistas)					
3. En mi compañ ía, quienes generalmente deciden la adopción de nuevos equipos de seguridad son:	Completa- mente en desacuerdo	Estoy en desacuerdo	Neutral	Estoy de acuerdo	Completa mente de acuerdo
■ Los gerentes (Ej. Dueño, supervisores o capataz).					
■ Cada trabajador					
■ Acuerdo general de todos los miembros desde el dueño hasta los empleados.					
4. Por lo menos una persona:	Completa- mente en desacuerdo	Estoy en desacuerdo	Neutral	Estoy de acuerdo	Completa mente de acuerdo
■ dentro de mis compañeros de trabajo puede influenciar las decisiones de otros individuos para adoptar nuevos equipos de seguridad.					
de seguridad					
5. El trabajador promedio en mi compañ ía puede adoptar nuevos equipos de seguridad mas rápido de lo esperado					
6. En general, a mi compañ ía no le gusta adoptar nuevos equipos de seguridad.					

En la siguiente sección, los sistemas de protección contra caídas se refieren a: (1) Barandillas, (2) Arnés, cuerda de salvamento /cordón de seguridad, (3) Redes de seguridad, (4) líneas de advertencia, (5) monitores de seguridad, (6) Zonas de acceso controlado, etc. Por favor marque la casilla que mejor exprese su respuesta

7. ¿Que información debería de agregarse al programa de entrenamiento para evitar caídas usado en su empresa?	Completa- mente en desacuerdo	Estoy en desacuerdo	Neutral	Estoy de acuerdo	
■ Identificación de los posibles riesgos de caídas en su sitio de trabajo.					
■ Maneras de minimizar riegos de caídas para cumplir con las regulaciones de la OSHA					
■ Que hacer cuando hay un sistema de monitoreo de seguridad					
■ Que hacer en el plan alternativo de protección de caídas de mi empresa cuando el uso de los sistemas tradicionales de protección contra caídas no funcionan					
■ Limitaciones en los sistemas mecánicos de protección contra caídas utilizados para trabajos en techos					
■ Procedimientos estándar para ■ Mantener, desarmar, e inspeccionar sistemas de protección contra caídas					
■ Usar sistemas de protección contra caídas					
■ Manejo y almacenamiento de equipos mecánicos utilizados para trabajar en techos de poca inclinación					
■ Manejo y almacenamiento de materiales para techar					
■ Poner sistemas de protección que protegen al trabajador de que le caigan objetos					
7. Por favor especifique cualquier información adicional que le gustaría se incluyera en el método de entrenamiento empresa que pueda ayudarlo a usted a evitar caídas. Responda aquí:	de protecc	ión contra	a ca ídas	usado ei	n su

APPENDIX B1: INFORMED CONSENT FORM – QUESTIONNAIRE (ENGLISH)

Grado Department Industrial & Systems Engineering, Virginia Tech

Participant number:	
-	

TITLE: Facilitating Technology Adoption and Safety Training in Small Roofing Companies: Development of a Fall-Protection Training Tool

PRINCIPAL INVESTIGATOR: Tonya L. Smith-Jackson, Ph.D.; Woodrow W. Winchester, III, Ph.D.

CO-PRINCIPAL INVESTIGATOR: Yu-Hsiu Hung, M. S.

PURPOSE

You are invited to participate in a study on fall-protection training practices in the roofing industry. The aim is of this study is to understand the themes of current fall-protection practices and technology adoption barriers in small roofing companies for developinging a fall-protection training tool. A survey instrument is developed to achieve this goal. There is no right or wrong answer. We are simply interested in your opinions about: (1) how fall-protection training is implemented in your company, and (2) in your company, how new technologies are typically introduced. This survey will last no more than 30 minutes to complete.

PROCEDURE

The study will begin with you reading and signing the informed consent document. After you provide you consent to the study, you will be asked to complete, to the best of your ability, a questionnaire. The questionnaire has 4 parts. The first part is intended to inquire your demographic information. The second part is intended to investigate factors affecting the diffusion & adoption of construction technology. The third part is intended to investigate current fall-protection training practice. The forth part is intended to investigate your needs to fall-protection training. There are 5 response categories to each question, from 1 (Strongly Disagree) to 5 (Strongly Agree). Please check the box that best fits your opinion. For example, if you strongly agree with the description of a questionnaire item, you check 5 (Strongly Agree). If you are interested in the results of this study, please send an e-mail to Mr. Yu-Hsiu Hung on or after December, 10^{th} , 2008.

RISKS OF PARTICIPATION

Participation in this study does not place you at more than minimal risk of harm. Although some of the questions may relate to OSHA (Occupational Safety and Health Administration) compliance issues, the information we obtain is only for the development of a fall-protection training tool to complement your current training methods.

BENEFITS

You will receive a copy of the survey results by contacting the co-principal investigator. You will also benefit from knowing that you have participated in worthwhile research that has immediate and positive applications. To get the results of the survey, please send an email to Mr. Yu-Hsiu Hung.

COMPENSATION

There is no monetary compensation for participation in this study.

ANOYNMITY AND CONFIDENTIALITY

The data from this study will be kept strictly confidential. No data will be released and no reference will be made in oral or written reports that could link you to the data. Data will be identified by your participation number.

APPROVAL OF RESEARCH

This study has been approved, as required, by the Institutional Review Board for research involving human subjects at Virginia Tech and by the department of Industrial & Systems Engineering.

FREEDOM TO WITHDRAW

You are free to withdraw at any time from the study at any time for any reason. There is no penalty if you choose to withdraw from this study.

PARTICIPANT'S PERMISSION

I have read the informed consent and fully understand the procedures and conditions of the study. I have had all my questions answered, and I hereby give my voluntary consent to be a participant in this research study.

Signature of Subject:	Date:
us understand more about fa issues in your company, pleas personal information will be compensated \$10 or a Wal-Ma interview can be any place on	rticipate in the interview sessions of this study, which helps all-protection training practices and technology adoption se leave your contact information in the following. Your only used for contacting you in the future. You will be art gift card (worth \$10) for the interview. The place for the a your jobsites. If you prefer to do the interview over the ange a phone interview for you as well.
Name:	
Daytime phone #:	E-mail address:

CONTACT

If you have questions at any time about the study or the procedures, you may contact the co-principal investigator, Yu-Hsiu Hung at 540-267-6242, isehung@vt.edu (562 Whittemore Hall, Virginia Tech). If you feel you have been not treated according to the descriptions in this form, or your rights as a participant have been violated during the course of this study, you may contact Dr. David Moore, Chair of the Institutional Review Board Research Division at 540-231-4991.

APPENDIX B2: INFORMED CONSENT FORM – QUESTIONNAIRE (SPANISH)

Grado Department Industrial & Systems Engineering, Virginia Tech

Titulo:	Facilitación	de adopción	de tecnologí	a v entrenamient	o de seguridad	l para co	mpañ ías

techadoras pequeñas: Desarrollo de una herramienta para la protección contra caídas.

INVESTIGADOR PRINCIPAL: Tonya L. Smith-Jackson, Ph.D.; Woodrow W. Winchester, III, Ph.D.

INVESTIGADOR PRINCIPAL AYUDANTE: Yu-Hsiu Hung, M. S.

PROPOSITO:

Numero de participante: _____

Usted está invitado a participar en un estudio acerca de cómo son las practicas de entrenamientos de protección contra caídas en la industria de los techos. El objetivo de este estudio es el de entender lo temas de las practicas de protección contra caídas actuales y las barreras que existen en cuanto a la a la adopción de tecnología para desarrollar una herramienta de entrenamiento de protección contra caídas en las empresas pequeñas. Hemos desarrollado una encuesta para alcanzar esta meta. Nosotros solo estamos interesados en su opinión acerca de: (1) Como son implementados los entrenamientos para protección de caídas en su empresa, y (2) en su compañía, como son introducidas típicamente nuevas tecnologías. Esta encuesta no va a tomarle más de 30 minutos en completar.

PROCEDIMIENTO

El estudio comienza cuando usted lee y firma el documento informativo de consentimiento. Después que usted haya dado el consentimiento requerido para el estudio, usted va a tener que completar, al máximo de su capacidad, el cuestionario. El cuestionario tiene 4 partes. En la primera pretendemos saber su información demográfica. En la segunda pretendemos investigar los factores que afectan la difusión y adopción de tecnolog ía en la construcción. En la tercera parte pretendemos investigar las prácticas actuales de los entrenamientos para protección contra caídas. La cuarta parte pretende investigar sus necesidades con respecto a los entrenamientos para la protección contra caídas. Hay 5 categor ías de respuesta para cada pregunta, desde 1 (estoy en complete desacuerdo) hasta 5 (estoy completamente de acuerdo). Por favor marque la casia que más se acerque a su opinión. Por ejemplo, si usted está completamente de acuerdo con la descripción de un artículo de una pregunta, usted marca el 5 (estoy completamente de acuerdo). Si usted está interesado en los resultados de este estudio, por favor mande su correo electrónico al Sr. Yu-Hsiu Hung el o después del 31 de diciembre del año 2010.

RIESGO DE PARTICIPACION

La participación en este estudio no lo pone a usted en ningún peligro. Aunque algunas de las preguntas pueden referirse a asuntos que corresponden a OSHA (Ocupacional Safety and Health Administración), la información que obtengamos será solo para el desarrollo de una herramienta para la protección contra caídas que complementara sus métodos actuales de entrenamiento.

BENEFICIOS

Usted recibirá una copia de los resultados de la encuesta con solo contactar al Sr. Yu-Hsiu Hung. Usted será también beneficiado al saber que usted ha participado en una investigación que vale la pena y que va a tener aplicaciones inmediatas. Para conseguir los resultados de la encuesta, por favor mande su correo electrónico al Sr. Yu-Hsiu Hung...

COMPENSACION

No hay ninguna compensación monetaria por la participación en este estudio,

ANONIMATO Y CONFIDENCIALIDAD

Los datos del estudio van quedar estrictamente confidenciales. Ningún dato va a hacerse público y no se va a hacer ninguna referencia en reportes orales o escritos que lo puedan vincular a usted con los datos. Los datos serán identificados conforme a su número de participación.

APROVACION DE LA INVESTIGACION

Este estudio ha sido aprobado, como se requiere, por la Junta de Revisión Institucional para investigaciones que involucran sujetos humanos en Virginia Tech y por el departamento de Ingenier a Industrial y Sistemas.

LIBERTAD DE ABANDONAR

Usted es libre de abandonar el estudio en cualquier momento por cualquier razón. No hay ninguna penalización por elegir el abandono del estudio.

PERMISO DEL PARTICIPAN

He leído el consentimiento informativo y entiendo completamente los procedimientos y condiciones del estudio. Todas mis preguntas han sido respondidas, y por lo tanto doy mi consentimiento voluntario de ser un participante en este estudio de investigación.

☐ Si, yo apruebo mi participación	
☐ No, yo no deseo participar	
Firma de la persona: F	'echa:
Nota: Si usted está dispuesto a participar en la sesión	, .
a ayudarnos más a entender las prácticas de entrenan	
y las complicaciones en la adopción de tecnología	1 / 1
información para poder contactarlo en lo siguie	
únicamente utilizada para contactarlo en el futuro. U	-
tarjeta de regalo de Wal-Mart (\$10) por la entrevista	•
en cualquier lugar en su lugar de trabajo. Si uste	ed prefiere hacer la entrevista por
teléfono, nosotros estaremos contentos de arreglar la e	entrevista por teléfono también.
Nombre:	
Numero de tel. durante el día#:	
Dirección de correo electrónico:	

CONTACTO

Si usted tiene cualquier pregunta a cualquier hora con referencia al estudio o los procedimientos, por favor contacte al Sr. Yu-Hsiu Hung al 540-267-6242, <u>isehung@vt.edu</u> (562 Whittemore Hall, Virginia Tech). Si usted siente que no ha sido tratado conforme a las descripciones dadas en este formulario, o que sus derechos como participante han sido violados, usted puede contactar al Dr. David Moore, Jefe de la Junta de Revisión Institucional de la División de Investigación al 540-231-4991.

APPENDIX C1: INFORMED CONSENT FORM – SEMI-STRUCTURED INTERVIEW (ENGLISH)

Grado Department Industrial & Systems Engineering, Virginia Tech

Participant number

TITLE: Facilitating Technology Adoption and Safety Training in Small Roofing Companies: Development of a Fall-Protection Training Tool

PRINCIPAL INVESTIGATOR: Tonya L. Smith-Jackson, Ph.D.; Woodrow W. Winchester, III. Ph.D.

CO-PRINCIPAL INVESTIGATOR: Yu-Hsiu Hung, M. S.

PURPOSE

You are invited to participate in a study on fall-protection training practices in the roofing industry. You will be receiving an interview to explain the responses you provided in the questionnaire. The purpose is to get in-depth information about your company's fall-protection training practices and workers' attitudes towards new construction tools and equipment. The goal of this study is to develop a fall-protection training tool not only has a better chance to be adopted by roofing subcontractors, but also complement their current training methods. There is no right or wrong answer. We are simply interested in your opinions.

PROCEDURE

The study will begin with you reading and signing the informed consent document. After you provide you consent to the study, the interviewer will show you your responses to the questionnaire and ask you to explain them in details. The interviewer may ask follow-up questions to get a better understanding of your responses. To maintain a natural flow during administration of questions, the interview will be audio-recorded. Your name will not be associated with the content of this interview.

All your responses will only be used for data analysis. The interview will last no more than 1 hour. If you do not feel comfortable to If you are interested in the results of this study, please send an e-mail to Mr. Yu-Hsiu Hung on or after December, 10th, 2010.

RISKS OF PARTICIPATION

Participation in this study does not place you at more than minimal risk of harm. Although some of the questions may relate to OSHA (Occupational Safety and Health Administration) compliance issues, the information we obtain is only for the development of a fall-protection training tool to complement your current training methods.

BENEFITS

You will receive a copy of the interview results by contacting the co-principal investigator. You will also benefit from knowing that you have participated in worthwhile research that has immediate and positive applications. To get the results of the interview, please send an email to Mr. Yu-Hsiu Hung.

COMPENSATION

You will be compensated \$10 or a Wal-Mart gift card (worth \$10) for the interview.

ANOYNMITY AND CONFIDENTIALITY

The data from this study will be kept strictly confidential. No data will be released and no reference will be made in oral or written reports that could link you to the data. Data will be identified by your participation number.

APPROVAL OF RESEARCH

This study has been approved, as required, by the Institutional Review Board for research involving human subjects at Virginia Tech and by the department of Industrial & Systems Engineering.

FREEDOM TO WITHDRAW

You are free to withdraw at any time from the study at any time for any reason. There is no penalty if you choose to withdraw from this study.

PARTICIPANT'S PERMISSION

I have read the informed consent and fully understand the procedures and conditions of the study. I have had all my questions answered, and I hereby give my voluntary consent to be a participant in this research study.

Signature of Subject:	Date:
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CONTACT

If you have questions at any time about the study or the procedures, you may contact the co-principal investigator, Yu-Hsiu Hung at 540-267-6242, <u>isehung@vt.edu</u> (562 Whittemore Hall, Virginia Tech). If you feel you have been not treated according to the descriptions in this form, or your rights as a participant have been violated during the course of this study, you may contact Dr. David Moore, Chair of the Institutional Review Board Research Division at 540-231-4991.

APPENDIX C2: INFORMED CONSENT FORM – SEMI-STRUCTURED INTERVIEW (SPANISH)

Grado Department Industrial & Systems Engineering, Virginia Tech

Numero del Participante	
• -	

Título

Desarrollo de una Herramienta de Entrenamiento de protección contra caídas: Facilitar la adopción de tecnología y capacitación de seguridad en las empresas pequeñas para techos

PRINCIPAL INVESTIGATOR: Tonya L. Smith-Jackson, Ph.D.; Woodrow W. Winchester, III, Ph.D.

INVESTIGADOR PRINCIPAL: Tonya L. Smith-Jackson, Ph.D.; Woodrow W. Winchester, III, Ph.D.

COOPERADOR DEL INVESTIGADOR PRINCIPAL: Yu-Hsiu Hung, M. S.

PROPOSITO

Usted está invitado a participar en un estudio sobre las prácticas de protección contra caídas en la industria del techado. Usted va a recibir una entrevista para explicar las respuestas que proporcione en el cuestionario. El propósito es obtener información detallada acerca de las prácticas de su empresa y el desarrollo de la protección contra caídas y actitudes de los trabajadores hacia las herramientas de construcción y equipos nuevos. El objetivo de este estudio es desarrollar una herramienta de protección contra caídas que no sólo tiene muchas posibilidades de ser aprobado por los subcontratistas para techos, sino también para complementar sus métodos de entrenamiento actual. No hay una respuesta correcta o incorrecta. Simplemente estamos interesados en sus opiniones.

Procedimiento

El estudio se iniciará con la lectura y que la firma del documento de consentimiento informado. Después de dar su consentimiento para el estudio, el entrevistador le mostrará sus respuestas del cuestionario y le pidera que explique con detalles. El entrevistador puede hacer preguntas de seguimiento para obtener una mejor comprensión de sus respuestas. Para mantener un flujo natural durante la administración de preguntas, la entrevista serán grabadas en audio. Su nombre no se asociará con el contenido de esta entrevista.

Todas sus respuestas sólo será utilizada para el análisis de datos. La entrevista tendrá una duración de no más de 1 hora. Si usted no se siente cómodo, si usted está interesado en los resultados de este estudio, por favor envíe un e-mail al Sr. Yu-Hsiu Hung después de diciembre 10 de 2010.

Riesgo de Participación

La participación en este estudio no se coloca en un riesgo mínimo de daño. Aunque algunas de las preguntas pueden referirse a OSHA (Occupational Safety and Health Administration) problemas de seguimiento, la información que obtenemos es sólo para el desarrollo de una herramienta de formación de protección contra caídas para complementar sus actuales métodos de entrenamiento.

Beneficios

Usted recibirá una copia de los resultados de las entrevistas poniéndose en contacto con el investigador co-principal. También se beneficiarán de saber que usted a participado en la investigación que vale la pena y que tiene aplicaciones inmediatas y positivas. Para obtener los resultados de la entrevista, por favor envíe un correo electrónico al Sr. Yu-Hsiu Hong.

Compensación

Usted será compensado \$ 10 o una tarjeta de regalo de Wal-Mart (con un valor de \$ 10) para la entrevista.

Anonimato y confidencialidad

Los datos de este estudio se mantendrán estrictamente confidenciales. No hay datos se dará a conocer y no se hará referencia en los informes orales o escritas que pueda vincular a los datos. Los datos serán identificados por su número de participación.

APROBACIÓ N DE LA INVESTIGACIÓ N

Este estudio ha sido aprobado, según requerido por la Junta de Revisión Institucional para la investigación en seres humanos en la Universidad Virginia Tech y por el departamento de Ingenier a Industrial y de Sistemas.

LIBERTAD PARA RETIRARSE

Usted es libre de retirarse en cualquier momento del estudio y por cualquier motivo. No hay penalidad si decide retirarse de este estudio.

PERMISO DEL PARTICIPANTE

He leído el consentimiento informado y entiendo plenamente los procedimientos y las condiciones del estudio. Tengo todas las preguntas respondidas y yo doy mi consentimiento voluntario para ser un participante en este estudio de investigación.

Firma del participante:	Fecha:
CONTACTO	

Si usted tiene preguntas en cualquier momento sobre el estudio o los procedimientos, puede comunicarse con el investigador co-principal, Yu-Hsiu Hung al 540-267-6242, o a la dirección de correo electronico isehung@vt.edu (562 Whittemore Hall, Virginia Tech). Si usted siente que no han sido tratados de acuerdo con las descripciones de este documento, o que sus derechos como participante han sido violados en el curso de este estudio, puede comunicarse con el Dr. David Moore, Presidente de la Junta de Revisión Institucional de Investigación de la División al teléfono 540 -231-4991.

APPENDIX D: INFORMED CONSENT FORM – PARTICIPATORY DESIGN

Grado Department Industrial & Systems Engineering, Virginia Tech

Participant	number:	
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TITLE: Facilitating Technology Adoption and Safety Training in Small Roofing Companies: Development of a Fall-Protection Training Tool

PRINCIPAL INVESTIGATOR: Tonya L. Smith-Jackson, Ph.D.; Woodrow W. Winchester, III. Ph.D.

CO-PRINCIPAL INVESTIGATOR: Yu-Hsiu Hung, M. S.

PURPOSE

The purpose of this study is to develop an easily-adopted fall-protection training intervention for residential roofers. Participants will join a Participatory Design (PD) session and work with the researchers to identify an intervention that not only fits well with the day-to-day work practices, but also helps improve worksite safety.

PROCEDURE

The study will begin with you reading and signing the informed consent document. After you provide your consent to the study, you will be briefed the purpose of the study and be asked to introduce yourself and get familiar with the other participants and researchers on a more personal basis. This will help to open lines of communications and make sure that everyone is comfortable contributing to the PD process.

The researchers will then act as impartial moderators and facilitators for the PD session. The researchers will bring up issues/questions one by one in the meeting. For example: What are the barriers leading to poor training practices? What kind of fall-protection training will improve and fit company's work practices? You will be asked to join the discussion of the shown questions/issues and help isolate the user requirements for a fall-protection training intervention.

In PD, you will be provided with pencils and papers to help convey your ideas. You will also be asked to propose design recommendations using a brainstorming design approach. Everyone will have a chance to express and share any ideas. Discussions will continue until all participants are satisfied with the final safety training intervention. If disagreements among the participants occur and could not be resolved, all team members will be asked to vote the ideas. The PD session will last about 2 hours. You will be thanked and compensated at the end of the PD session.

The PD session will be audio-taped for data analysis. If you are interested in the results of this study, please call or send an e-mail to Mr. Yu-Hsiu Hung at the end of December, 2010.

RISKS OF PARTICIPATION

Participation in this study does not place you at more than minimal risk of harm. Although some of the questions may relate to OSHA (Occupational Safety and Health Administration) compliance issues, the information we obtain is only for the development of a fall-protection training intervention to complement your current training methods.

BENEFITS

You will benefit from knowing that you have participated in worthwhile research that has immediate and positive applications to construction safety. To get the results of the survey, please call or send an email to Mr. Yu-Hsiu Hung.

COMPENSATION

There is \$50 compensation for participation in this study.

ANOYNMITY AND CONFIDENTIALITY

The data from this study will be kept strictly confidential. No data will be released and no reference will be made in oral or written reports that could link you to the data. Data will be identified by your participation number.

APPROVAL OF RESEARCH

This study has been approved, as required, by the Institutional Review Board for research involving human subjects at Virginia Tech and by the department of Industrial & Systems Engineering.

FREEDOM TO WITHDRAW

You are free to withdraw at any time from the study at any time for any reason. There is no penalty if you choose to withdraw from this study.

PARTICIPANT'S PERMISSION

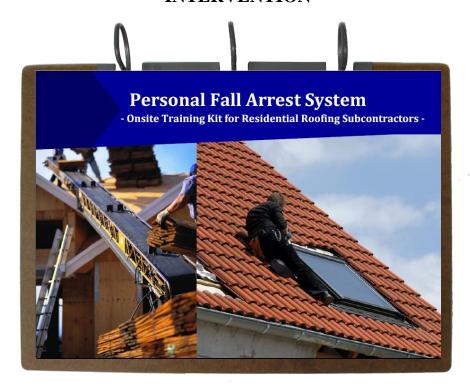
I have read the informed consent and fully understand the procedures and conditions of the study. I have had all my questions answered, and I hereby give my voluntary consent to be a participant in this research study.

Signature:	 Date:	
U	_	

CONTACT

If you have questions at any time about the study or the procedures, you may contact the co-principal investigator, Yu-Hsiu Hung at 540-267-6242, isehung@vt.edu (562 Whittemore Hall, Virginia Tech). If you feel you have been not treated according to the descriptions in this form, or your rights as a participant have been violated during the course of this study, you may contact Dr. David Moore, Chair of the Institutional Review Board Research Division at 540-231-4991.

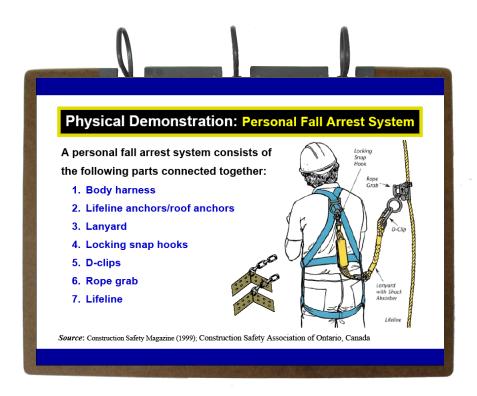
APPENDIX E: TRAINING SHEETS – PFAS TRAINING INTERVENTION



Page 1 (Front): Cover page of the PFAS training intervention (photos obtained from Microsoft Clipart)

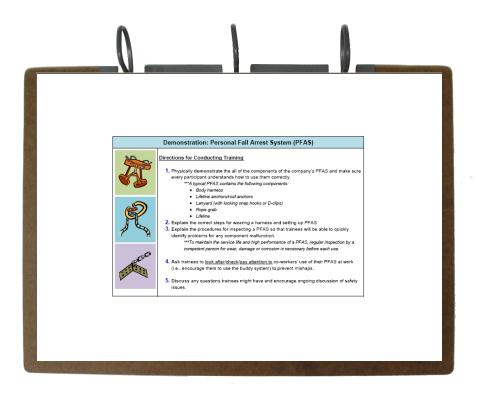


Page 1 (Back): Instructions for use (photos and graphics obtained from Microsoft Clipart; Warning sign designed by author, 2010)



Page 2 (Front): Components of a PFAS (Illustration under "Fair Use" copyright guidelines)

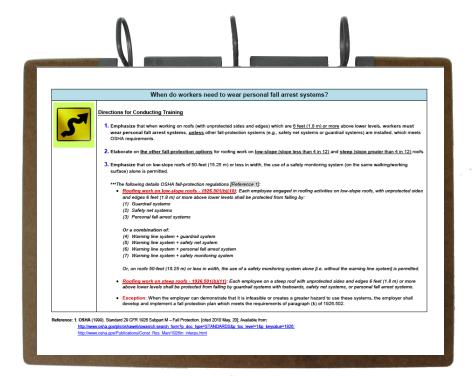
Source: Construction Safety Association of Ontario. (1999). Falls: The Number One Cause of Construction Deaths. Construction Safety Magazine, 10(3), Autumn. (Fair Use determination attached).



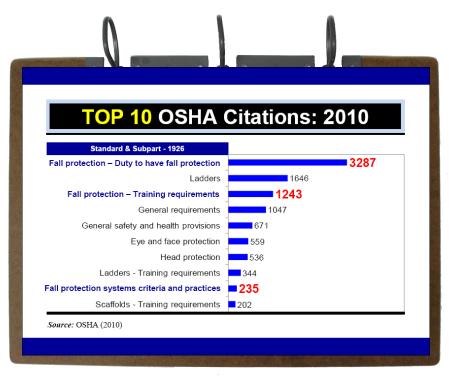
Page 2 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



Page 3 (Front): Fall-protection options at differing heights (photos and graphics obtained from Microsoft Clipart)

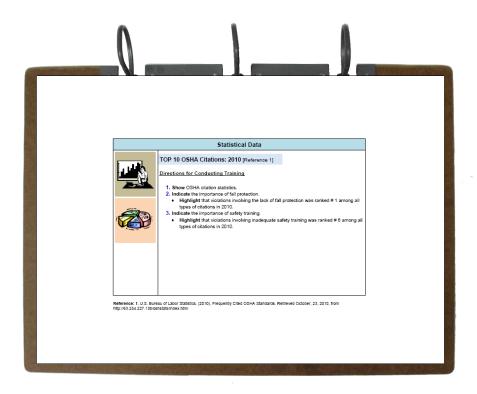


Page 3 (Back): Instructions for use (graphics obtained from Microsoft Clipart)

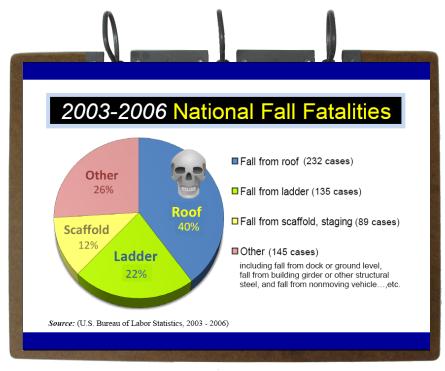


Page 4 (Front): Top 10 OSHA citation statistics in 2010

Data source: U.S. Bureau of Labor Statistics. (2010). Frequently Cited OSHA Standards. Retrieved October, 23, 2010, from http://63.234.227.130/oshstats/index.html

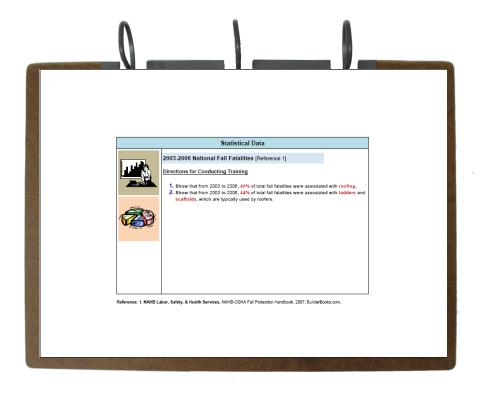


Page 4 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



Page 5 (Front): Fall fatalities associated with roofing (from 2003 to 2006) (graphic obtained from Microsoft Clipart)

Data source: U.S. Bureau of Labor Statistics. (2003 - 2006). Census of Fatal Occupational Injuries. Retrieved October, 23, 2010, from http://stats.bls.gov/iif/oshcfoi1.htm



Page 5 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



Page 6 (Front): Negative consequences of a fall (Permission by Worksafebc.com; photos under "Fair Use" copyright guidelines)

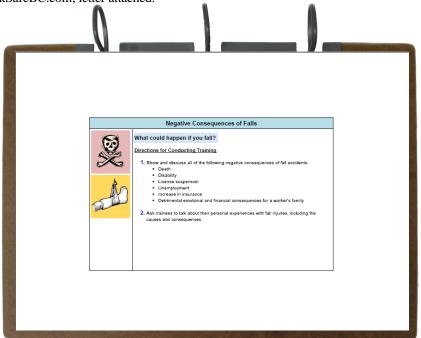
Source:

Raha, S. (2010). India needs new legislation on Disability Rights. Retrieved November 01, 2010, from http://infochangeindia.org/201003228194/Disabilities/Analysis/India-needs-new-legislation-on-Disability-Rights.html (Fair Use determination attached).

The Cubs Brickyard. (2009). Rich Harden Scratched from Scheduled Start with "Broken Leg-like Symptoms". Retrieved November 01, 2010, from

http://www.thecubsbrickyard.com/2009/03/24/rich-harden-scratched-from-scheduled-start-with-broken-leg-like-symptoms/ (Fair Use determination attached).

WorkSafeBC. (2010). You're a Pro: Falls from ladders. Retrieved November 01, 2010, from http://www2.worksafebc.com/Publications/Multimedia/Videos.asp?ReportID=34742. Used with permission from WorkSafeBC.com; letter attached.



Page 6 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



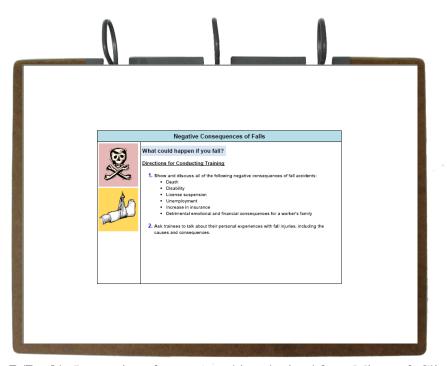
Page 7 (Front): Negative consequences of a fall (photos under "Fair Use" copyright guidelines)

Source:

Internet-gazette.com. (2010). Obama Restores Jobless Benefits. Retrieved November 01, 2010, from http://internet-gazette.com/obama-restores-jobless-benefits/853/. (Fair Use determination attached).

OSHA. (2010). Directorate of Cooperative and State Programs - Office of Outreach Services and Alliances. Retrieved November 5, 2010, from http://www.osha.gov/dcsp/oosa/index.html. (Fair Use determination attached).

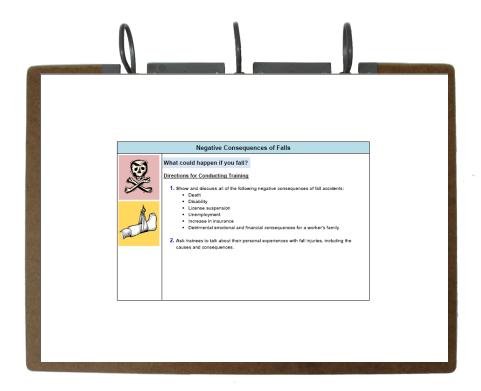
PR-inside.com. (2010). Albany Speeding Ticket Lawyer Offers Free Advice. Retrieved November 5, 2010, from http://www.pr-inside.com/albany-speeding-ticket-lawyer-offers-free-r1686125.htm. (Fair Use determination attached).



Page 7 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



Page 8 (Front): Negative consequences of a fall (photos obtained from Microsoft Clipart)



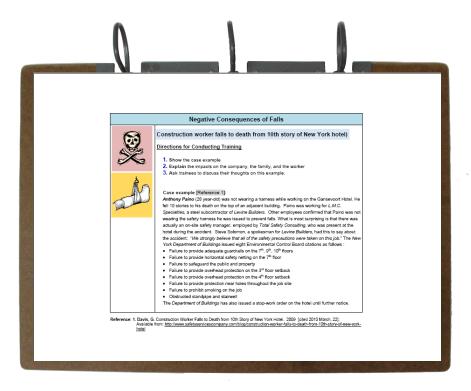
Page 8 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



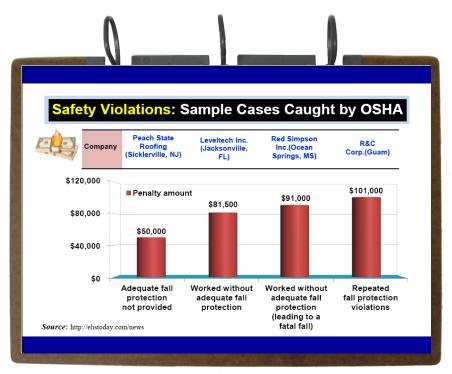
Page 9 (Front): Real-world example of a deadly fall on a construction site

Source: Davis, G. (2009). Construction Worker Falls to Death from 10th Story of New York Hotel. Retrieved March, 22, 2010, from

 $\underline{http://www.safetyservicescompany.com/blog/construction-worker-falls-to-death-from-10th-story-of-new-york-hot}\\ \underline{el}$



Page 9 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



Page 10 (Front): Types of OSHA citations and associated costs

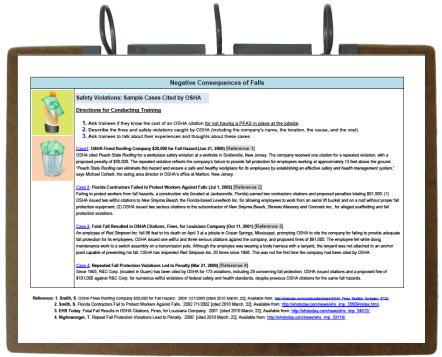
Data Source:

Nighswonger, T. (2000). Repeat Fall Protection Violations Lead to Penalty. Retrieved March, 22, 2010, from http://ehstoday.com/news/ehs_imp_33119/

Smith, S. (2001). Fatal Fall Results in OSHA Citations, Fines, for Louisiana Company. Retrieved March, 22, 2010, from http://ehstoday.com/news/ehs_imp_34812/

Smith, S. (2002, 7/1/2002). Florida Contractors Fail to Protect Workers Against Falls. Retrieved March, 22, 2010, from http://ehstoday.com/news/ehs imp 35609/index.html

Smith, S. (2009, 1/21/2009). OSHA Fines Roofing Company \$50,000 for Fall Hazard. Retrieved March, 22, 2010, from http://ehstoday.com/construction/news/OSHA_Fines_Roofing_Company_8732/

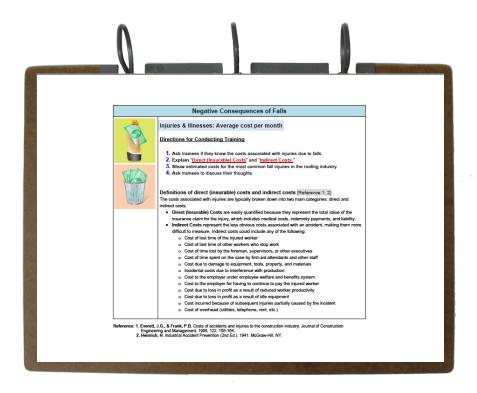


Page 10 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



Page 11 (Front): Type of injuries caused by falls (Fredericks et al., 2005) and associated monthly costs

Data source: OSHA. (2010). OSHA's \$afety Pays Program. Retrieved October, 25, 2010, from http://www.osha.gov/dcsp/smallbusiness/safetypays/index.html



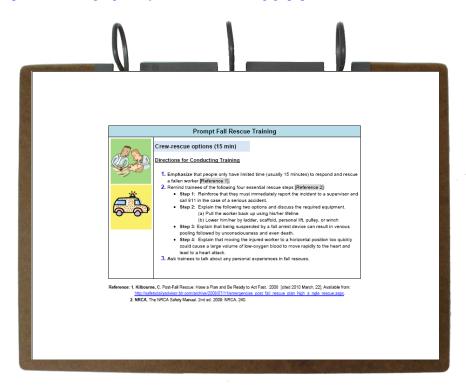
Page 11 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



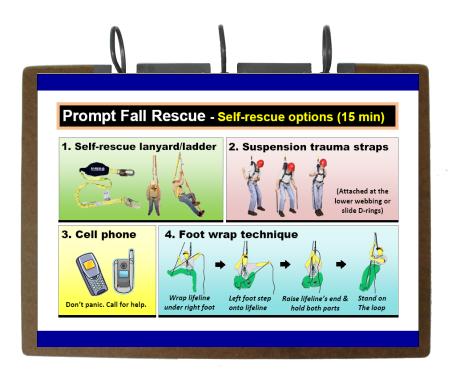
Page 12 (Front): Crew-rescue procedures for a fall incident (graphics in Step 1 and 2 obtained from Microsoft Clipart; photos in Step 2 and 3 under "Fair Use" copyright guidelines; photo in Step 4 by author, 2010)

Source:

Leading Edge Safety. (2008). Rescue at Height (Haul Casualty Raising). Retrieved November 5, 2010, from http://www.leadingedgesafety.co.uk/rescue-at-height-gs.php. (Fair Use determination attached). Step 2. Leading Edge Safety. (2008). Fall Arrest Rescue Training - Low Height (Lowering) Retrieved November 5, 2010, from http://www.leadingedgesafety.co.uk/rescue-training-gs.php. (Fair Use determination attached). Step 3.



Page 12 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



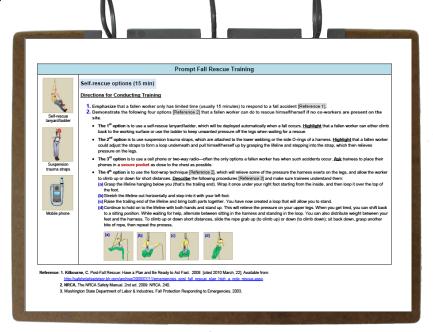
Page 13 (Front): Self-rescue procedures for a fall incident (graphics in Option 3 obtained from Microsoft Clipart; illustrations under "Fair Use" copyright guidelines)

Source:

Capital Safety Inc. (2004). Instructions for Use (The Suspension Trauma Safety Strap). Retrieved November 5, 2010, from http://media.capitalsafety.com/Assets/EUR/Instructions/ifu 5902486 trauma straps.pdf. (Fair Use determination attached). *Option 2*.

FrenchCreek Production, I. (2009). 2009 Product Catalog. Retrieved November 5, 2010, from http://www.frenchcreekproduction.com/index.htm. (Fair Use determination attached). *Option1*.

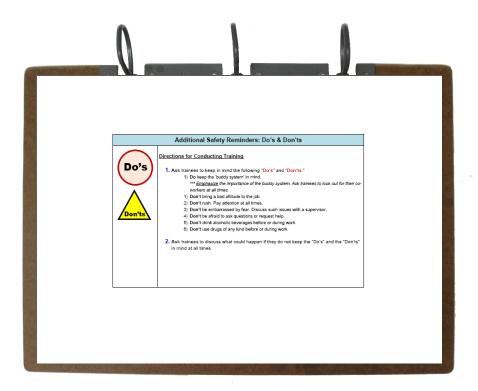
Washington State Department of Labor & Industries. (2003). Fall Protection: Responding to Emergencies. Retrieved November 5, 2010, from http://www.lni.wa.gov/formpub/Detail.asp?DocID=1776. (Illustrations are allowed to be used without copy permission); original document and copy right statements attached. *Option 4*.



Page 13 (Back): Instructions for use (illustrations under "Fair Use" copyright guidelines)



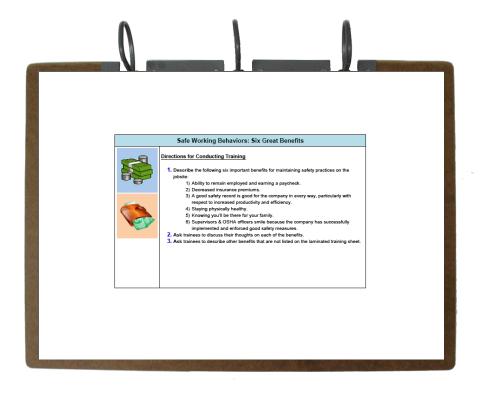
Page 14 (Front): Safety reminders to prevent falls (photos and graphics obtained from Microsoft Clipart)



Page 14 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



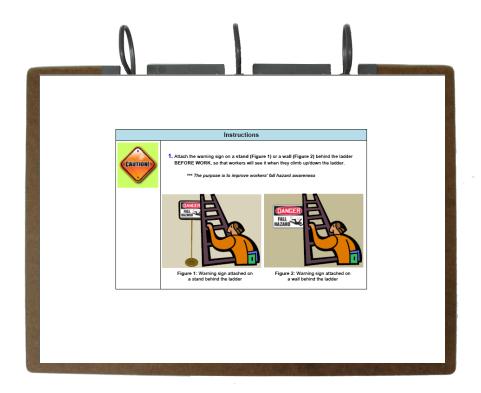
Page 15 (Front): Benefits of safe working behavior (graphics and photos obtained from Microsoft Clipart)



Page 15 (Back): Instructions for use (graphics obtained from Microsoft Clipart)



Page 16 (Front): Safety warning sign (created by author, 2010)



Page 16 (Back): Instructions for use (graphics obtained from Microsoft Clipart)

APPENDIX F: ADOPTION PROPENSITY QUESTIONNAIRE

Pa	rticipant #:			Demographic Info	ormation		
1.	Age:						
2.	Job Title:	□ Constr	ruction Owner	□ Construction Supervisor	□ Foreman	□ Worker	
3.	Ethnicity:	□ Africa:	n American/Black	□ Hispanic/ Latino	□ Caucasian/white	□ Other:	
4.	Education	(Highest A	ttended):				
		□ Eleme	ntary School	☐ Middle/Junior High School	□ Senior High School	ol	
		□ Comm	nunity College	□ Four-year College	□ Beyond 4 year deg	gree	
5.	What const	truction fie	eld do you work in?	(Check all that apply)			
	□ Ro	oofing	□ Painting	□ Wood Framing	□ Siding □	Concrete	□ Guttering
	\Box M	asonry	□ Drywalling	□ Water & damp proofing	□ Steel Erecting/ She	eet-Metal Work	□ Other
6.	How long h	ave you be	een working in the	roofing industry?	year(s)		
7.	How are fall-protection training programs typically done in your company?						
		□ My con	npany does not prov	ide fall-protection training			
		□ Fall-pro	otection training is d	one informally (ex. senior workers	guide/teach others on	the sites)	
		□ Fall-pro	otection training is d	one formally (ex. presentations)			
		□ I do not	t know				
8.	I prefer fall	l-protection	n training to be doi	ne:			
		□ Informa	ally (with senior wor	kers training others)			
		□ Formal	ly (with presentation	as)			

Evaluation of Adoption Intention – Personal Fall Arrest System for Smaller Subcontractors

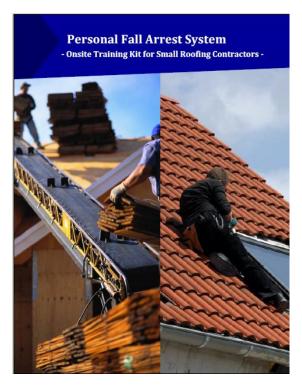




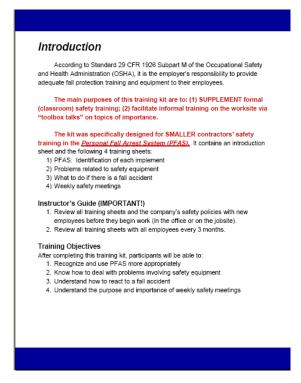
Please check $\, m{\mathcal{U}} \,$ the box that best fits your response.

	Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		1	2	3	4	5
1.	It is worthwhile for my company to use this training package.					
2.	I would like for my company to use this training package in the future.					
3.	I will recommend that others use this training package.					
4.	I would have no difficulty telling others about the advantages of using this training package.					
5.	I believe I could communicate to others the results of using this training package.					
6.	The advantages to using this training package are clear to me.					
7.	I would have no difficulty explaining why using this training package may or may not be beneficial.					
8.	After using this training package, I believe:					
	 Workers are more concerned for their safety on the job. 					
	■ Workers are less likely to get injured.					
	■ The safety problems on the job are reduced.					

APPENDIX G: TRAINING SHEETS – STANDARD PFAS TRAINING INTERVENTION



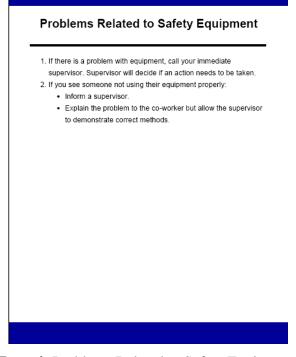
Page 1: Cover sheet (photos obtained from Microsoft Clipart)



Page 2: Instruction sheet

Personal Fall Arrest System (PFAS): Identification of Each Implement STEP 1: Supervisor/foreman physically demonstrates the use of the PFAS, including the implementation of each component. (1) Harness (2) Anchor · The spacing of fasteners There are different types of fasteners. Different anchors require the use of different numbers of fasteners. Each anchor is only for one person. NEVER connect to another person's anchor. (3) Rope and Rope Grab STEP 2: Tips and reminders: Check the organization of your tools before work. Follow safety rules at all times. Safety violations will result in injuries and OSHA fines of up to \$ 101,000 for the company. · Inspect your equipment daily . There are different types of roofs, and their associated hazards might vary. Know what they are and keep a clear head from the Failure to comply with safety rules could result in termination. Compliance (i.e., reduction in injuries) translates to greater company profits, which benefits ALL employees.

Page 3: Personal Fall Arrest System (PFAS): Identification of Each Implement



Page 4: Problems Related to Safety Equipment

What to Do if There is a Fall Accident

- 1. Secure the work area and then assist your co-worker.
- Assess the situation to the best of your ability. Always call 911 in the case of serious injuries.
- Even if there are no apparent injuries, report the incident to the supervisor immediately and remove worker from the area.
- 4. Supervisor will decide if it is safe for him/her to return to work.

Page 5: What to Do if There is a Fall Accident

Weekly Safety Meetings

- Each week a short safety meeting will be held to discuss any incidents, describe potential job-specific hazards, and share tips for enhancing safety behaviors. The weekly safety meetings are for your benefits.
- Participate in the weekly safety meeting and keep in mind all mandated safety behaviors.
- The safety monitor (i.e., safety enforcer) on the site will be introduced. The safety monitor is responsible for supplying you with necessary equipment to avoid injuries.
- Rewards for projects completed without injuries or OSHA fines will be discussed.

Page 6: Weekly Safety Meetings

APPENDIX H: INFORMED CONSENT FORM – SUMMATIVE COMPARATIVE EVALUATION

Grado Department Industrial & Systems Engineering, Virginia Tech

Participant	number:	
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TITLE: Facilitating Technology Adoption and Safety Training in Small Roofing/Framing Companies: Development of a Fall-Protection Training Tool

PRINCIPAL INVESTIGATOR: Tonya L. Smith-Jackson, Ph.D.; Woodrow W. Winchester, III. Ph.D.

CO-PRINCIPAL INVESTIGATOR: Yu-Hsiu Hung, M. S.

PURPOSE

The purpose of this study is to investigate framing/roofing workers' adoption propensity of 2 fall-protection training interventions.

PROCEDURE

The study will begin with you reading and signing the informed consent document. After you provide your consent to the study, you will be briefed the purpose of the study.

The researchers will then show you materials of 2 fall-protection training interventions, with a focus on <u>Personal Fall-arrest System</u>. After you review each training intervention, you will be asked to complete a short questionnaire and explain your responses. Your verbal responses will be audio-recorded for data analysis.

You could take your time to perform your evaluations. There is no time constraint for the evaluation. You will be thanked and compensated at the end of your evaluation. If you are interested in the results of this study, please call or send an e-mail to Mr. Yu-Hsiu Hung at the end of December, 2010.

RISKS OF PARTICIPATION

Participation in this study does not place you at more than minimal risk of harm. Although some of the questions may relate to OSHA (Occupational Safety and Health Administration) compliance issues, the information we obtain is only for the development of a fall-protection training intervention to complement your current training methods.

BENEFITS

You will benefit from knowing that you have participated in worthwhile research that has immediate and positive applications to construction safety. To get the results of the study, please call or send an email to Mr. Yu-Hsiu Hung.

COMPENSATION

Your company will get the fall-protection training packages for participation in this study.

ANOYNMITY AND CONFIDENTIALITY

The data from this study will be kept strictly confidential. No data will be released and no reference will be made in oral or written reports that could link you to the data. Data will be identified by your participation number.

APPROVAL OF RESEARCH

This study has been approved, as required, by the Institutional Review Board for research involving human subjects at Virginia Tech and by the department of Industrial & Systems Engineering.

FREEDOM TO WITHDRAW

You are free to withdraw at any time from the study at any time for any reason. There is no penalty if you choose to withdraw from this study.

PARTICIPANT'S PERMISSION

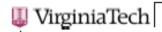
I have read the informed consent and fully understand the procedures and conditions of the study. I have had all my questions answered, and I hereby give my voluntary consent to be a participant in this research study.

Signature:	Date:
Digitatui C.	Bate.

CONTACT

If you have questions at any time about the study or the procedures, you may contact the co-principal investigator, Yu-Hsiu Hung at 540-267-6242, <u>isehung@vt.edu</u> (562 Whittemore Hall, Virginia Tech). If you feel you have been not treated according to the descriptions in this form, or your rights as a participant have been violated during the course of this study, you may contact Dr. David Moore, Chair of the Institutional Review Board Research Division at 540-231-4991.

APPENDIX I: IRB APPROVAL



Office of Research Compliance Institutional Review Board 2000 Kraft Drive, Suite 2000 (0497) Blacksburg, Vrighira 24060 540/231-4005 Fax 540/231-0959 e-mail irb@ytledu Websitis: www.lib.ytledu

MEMORANDUM

DATE: October 15, 2010

TO: Tonya L. Smith-Jackson, Woodrow Winchester, Yu-Hsiu Hung, Alex Leatherman, Juan Riofrio,

Jessi Kane

FROM: Virginia Tech institutional Review Board (FWA00000572, expires June 13, 2011)

PROTOCOL TITLE: Facilitating Technology Adoption and Safety Training in Small Roofing

Companies: Development of a Fall-Protection Training Tool

IRB NUMBER: 08-661

Effective October 28, 2010, the Virginia Tech IRB Administrator, Carmen T. Green, approved the continuation request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at http://www.irb.vt.edu/pages/responsibilities.htm (please review before the commencement of your research).

PROTOCOL INFORMATION:

Approved as: Expedited, under 45 CFR 46.110 category(les) 6, 7

Protocol Approval Date: 10/28/2010 (protocol's Initial approval date: 10/28/2008)

Protocol Expiration Date: 10/27/2011" Continuing Review Due Date": 10/13/2011

"Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federally regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals / work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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