Introduction

The U.S. work force is becoming more multicultural, and this trend is also evident in the construction industry. The number of Hispanics employed in the construction industry rose from 342,000 in the year 1980 to 1,408,000 in the year 2000 as shown in Exhibit 1 published by The Construction Chart Book (2002). This publication reports that 17% of construction wage and salary workers are Hispanic.

Exhibit 1. Number of Hispanic Employees in Construction – at different time periods (CPWR 2002)

Hispanics make up a disproportionately large share of workers in some construction trades, accounting, for instance, for 33% of drywallers, 31% of tile setters, 27% of concrete workers, 26% of painters, 23% of roofers, and 21% of laborers (CPWR 2002, Ruttenberg and Lazo 2004 Jaselskis et al. 1996, Jaselskis et al. 2004). The construction sector attracts a great number of Hispanic workers due to the ease of entry, relatively high wages, low skill requirements, lax legal documentation, limited need for English literacy, and the availability of jobs. Between 1980 and
2000, the number of construction workers who identified themselves as Hispanic quadrupled to 1.4 million, or 17% of wage-and-salary workers (CPWR 2002). As the number of Hispanics working in construction increases, the fatality rate has risen disproportionately. John Henshaw, the assistant secretary of labor for the Occupational Safety and Health Administration (OSHA), determined that in 2000 Hispanics accounted for an inconsistent number of workplace fatalities in all industries—13.8%, compared with their proportion of employment, 10.7%. (Henshaw 2002). Other studies have shown that between 1992 and 2003 the construction laborer fatalities among Hispanics have more than doubled from 108 to 263 (Dong et. al. 2005). According to a 2000 BLS report on fatalities, 815 Hispanic or Latino workers died as a result of job-related injuries in 2000. Nearly 20% of Hispanic fatalities were due to falls and contact with equipment, events more common in construction work sites than other employment areas (Henshaw 2002). In addition, approximately 627,000 construction workers – roughly half of the Hispanic construction workers in the U.S. – are illegal immigrants, who may not complain about unsafe work because they are afraid to lose their job or face deportation (Hopkins 2003). It is important to note that any research effort aimed at improving the safety conditions of Hispanic workers, should not consider residency status since this may limit participation in of this population. To compound the language problem, many Hispanic construction workers in the U.S. have limited literacy in Spanish, as well as in English. The distribution of educational attainment in construction for the year 2000 shows that 54% of Hispanic workers had not earned a High School diploma. For the same year, only 15% of non-Hispanic workers had attained less than a High School diploma (CPWR 2002).

OSHA has been working to provide employees with better tools addressing and ensuring their safety in the workplace. This has been done by different means including compliance inspections, citations and penalties. In addition to the enforced procedures, OSHA has been working to encourage safety practices among contractors, and providing support through courses on safety and health issues (CPWR 2002). Among these efforts, there has been increasing attention to the Hispanic workforce. Nonetheless, the number of fatalities involving Hispanic workers has risen while the overall statistics regarding the other sub-populations of the workforce have declined. For instance, the fatality rate among Hispanic workers in private construction increased from 10% in 1992 to 20% in 2002 (Richardson 2005). Exhibit 2 (developed using data from the U.S Bureau of Labor Statistics) shows the number of fatalities involving Hispanic workers from 1992 to 2002. Clearly, there is a need for more effective programs targeting attitudes and behavior in order to improve the overall safety in the workplace, especially in the construction workplace.
Key issues impacting safety that have been identified include: nuances of language and culture of Hispanic workers, especially those born outside the country, level of literacy, type of societal values – matriarchal/patriarchal, deference to authority, economic standing, etc. Pinch (2005) emphasizes the statements made by Dr. John Howard, Director of the National Institute of Occupational Safety and Health (NIOSH), that “there is a need to learn about social values with each Hispanic community to help get the safety message across. Lumping Spanish-speaking workers into a single category can create tension. We need to learn about, and take into consideration, the very real cultural differences between workers from Mexico and those from Central American countries, from South American countries, from Puerto Rico, and from Cuba. Our sensitivity to these differing cultures will affect how successful we will be in achieving trans-cultural workplace safety.”

A recent study by Thomson and Siddiqi (2007) has discussed the importance of understanding the culture of the different Hispanic groups as a good practice to improve safety among construction workers. This study divides the cultural differences into five categories as follows: importance of family, machismo, immigration status (of the worker), differences between countries of origin, and trustworthiness of those who wield authority.

Some Hispanic groups have great respect for their elders, some are more matriarchal than patriarchal, and others have a strong deference to authority. Each of these factors has impact(s) on the effectiveness of implementation of safety training tools. The level of literacy and prior exposure to educational technology also affect the implementation of safety training. Foreign-
born workers from rural towns, particularly in economically devastated areas, may have limited access to secondary education and exposure to technology.

Other studies (Abraham et al. 2004, Arboleda and Abraham 2004) report situations in which Hispanic workers appear willing to take more risks, i.e., the image of the ‘macho’ construction worker tends to prevail in Hispanic communities. Pinch (2005) explains that Hispanic workers “may take more risks to prove their manhood or may avoid wearing protective equipment like hard hats or safety glasses. Safety measures the American person takes for granted have to be taught.”

In the research team’s prior interactions with construction safety coordinators and competent persons on job sites, we found that a serious concern arises when workers “pretend they understand safety directions.” In many cases, admitting that the instructions were not comprehensible is viewed as ‘being disrespectful to authority.’ In one of the trenching accident cases brought to the attention of our research group, the employment status and the economic condition of the worker were keys to understanding why the worker chose to work in unsafe conditions. In this specific case, the worker was an immigrant Hispanic laborer, who was hired in a temporary position. For him, holding onto the job to support his wife and two kids was more important than seeking and finding more information about the safety of the construction operation.

As a growing number of Hispanics enter the construction industry workforce, contractors face a range of opportunities and challenges, particularly in providing safer workplaces. Addressing safety practices can present a special challenge for companies who employ people from different cultural backgrounds. The complexity of the problem relies on several factors, such as the perception of safety and hazards, workers’ engagement with safety behavior, lack of familiarity with existing safety standards, and the availability of organizational commitment to provide a safety climate.

Current safety training practices include classroom training that use printed materials, videos, and instructors. Although these materials are developed in Spanish, they do not address culture-specific issues of the Hispanic workforce and do not measure workers’ changes in risk perception that may impact jobsite safety. In addition, group learning dynamics in Hispanic cultures are not considered when developing such instructional materials.

Our focus in this research project is developing the framework to assess the risk perception of Hispanic workers and evaluate if the socio-cultural factors previously referenced, personal factors, and work environment factors influence their risk perception. By developing such a framework, interventions can be developed to improve the safety of this special population of workers by addressing potentially hazardous behaviors before they can result in injuries or even fatalities.

This paper will discuss innovative technology-based safety training that addresses identified safety issues among the Hispanic construction workforce, in order to reduce workplace accidents among this group. The proposed systems complement current safety training practices and addresses these issues by providing an interactive training solution that is tailored specially for the Hispanic worker, and specifically those working in small and medium-sized construction companies (SMEs), (< $100 mil of revenue per year). These companies face significant challenges when developing safety strategies because they may not have the resources (financial or personnel) to dedicate solely or significantly to addressing safety on construction projects. In our prior analysis of 296 trenching fatality reports we found that 72% of fatalities occurred on
projects with total cost less than one million dollars (Arboleda and Abraham 2004). These projects are mainly executed by small/medium size companies, further highlighting the need for development of special safety strategies to assist this segment of the construction industry. The system considers the specific safety issues related to his/her cultural background and other identified factors that could affect his/her safety in the workplace.

Before technology-enhanced safety training is discussed, it is important to provide some background on technological approaches to enhancing safety on jobsites. Some of the technologies that are described have great potential by addressing jobsite hazards in a surveillance mode. The goal of technology-enhanced training is that of prevention by identifying training needs and addressing them before the worker engages in unsafe behaviors. It is also important to note that the technologies described in the next section go beyond the traditional personal protective equipment or engineering controls used today on jobsites. The systems described use a high technology approach to address many of the hazards found on construction jobsites.

**Examples of Emerging Technologies for Enhancing Construction Safety**

**Wireless Jobsite Safety Monitoring**

An approach that would help in reducing fatality events using novel technologies involves the use of active identification and positioning of equipment, dangerous areas, and location of workers, with the purpose of detecting potentially hazardous events before they occur. Ultra Wideband (UWB) is an emerging wireless technology for communications and precision localization. Broader applications include high-speed communications networks and data links, collision and obstacle avoidance, precision systems for personnel location, asset tracking and inventory control, and intelligent transportation systems. Due to their low system complexity, adaptiveness and low costs, UWB systems are a promising alternative to barcodes, standalone Radio Frequency Identification (RFID) and Global Positioning Systems (GPS) used for tracking assets in building construction sites. In addition to detecting construction equipment, risk areas or workers, UWB is able to position them with a great level of accuracy, thereby relating these positions with Computer Aided Design (CAD) information and assisting in the identification of potential hazards in the construction site such as those caused by spatial conflicts between workers and equipment and worker proximity to hazardous conditions in the jobsite.

Shown in Exhibit 3 is the conceptual model for the Integrated Surveillance and Automated Frequency Estimation of Threats system (i-safe-T), which continuously estimates the proximity of workers to safety threats previously identified in the job site and automatically determines if the worker is at risk of injury, taking the necessary action to reduce the risk of injury to the worker. The implementation of this system has the potential to greatly reduce the occurrence of accidents on jobsites, saving countless workers from injuries and fatalities (Castro et al. 2007).
Visual Technologies for Safety Assessment
Research by Teizer (2007) identified that automated soil classification, trench and environment dimension measuring, and trench monitoring using emerging technologies and data processing tools have the potential to further improve safety in excavation work. That research presented initial work in detecting static and moving objects in trenches classified as stable rock using a real-time 3D video range imaging camera. The focus of the study was to detect and track objects in trenches to warn workers of potential hazardous situations. This was accomplished by finding the precise location of a worker or any other construction resource (e.g., workforce, materials, equipment) within the trench. The resulting 3D model was then integrated into a 3D obstacle avoidance system where locations of all construction resources were stored and tracked in real-time. The expected result is the prevention of accidents such as struck by or contact from heavy equipment. An example of the application of such technology described by Teizer (2007) was that of a work crew which includes machines (e.g., backhoe installing precast pipes), where a visual or acoustical warning signal to equipment operator and trench worker would be issued if loads were placed too close or above workers and both were recognized with the 3D range camera.

Both wireless jobsite safety monitoring and visual technologies for safety assessment have great potential to improve safety on jobsites. These technologies could be implemented allowing safety related tasks such as;

- Continuously estimating the proximity of workers to safety threats and automatically determining if the worker is at risk of injury.
• Real-time evaluation of trench slope and depth in unstable soils where sloping is used instead of a trench box.
• Precise cause of accidents and post event simulation, e.g. black box recording of relevant accident data that later on can be analyzed and used for training purposes.
• Classify soil types automatically based on exposed 3D texture during excavation.

Virtual Reality and Safety Training
Soedarmono et al. (1996) developed a Virtual Reality (VR) model for training construction workers. The model consisted of a virtual construction environment that incorporates working platforms that are known to pose fall hazards to workers. The working platforms represented were floor edges, floor holes, wall openings, tops of walls, and ladders. The respective safety devices were incorporated into each of these platforms. The trainee would move about the virtual construction environment and when one of the designated working platforms was reached, visual messages in the form of program windows would appear. These windows contained information from the actual OSHA safety standard applicable to the particular situation. Also, an audio explanation of suggested strategies that the worker could implement in order to improve safety inside the working platform was provided. One limitation of this application is that the user would observe the virtual environment on a computer monitor, limiting the immersive aspect of the environment.

Tawfik and Fernando (1999) developed a simulation tool that used VR technology for organization of the site layout considering productivity and safety. This tool was used to explore possible improvements in productivity and safety by minimizing travel times for activities such as material delivery, movement of equipment and materials, and movement of labor. Safety could be improved by minimizing risks associated with hazardous areas near equipment and processes.

Shiratumddin and Thabet (2003) developed a Virtual Environment (VE) design review system that allows facilities to be represented by a virtual three-dimensional (3D) environment that can be updated in real-time to reflect the changes and modifications made by the user. The system uses commercially available and affordable 3D game development tools. The benefits of this system are reduction in the design review cycle and the early detection of design conflicts.

Research conducted at the Building and Fire Research Laboratory of the National Institute of Standards and Technology explored the use of the Virtual Reality Modeling Language (VRML) for application in the construction industry (Lipman and Kent 2000). Modeling of geometric information of structural steel elements and construction equipment was accomplished using this approach. Possible applications of the modeling methodology are material tracking from arrival to site through final assembly and user controlled equipment operation. This will allow a real-time monitoring of the progress of construction activities and the development of training tools for equipment operators.

Irizarry and Abraham (2005) proposed a Virtual Construction Environment for Steel Erection (VCESE). In this system, different steel erection scenarios could be constructed using various geometric configurations of steel members and environmental conditions. Experiments would be conducted by selecting a specific steel erection task and selecting the desired scenario. The performance of the participant in the experiment could then be evaluated to measure how the selected conditions affected his performance. Another function of the system would be to provide safety training to ironworkers without exposing them to actual physical danger.
The cited examples of applications of virtual reality technology for safety training show that
that there exists great potential to improve current safety training practices by providing tools that
provide a realistic view of safety hazards without posing any real risk of harm to the trainee.
More development is needed in this area before the technology can be generally used by the
construction industry.

Technology Enhanced Construction Safety Training
for the Hispanic Worker

Risk Perception Concepts
Before we can describe the risk perception based safety training concept, we must first provide
some background information on risk taking behavior and accident causation, and factors
influencing safety performance. Having provided the necessary background information, the
paper will then provide more details on how risk perception can be used as a proactive means of
safety management by providing directed safety training in areas where reduced risk perception
could lead to accidents and injuries on the jobsite.

There are numerous definitions of risk, among which are the existence of threats to life or
health (Fischhoff et al, 1981), exposure to the chance of injury or loss (Hertz and Thomas, 1983),
and the likelihood that harm will occur (Health and Safety Commission, 1995). Risk-taking can
be defined as following a course of action selected at the end of a probabilistic process. Risk-
taking behavior has been identified as a leading cause of accidents (Wagenaar, 1992). In many
accident reports, the causes of accidents are attributed to irresponsible underestimation or
acceptance of risk. This leads to the hypothesis that misperceived risk or consciously accepted
risk is a major cause of accidents.

Two risk theories relevant to this paper are the risk homeostasis theory (Wilde, 1982) and the
zero-risk theory (Näätanen and Summala, 1974; 1976). The risk homeostasis theory states that an
individual’s behavior in risky situations is determined by a desire for cost minimization, which
explains how behavior can be in accordance with risks, even subjectively perceived risks, without
an ever-repeated process of conscious risk evaluation. This theory suggests that no safety measure
will ever help to reduce risk and that risk control measures should be replaced by cost control
measures. The zero-risk theory states that people seek situations in which there is no risk. Forces
that play a role in this model are perceptual, experimental, and motivational. Both of these
theories are important to the study of the risk perception of Hispanic workers because they relate
different dimensions of risk perception with resulting behaviors in risky situations. Understanding
these relationships can contribute to the development of safety training programs that target
worker risk perception as a method of hazard prevention and avoidance.

The experience of construction workers and their knowledge of safety are important factors to
consider in the evaluation of Hispanic worker risk perception. In a study of hazard perception and
risk estimation in accident causation, Zimolong (1985), found that acceptable risk levels are
established as a result of previous experiences and cognition. Information about accident-causing
factors was obtained from investigating working conditions and personal behavior in hazardous
situations. He concluded that workers are more likely to underestimate high-risk situations if they
had a long-time experience with these hazards.

Worker behavior regarding safety may be influenced by the worker’s perception of what is
safe or unsafe. Based on this perception, decisions are made when to adopt or not adopt required
safety precautions. This relationship was observed by Huang and Hinze (2003), who found that
approximately 33.3% of fall accidents are caused by misjudgment of workers about hazardous situations.

Other factors can affect safety on construction sites by increasing the probability of accidents. Toole (2002) found that the lack of proper training, deficient enforcement of safety behavior, not using provided safety equipment, and poor attitudes toward safety were among the root causes of construction accidents. Lack of proper training can limit the ability of a worker to recognize and avoid a hazardous situation and hence increase the risk of accidents. Deficient enforcement of safety can increase the risk of accidents since workers have less direction regarding applicable safety standards and there is less control of unsafe behaviors. Improper use of safety equipment is a common cause of construction accidents. The risk of accidents is significantly increased when safety equipment is not used effectively. In many instances, the use of safety equipment is reduced when the worker perceives that performance will be adversely affected. The perception that using safety equipment affects performance was investigated by Irizarry et al. (2004) and Irizarry and Abraham (2006). The studies indicated that task durations in steel erection were increased only by small levels when fall protection equipment was used. This negates the belief that using safety equipment reduces productivity to the point of justifying reduced use of personal protective equipment.

Poor attitudes toward safety involve worker beliefs, values, and work ethic. Workers may have been trained properly, but a “tough-guy” mentality prevents them from avoiding job hazards (Toole, 2002). Since the causes discussed are behavioral in nature, the factors that are involved in the causal process can be used to learn about the risk perception of workers.

Prior research studies have identified a number of factors that could impact safety at the construction site. Hinze and Gambatese (2003) identified several factors that influence the safety performance of specialty contractors (mechanical and roofing contractors). This study compared the factors that were believed to impact safety performance with the median injury rate of the specialty contractors surveyed. They concluded that factors such as turnover, drug testing programs, worker training, involvement of trade associations, and safety inspections significantly influence the safety performance of specialty contractors. Safety incentive programs were also considered in the study, but strong evidence to support their effectiveness in reducing injuries was not found. Recommendations that resulted from the findings of this study included the minimization of turnover, implementation of drug testing, and training with the assistance of trade associations (Hinze and Gambatese, 2003). Ahmad and Gibb (2003) identified the presence of a safety officer and tool-box talks as some of the safety control measures (SCMs) that affect safety performance on construction sites.

The relationship between age and worker fatalities was addressed by Chen and Fosbroke (1998), Buskin and Paulozzi (1987), Kisner and Fosbroke (1994), and Kisner and Pratt (1997). These studies suggest that older construction workers have a higher risk of injury. Height and weight are two factors that were found to affect safety performance. Kelsey and Golden (1998) found that workers with less than or greater than optimal body mass index have a higher risk of back injuries. It is important to be aware of factors such as those described for they provide valuable information in developing the methodologies that would allow the assessment of risk perception of construction workers considering their unique backgrounds and socio-cultural characteristics. The following sections will describe the proposed risk assessment methodology and training systems for the Hispanic workforce.

With the continuous changes in the construction industry workforce, contractors are challenged to provide safer workplaces in different ways. Construction companies have to
develop effective strategies that incorporate the needs of a diverse workforce. Safety and motivation of a construction work force to avoid hazardous situations is strongly influenced by cultural background and perceptions of acceptance within the societal group. Addressing safety practices can present a challenge for companies that employ people from different cultural backgrounds. The complexity of the problem is aggravated by worker specific factors such as the perception of safety and hazards, worker engagement on safety behavior, work experience, previous accidents or injuries as well as work environment factors such as safety training and employer safety management practices.

Risk Perception-Based Safety Training
The goal of the methodology presented is to develop the framework to assess the risk perception of Hispanic workers and evaluate if socio-cultural, worker specific, and work environment factors specific to this population of workers influence their risk perception. Interventions developed with this framework have the potential to improve the safety of Hispanic construction workers across many areas of the construction industry by considering risk perception of hazards and dangerous behaviors, one of the root causes of accidents. By identifying the factors influencing risk perception of Hispanic workers, the appropriate safety control (training, engineering, surveillance, or removal from hazard) can be implemented. The key objectives of the proposed methodology are:

- To develop a framework for assessing risk perceptions of the Hispanic worker from the evaluation of socio-cultural, personal, and work environment factors and their impact on safety. This will form the basis for developing interventions to communicate the safety hazards inherent in construction operations and prevent injuries and fatalities among this group of workers.

- To develop and test a risk perception-based early warning system for construction safety of Hispanic workers which employs risk perception assessment as a method of accident prevention and avoidance.

The ultimate goal of the research is to reduce the number of injuries and fatalities among Hispanic workers in construction by early intervention methods rather than after the fact interventions or extensive surveillance. The proposed research is based on a partnership between the research team, contracting companies who support the study, and the construction workforce who will directly benefit from the results.

The proposed research addresses components of various strategic goals of the National Occupational Research Agenda (NORA) National Construction Agenda (NORA – 2008): (a) Strategic goal 1.0: Falls, (b) Strategic Goal 3.0: Struck-by-Hazards, (c) Strategic Goal 8.0: Construction Culture, (d) Strategic Goal 9.0: Construction Industry and Work Organization (emphasis on small and mid-size contractors), (e) Strategic Goal 11.0: Training and Education Issues, and (f) Vulnerable Workers (emphasis on Hispanic workers).

Some advantages of such a system are:

- A low-cost individualized and on-demand approach to safety training that can be used by SMEs.

- The ability to provide re-fresher training for each worker to reinforce important safety concepts.
• Immediate feedback on understanding of learning objectives, which may not always be possible with traditional training methods.

• A scalable system that can be expanded for training in different areas of construction operations, such as heavy equipment operation, confined spaces, electrical work, and many others.

• The ability to measure changes in a worker’s risk perception over time allowing employers to address potential problems before they result in injuries or fatalities in the job-site.

Factors included in the initial development of the methodology which have been identified as issues impacting safety include: nuances of language and culture of Hispanic workers, especially those born outside the country, level of literacy, type of societal values – matriarchal/patriarchal, deference to authority, economic standing, the perceived “technology” gap, and the issues with ‘being disrespectful to authority” if admitting that instructions were not comprehensible. A brief description of the major components of the research methodology follows:

1. **Phase 1- Assessment of safety factors.** The purpose of this phase is to identify the most relevant safety factors related to the activities of interest (e.g., trenching, roofing, steel erection, etc.) This assessment is performed by evaluating previous studies in construction safety, focus groups, and a questionnaire both addressed to Hispanic workers, and job site visits.

2. **Phase 2- Identification and evaluation of safety training practices.** The purpose of this phase is to identify the most relevant safety training practices related to the construction activities of interest. A second survey questionnaire will be deployed in order to categorize practices implemented by construction companies and their success in addressing the needs of Hispanic workers in terms of their understanding of job-site hazards.

3. **Phase 3- Development of information technology enhanced safety training system.** Once the most relevant practices have been identified and evaluated, a safety training system which uses interactive touch display technology and incorporates factors that influence Hispanic worker’s perceptions of safety will be developed.

4. **Phase 4- Testing and evaluation of training system.** This evidence-based safety training system uses randomized trials of educational interventions to test its effectiveness in enhancing Hispanic workers’ awareness of job-site hazards. The results of system testing will be evaluated and compared with results from safety training practices identified in the previous phase. An important metric that will be used in the testing phase is the analysis of changes in Hispanic workers’ risk perception of the tasks they perform. Also, learning outcomes will be evaluated and compared with results from the safety training practices identified in the second phase of the study.

**Conclusions**

There is no question that construction continues to be one of the most dangerous occupations in the US economy. Traditionally, construction professionals have been addressing safety issues on job sites by implementing approaches such as specific training, toolbox meetings, monetary incentives, daily safety meetings, etc. All these methodologies are intended to increase awareness of construction workers regarding hazardous situations in the job site. However, existing technology makes it difficult to supervise if workers are following their safety guidelines during the execution of their activities or fully understanding the concepts transmitted on by the training
received. As a result, accidents and fatalities still occur on the job sites even after extensive training and supervision. Technological advances in PPE have improved safety by protecting workers from injuries or by minimizing injuries if an accident occurs. But there are other technologies that are yet to be tapped to accomplish the goal of reducing injuries and fatalities in construction. Some of those technologies described in this paper include wireless jobsite safety monitoring, visual technologies for safety assessment, and virtual reality for safety training. This paper has presented an innovative approach to address the safety needs of Hispanic workers by developing a methodology that involves the development of technology enhanced safety training based on risk perception assessment. The expected outcome of the proposed methodology is an interactive training system; this portable technology can be used on the job site and will incorporate the issues related to the Hispanic workforce that may impact their understanding and perception of safety hazards in the many construction activities they perform.

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