An Evaluation of Perceived and Observed Safety and Productivity in Residential Construction

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ABSTRACT

The construction industry leads the private sector with the most fatalities of any industry in the United States. With an expected growth of the industry in the next century, safe work environments are imperative. They will impact the bottom line of the industry through the reduction of fatal and non-fatal injuries.

Although the causes of injuries and illnesses in construction have long been tracked, reported and researched, the industry continues to lead in occupational related fatal and non-fatal injuries. It is critical to understand if a tradeoff exists between safety and productivity to avoid shortcut behaviors in the field. This is specifically important due to the number of contractors, subcontractors and laborers that participate in the different projects.

The overall objective of this research was to increase the understanding of the relationship between perceived and observed safety and productivity and to understand the variability in perception and behavior between crews working for the same general contractor in the homebuilding construction industry. For this research, questionnaires and behavioral observations were employed.

The results demonstrated a significant moderate positive relationship between safety climate and perceived risk behavior at the crew level. A model was developed that suggests that safety climate and work ownership are predictors of perceived risk behaviors. This relationship is important to understand since employee attitudes, safety commitment and organizational factors may affect acceptability of safety processes and procedures.

The differences among construction crews were evaluated at two levels, individual crews and critical path groups. All tests were significant for differences among crews. To further understand these differences, crews were grouped in accordance with the critical path of a homebuilding schedule. A significant difference existed for risk behavior, productivity loss and work ownership.

Behavioral observations were used to evaluate crew performance. Top contributing behaviors of productivity, safety and waste were identified. The top behaviors provide improvement areas for productivity, safety and waste.

Overall, learning from this research provided insight into the relationships between safety climate, risk behavior, productivity and work ownership. Understanding this relationship can contribute to the design of safety interventions, and consequently, the reduction of injuries and fatalities.

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Chapter 1. Introduction

1.1 Background

1.1.1 Construction Industry

The construction industry leads the private sector with the most fatalities of any industry in the United States. The private construction industry sector recorded 969 fatal work injuries in 2008 with a rate of 9.6 per 100,000 workers (Figure 1). Additionally, in 2008, construction workers had an incidence rate of 4.7 per 100 full time workers (BLS, 2010c). The private sector definition describes ownership type. The private sector total values exclude state and local government ownership values.

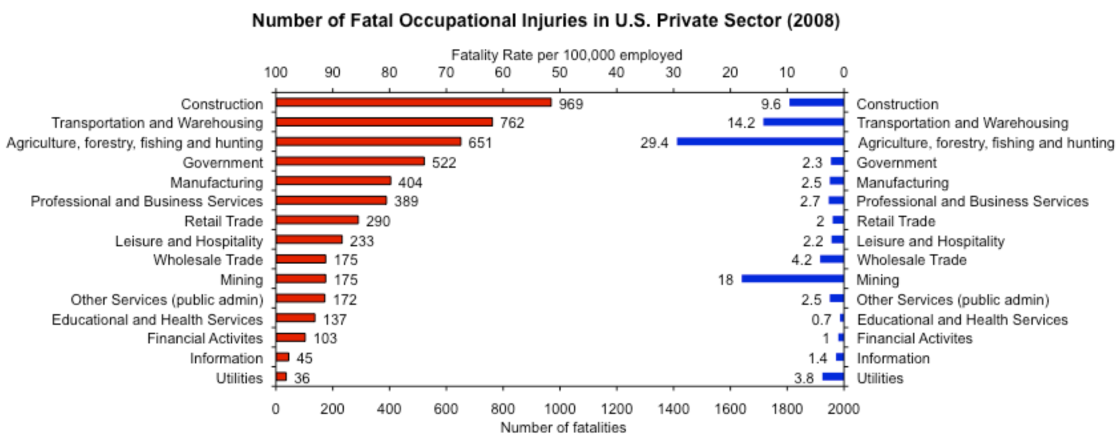


Figure 1 - Fatal Occupational Injuries in the Private Sector for 2008 (BLS, 2010c)

In 2008, the construction industry reported 120,240 nonfatal occupational injuries and illnesses involving days away from work (BLS, 2009). Among construction occupations, laborers and carpenters accounted for approximately 35% of the total number of cases. The incidence rate for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full time workers was reported as 174.3. The incidence rate per 10,000 full time workers for the leading nature of nonfatal injuries and illnesses for 2008 included: sprains (57.9), fractures (19.5), cuts/lacerations (19.3), bruises/contusions (11.4), multiple traumatic injuries

(6.9) and punctures (5.6) (BLS, 2009). These alarming statistics continue to highlight the health and safety concerns of the construction industry in the United States.

The costs of fatal occupational injuries in the United States was estimated to be a total of $10.4 billion for the 10 year period from 1992 to 2002 (NIOSH, 2006). This amount was estimated using direct costs, including medical expenses, and indirect costs derived by calculating the present value of future earnings summed from the year of death until the decedent would have reached age 67. The report estimated a $864,000 average per-fatality costs (NIOSH, 2006). The need to create and maintain safe work environments is a high priority. A dedicated commitment to safety has never been more important. With an expected growth of the industry in the next century, safe work environments will impact the bottom line of the industry through the reduction of fatal and non-fatal injuries. The U.S Bureau of Labor Statistics projects investment in residential structures will grow by five percent annually between 2008 and 2018 with construction of single-family homes growth by an average of 7.5 percent annually from 2008 to 2018 (Wyatt & Byun, 2010). Additionally, BLS projects that nonresidential investments will grow by three percent per year from 2008-2018 (Wyatt & Byun, 2010).

The construction industry is complex with challenges specific to each individual project such as unique products, production processes, temporary production systems, shared resources between projects by subcontractors, organizational structures, size, location, labor composition, safety, and logistics management (Bertelsen, 2004). Construction is a temporary endeavor for which a new organization is created for every project. Worksites are dynamic due to sequential work processes, levels of technology, tool iterations, workforce factors, and the various levels of safety awareness and training of personnel (Bertelsen, 2003). The industry is highly fragmented, including projects which are divided into parts that are subcontracted to separate companies, often awarded to the lowest bidder (Bertelsen, 2003).

The construction industry has four distinctly different sectors - residential, commercial, industrial and heavy construction, with specialty trade contractors (e.g., carpenters, plumbers) involved in all four sectors (NIOSH & IOM, 2008). In the construction industry, general contractors (GC) specialize in a specific type of construction, coordinate the work and often subcontract to heavy construction or specialty trade contractors. Specialty trade contractors do the work of one trade such as carpentry, electrical, or masonry and have responsibility for fitting their work to that of other trades (BLS, 2010a). The specialty trade contractor may also hire day laborers to help complete the work. Day laborers are hired and paid one day at a time.

The residential sector is the largest of the four sectors with millions of small contractors and a relatively unstructured craft environment (NIOSH & IOM, 2008). Construction includes a large number of self-employed workers and about 68% of the establishments employ fewer than five people (BLS, 2010a).

The residential sector builds single-family houses, townhouses and low-rise (up to five-story) multifamily apartments and condominiums (NIOSH & IOM, 2008). Residential sub-contractors may support several projects (and General Contractors) simultaneously. There is a large variability in health and safety training, with some workers having formal training and others only having on-the-job training. Compliance with regulations or the use of best practices is problematic since contractors may not have the knowledge, training or incentives to apply best practices while regulatory agencies may not have the resources to inspect small projects (NIOSH & IOM, 2008).

1.1.2 Construction Industry Awareness and Regulations

The increasing awareness of construction workplace hazards has resulted in the creation of special-interest U.S. research groups such as The Center for Innovation in Construction Safety and Health Research (CSC) and The Center for Construction Research and Training (CPWR) which conduct research and provide information and services on occupational safety and health (Appendix A). These groups often conduct research that focuses on the application and practice of their findings. The continuing health, and safety awareness and research continue to provide greater understanding of the industry, especially the personnel subsystem, which has experienced significant demographic changes.

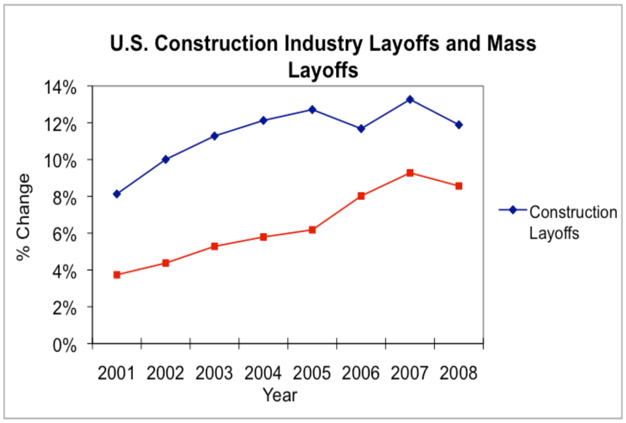
The United States Federal Government and industry continue to focus regulations on worker health and safety through safety awareness, research and communication. The Healthy People 2010 ("Healthy People 2010," 2000) agenda, a national health promotion and disease prevention initiative including national objectives for high-risk sectors, targeted a 30% reduction goal for work-related injuries and deaths among construction workers by 2010. According to the midcourse review, 52 percent of the targeted goal has been achieved ("Healthy People 2010 Midcourse Review," 2005).

There is a multitude of government regulations in the United States that apply to construction worksites to address unsafe work habits and practices. The interpretation and implementation of these standards, however, is often the responsibility of the employer, usually the general contractor. The OSH Act General Duty Clause states that each employer "shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employee" (OSHA, 2006). Additionally, The Occupational Safety and Health Administration Employee Workplace right states that an employer with more than ten employees must maintain records of all work related injuries and illnesses (OSHA, 2003). Isolating health and safety accountability to one party provides limited success since it does not distribute the responsibility of safety among all involved stakeholders, including all contractors and subcontractors.

The potential for a system accident, in a high risk system, can increase in a poorly-run organization (Perrow, 1999). If there is poor regulation, poor quality control, and/or poor training, there is an increased chance of failure in the design, equipment, procedures, operators, supplies, materials and environment. These can make the unexpected interaction of failures more likely, because there are more failures to interact (Perrow, 1999).

Additional confounding factors may impact the accident occurrences in the construction industry including production processes, temporary employment, seasonal employment, layoffs, changing population trends, productivity and schedule, amongst others. For example, in 2008, there was a total of 1,726 extended mass layoff events (Figure 2) in the United States resulting in 205,457 worker separations (BLS, 2010c). The threat of layoffs may put workers at risk for workplace injuries and accidents. Employees who may have to juggle competing job demands of production, quality and safety may feel pressure to cut safety corners to keep their production numbers high, especially if they fear losing their job (Ettner & Grzywacz, 2001; Probst & Brubaker, 2001).

The ability of an occupational safety and health solution, including safety regulatory requirements and performance to fit with the needs and constraints of an overall construction company is not the same as its ability to fit with the contractors and sub-contractors of the company. The uniqueness of each project should not be considered a constraint to the integration of health and safety in the construction process. This is especially the case in residential construction, where different approaches by subcontractors, may introduce variability in the system. Safety in construction has been long researched by academics and industry to understand root causes that negatively impact health and safety.



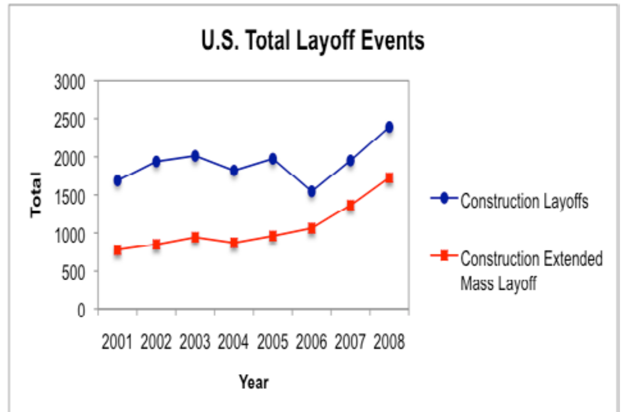


Figure 2 - U.S Layoff Events (a) Percentage of Total and (b) Total (BLS, 2010c)

1.2 Health and Safety in Construction

Construction worker health and safety continues to be at the forefront of concerns for the industry. Although the causes of injuries and illnesses in construction have long been tracked, reported and researched, the industry continues to lead the occupational related fatal and non-fatal injuries.

There have been extensive analyses of safety issues and best practices published in the construction research literature. The role of management's influence on site safety was evaluated by Baxendale and Jones (2000). The roles of designers, owners and workers have also been researched (Gambatese & Hinze, 1999; Hinze & Wiegand, 1992; Huang & Hinze, 2006). Many researchers have evaluated and studied safety climate (Mohamed, 2002; Wamuziri, 2006; Zohar, 1980). Gambatese, Hinze and Behm (2005) outlined the potential for a safety in design approach. Zero injury techniques, a best practice by the Construction Industry Institute (1993), focuses on recognizing the value of each employee.

The construction industry has historically functioned as independent parties that "pass down" the responsibilities of the project after their section has been completed. For example, the information exchange model for residential construction can lead to the isolation of information within each technical trade or technology in the business process, resulting in the optimization of compartmentalized components and subsystems without regard to the overall performance effects of the house (O'Brien, Wakefield, & Beliveau, 2000). This is further emphasized by the summary that about 135 people are involved with the process of making a house from design to final inspection (O'Brien et al., 2000).

Integration of roles has historically been lacking. The aforementioned research has highlighted the influence of the personnel sub-system in the construction industry and on overall safety. Training programs are a common approach to health and safety in construction. The continuity of these, however, is hard to measure due to the various models of communication and responsibility among design, engineering and the building professionals.

Construction companies often use safety training, toolbox talks, pre-task hazard planning, inspections, incentives and citation programs to prevent accidents (Mitropoulos, Howell, & Reiser, 2003). The challenge for any safety program, however, occurs when apparent conflicting priorities exist. These can include necessary productivity increases, expedited schedules, and schedule slips, among others. Workers may engage in unsafe behavior because they believe it to be more productive.

The need to understand safety culture in the construction industry has been established by the National Occupational Research Agenda (NORA). The National Institute for Occupational Safety and Health (NIOSH) is the steward of NORA, which includes the development and implementation of research agendas for the occupational safety and health community for 2006-2016. A draft agenda has been published by the NORA construction sector, which includes in Section 2, *Construction Safety and Health Culture* (Table 1). The strategic goal 8.0 outlines a series of intermediate goals to fulfill the need, “Increase understanding of factors that comprise both positive and negative construction safety and health cultures; and, expand the availability and use of effective interventions at the policy, organizational, and individual level to maintain safe work practices 100% of the time in the construction industry (NIOSH, 2008, p. 64).”

A study, including 239 study participants employed in diverse hazardous occupations, suggests that workers differ in their perception of the compatibility of safety and production demands (McLain & Jarrell, 2007). These differences show up in safe work behavior, influencing the effectiveness of safety management efforts and the trust workers have in management's concern for safety. This is consistent with the description by Zohar (2008), that suggests that safety issues often compete with operational issues such as speed or flow of production, and as such, enforced safety policies and procedures can be construed in terms of the relative priorities of safety and other production goals. It is important to understand if worker perception of safety (i.e. safety climate) and productivity affect behaviors in the field.

Table 1 - National Occupational Research Construction Agenda Goals (NIOSH, 2008)

Topic: Traumatic Injury/Events - Strategic Goal 1.0: Falls - Strategic Goal 2.0: Electrocution - Strategic Goal 3.0: Struck-by Hazards
Topic: Health Hazards - Strategic Goal 4.0: Noise and Hearing Loss - Strategic Goal 5.0: Silica Exposures and Illnesses - Strategic Goal 6.0: Welding Fumes and Illnesses
Topic/Strategic Goal 7.0: Musculoskeletal Disorders
Topic/Strategic Goal 8.0: Construction Culture
Topic/Strategic Goal 9.0: Construction Safety and Health Management
Topic/Strategic Goal 10.0: Construction Industry and Work Organization
Topic/Strategic Goal 11.0: Training and Education Issues
Topic/Strategic Goal 12.0: Disparities in Health and Safety in Construction
Topic/Strategic Goal 13.0: Construction Hazard Prevention Through Design (CHPtD)
Topic/Strategic Goal 14.0: Improving Surveillance of Hazards and Outcomes
Topic/Strategic Goal 15.0: Engage the Media to Raise Awareness and Improve Safety and Health in Construction

1.3 Safety Climate and Safety Culture

Safety climate relates to shared perceptions with regard to safety policies, procedures and practices (Zohar, 2003). It is a snapshot of the state of safety providing an indicator of the underlying safety culture of a work group, plant or organization (Flin, Mearns, O'Connor, & Bryden, 2000). Safety climate has been shown to be a predictor of injury records (Barling, Loughlin, & Kelloway, 2002; Zohar, 2000).

Safety culture is, "a sub-facet of organizational culture, which is thought to affect members' attitudes and behavior in relation to an organization's ongoing health and safety performance (Cooper, 2000, p. 111). In differentiating culture and climate, safety culture is the shared values and beliefs of an organization and safety climate describes the prevailing influences of safety at that particular time (Stricoff, 2005). Taking a snapshot in time of culture versus climate could help identify their relationship. The mood of the organization at a specific time (climate) and the personality (culture) are not necessarily available through the review of the mission, vision, and values.

There exists a large body of research, some conflicting, on the concept of safety climate and culture (Guldenmund, 2000). Several studies indicate that safety climate is often erroneously used interchangeably with the term safety culture (Clarke, 2000; Guldenmund, 2000).

Lund and Aaro (2004, p. 273) propose that the concept of safety culture is an outgrowth of 'safety climate', which is in turn a derivate of 'organizational climate'. The organization climate construct includes facet-specific concepts like climates for service or safety. The operationalization of safety climate has led to many different scales. The number of dimensions of safety climate remains disputed, although there are some common themes across the surveys which include management, safety systems, risk, work pressure and competence (Flin et al., 2000).

It has long been assumed that people presume a tradeoff exists between productivity and safety. In the construction industry, it is critical to understand if a tradeoff actually exists between safety and productivity. Perceptions of performance pressure can lead workers to perceive that engaging in short cut behavior is expected or a required part of the job (Wright, 1986). Workers who perceive a high degree of performance pressure can focus their attention on completing work and less on the safety of their work procedures (Hofmann & Stetzer, 1996). This is particularly important in the construction industry, based on the number of contractors, subcontractors and laborers that are hired for each job.

1.4 Demographics in Construction

Over the past two decades, the United States has experienced one of the largest waves of immigrations in its history (Brunette, 2005). The United States Census Bureau (2000) reported that Latinos make up 13% of the total population. These numbers may be underrepresented since there are additional percentages of people who responded with more than one race or people who did not respond at all. The increase in Latino portion of the labor force in the United States from 1990-2005, showed the proportion of workers who identified themselves as Latinos increased by 86% for all industries, with a 156% increase for construction (CPWR, 2008).

The number of Latino workers employed in construction almost quadrupled, from 704,606 in 1990 to 2.6 million in 2005 and their residence patterns include the South and West (CPWR, 2008). Latino construction workers residence was reported as high as 57% in New Mexico, 54% in Texas, 48% in California, 47% in Arizona, 41% in Nevada, 34% in District of Columbia and 31% in Colorado (CPWR, 2008). These labor and population trends are important for health and safety solutions.

The terms Hispanic and Latinos have been used interchangeably in the literature. According to the U.S Census (2010a), Hispanics or Latinos are those people who classified themselves in one of the specific Spanish, Hispanic, or Latino categories, "Mexican, Mexican American, Chicano," "Puerto Rican", or "Cuban" as well as those who indicate that they are "other Spanish/Hispanic/Latino." In order to keep the integrity of the work cited both terms will be used accordingly.

In the construction private industry, the Latino population fatalities percentage remained unchanged at 26 percent and showed a two percent increase in non-fatal injuries and illnesses with days away from work (case numbers). The Latino population is the only group that showed an increase in non-fatal injuries and illnesses with days away from work (Figure 3).

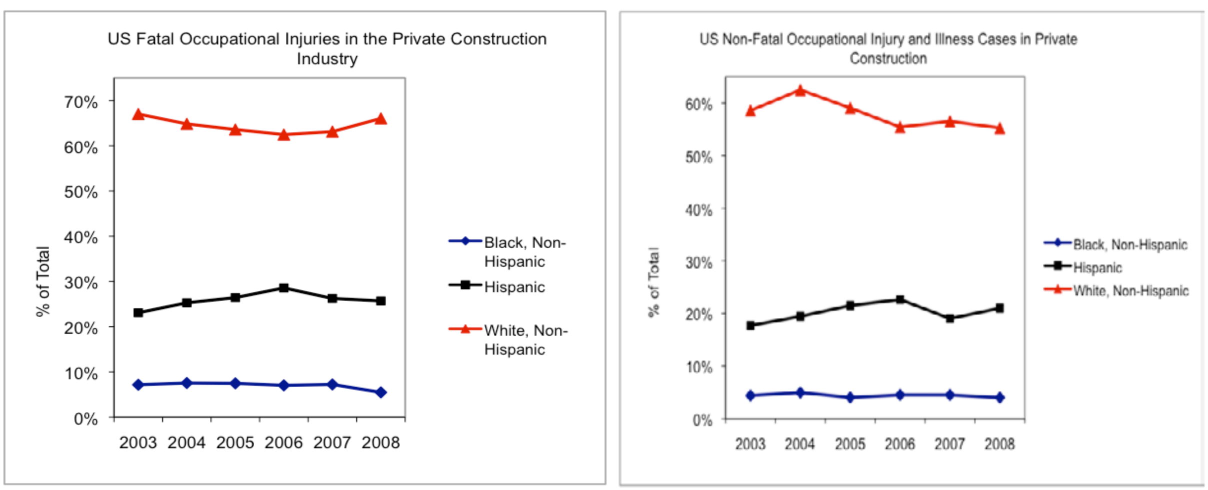


Figure 3 - Fatal and Non-Fatal Occupational Injuries by Ethnicity (BLS, 2010c)

Latino workers are more likely to work in production occupations in the industry (CPWR, 2008). The top percentage of construction occupations for Latino workers include: 49% drywall, 45% concrete, 40% roofer, 39% laborer, 37% painter, 36% carpet/tile, 34% mason, 25%

welder, and 24% carpenter (CPWR, 2008). These demographics are important for the construction industry, specifically when designing safety programs and interventions.

1.5 Residential Construction

A study was completed by the National Association of Home Builders to understand fatalities in the home building industry using information from the Bureau of Labor Statistics. There were 4,777 work-related fatalities in the construction industry from 2003-2006, 3,232 nonresidential (68%), 1385 residential (29%) and 160 Multi-family (3%) (NAHB, 2008b). From the 1,385 homebuilding fatalities, 482 occurred in residential construction and 903 occurred in residential specialty trades. The home building occupations with the most fatalities were laborers (376), carpenters (230), roofers (113), first-line supervisors and managers of construction trades (103), construction managers (93), and electricians (46) (NAHB, 2008b). From 2003 to 2007, there were 75 Latino framing contractor fatalities (BLS, 2010c).

Although the aforementioned data shows a high level review of the residential construction industry, more detailed information is critically needed to understand safety for specific occupations, industries and trades. Additional research is necessary to comprehend the residential construction industry supply chain, specifically the subsystems and their interactions.

The residential construction industry mostly includes a system of discrete trade subcontractors, with each being a small business whose priority has to be the efficient conduction of their defined contract. This can result in physical integration challenges such as inadequate access for maintenance and/or drain-line slopes, among others (O'Brien et al., 2000, p. 43). Although most residential construction companies have differences internal to their processes, there are several similarities and dissimilarities in processes that could be explored for improvement. A study that observed framing processes used by four production builders found the six categories of errors in building operations. Five are attributed to the information transmitted through the production process and the sixth to incompatibility between field and pre-manufactured component tolerances. The errors include interpretation, omission, representation, coordination and precision (O'Brien, Wakefield, & Beliveau, 2002, p. 14).

The housing production system includes many variations, mostly due to the contracting of the work. These create uncertainty in the production system. A possibility for these variations is the presence of waste. Waste has been defined, in the context of lean production systems as, "any human activity which absorbs resources but creates no value" (Womack, 2003, p. 15). Within the scope of this research, categories that contribute to a reduction in construction productivity will be considered waste.

Suboptimization of any construction process contributes to pressures that will be faced by the personnel subsystem. A study of a framing process found that much of the waste and variability in the framing process is caused by mistakes made in the frame or other systems including time spent building the item incorrectly, removing inaccurate components, reinstalling or reworking components, determining the right way to build (interpreting plans or waiting for information), working around previously installed systems, installing components with inferior tools, demobilization and remobilization (Johnson, 2007).

1.6 Lean Principles in Construction

The application of lean principles to the construction industry includes research that focuses on integrating lean production principles into construction. A fundamental principle of lean production is providing, "ways do to more with less, less human effort, less equipment, less time and less space while coming closer to providing customers with exactly what they want" (Womack, 2003, p. 15). A key component of this concept is reduction of waste.

Waste has been defined, in the context of lean production systems as, "any human activity which absorbs resources but creates no value" (Womack, 2003, p. 15). Monden (1993) identified four wastes that can be found in manufacturing including: 1) excessive production resources, 2) overproduction, 3) excessive inventory and 4) unnecessary capital investment. These wastes should be eliminated for cost reduction. Formoso et al. (1999, p. 328) defined non-value adding costs as, "any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client."

Alwi, Hampson and Mohamed (2002) collected data to explore variables that relate to non-value adding activities. The variables were separated into two classifications, waste categories that contribute to a reduction in the value of construction productivity and waste cause variables, defined as waste producing factors. The most significant waste causing variables found include: design changes, lack of trades' skill, slow decision making, poor coordination among project participants, poor planning, poor scheduling, delay of material delivery to site, inappropriate construction methods, poor design, poor quality site documentation, slow drawing revision, slow distribution, unclear site drawing supplied, unclear specification and weather (Alwi et al., 2002). It is further proposed that non-value adding activities can have an effect on safety. A construction site is a working place for humans, which includes cooperation and social interaction. Within a lean production paradigm, accidents are considered extreme forms of inefficiency and are to avoided at all costs (Wokutch & VanSandt, 2000b).

1.7 Construction as a Socio-technical System

Construction jobsites are highly transient social systems because of the temporary character of the projects (Bertelsen, 2003). An evaluation of construction as a socio-technical system includes a technical subsystem, a personnel subsystem, an external and internal environment and a organizational and management structure (Kleiner & Smith-Jackson, 2005). The technical subsystem is the manner in which the work is performed and includes heavy machinery, equipment, power tools, hand tools, methods and procedures. The personnel subsystem is the socio-cultural and socio-economic characteristics of the construction workers, including selection and training. The external environment encompasses the political, economic, technological, educational and cultural forces. The internal environment is the physical and cultural job site. The organizational and management structure can be formal or informal. Refer to Figure 4.

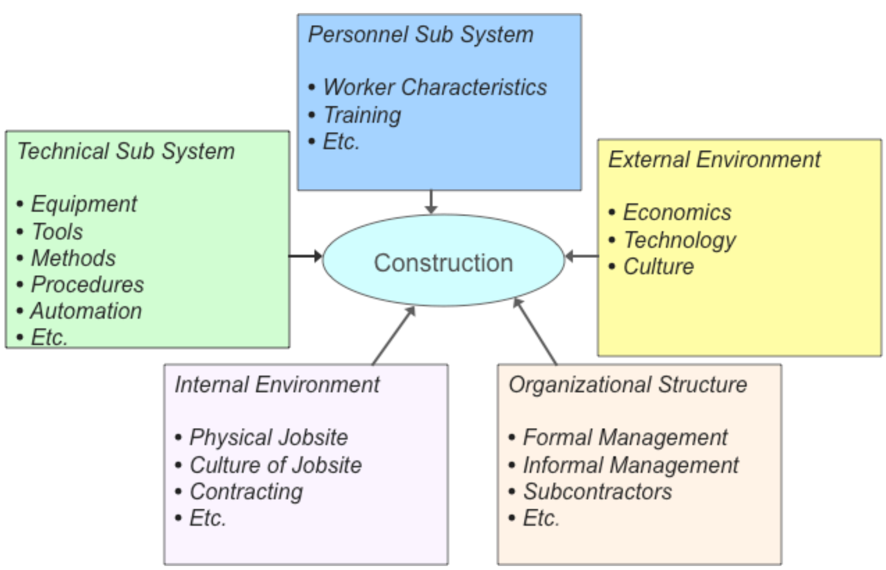


Figure 4 - Construction as a Socio-Technical System (Kleiner & Smith-Jackson, 2005)

The socio-technical systems (STS) model views organizations as transformative agencies which transform inputs into outputs (Hendrick & Kleiner, 2001). Socio-technical systems analysis involves analysis of the elements of an enterprise with regard to how they contribute to the enterprises' performance and create or meet the requirements of other elements. The major elements include: 1) technological, 2) work-relationship structure and 3) occupational roles (De Greene, 1973). Additionally, there are interrelationships of the elements. It is important to understand the interrelationship of the elements within the context of internal coordination and control within the enterprise, involving determination of the external environment in the analysis (De Greene, 1973). Socio-technical systems are open systems and do not remain static in changing environments (De Greene, 1973, pp. 83-84).

The term socio-technical system was first employed in 1951 by Trist and Bamforth (1951) of the Travistock Institute of Human Relations. The authors conducted a study in a British deep-seam coalmine to understand the effect of a technological change. The traditional method of mining involved small groups of miners (2-3 per group) which had internal work control. The technological change involved replacing the manual method with mechanical coal-cutters and conveyors (De Greene, 1973). This approach required a different type of group work organization (10-20 per group). The changes led to group defenses including, the formation of informal organizations, reactive individualism, mutual scapegoating, and absenteeism (Trist & Bamforth, 1951).

The detailed studies conducted in the coal-mining operations found that one social system can be found superior in terms of task performance, productivity, worker's personal requirements, personal and interpersonal reaction to crises and stresses (De Greene, 1973, p. 47). This can be particularly relevant to homebuilding, where different crews (subcontractors) may work for the same general contractor. The differences in performance and safety can be significant. Additionally, external factors, like the economy, may influence the available work and further stress the importance of performance.

1.8 Construction Economy

In the United States 2009 economy, the construction industry accounted for about 4.7 percent of all workers and 9.3percent (BLS, 2010b) of all establishments. This showed a decrease of 17 percent for employment and a decrease of 4.5 percent for establishments since the second quarter of 2008. In 2008, building construction accounted for 23% of total construction employment, with 11.5 percent being that of both residential and nonresidential buildings (BLS, 2010b).

In the United States, the private construction industry was strongly affected by the economic crisis starting in 2007 (Figure 5) and employment decreased significantly. For example, in 2008, the industry experienced employment reductions ranging from 15%-17% monthly from the previous year (BLS, 2010a).

The gross private domestic investment, a component of the Gross Domestic Product (GDP) for the United States, showed a decrease for construction in 2008 for both residential (owner occupied and rental housing) and nonresidential investments (building, machinery and equipment used for commercial or industrial purpose). The residential component showed a consistent decrease since 2007 (Figure 6). The number of houses constructed and sold (Figure 7) also represents the reduction (Census, 2010b). A slight increase, however, showed in the third quarter of the commercial component showing investment increases in 2009 (BEA, 2010).

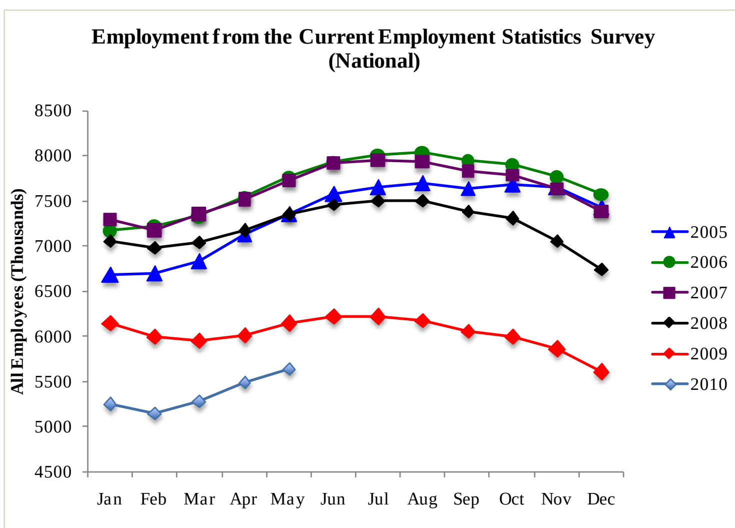


Figure 5 - Employment in the Construction Industry (BLS, 2010c)

Single-family structures were the most affected by the housing bubble within residential construction. In 2008, investment in single-family homes fell to the lowest point since 1991, resulting in an average annual decline of 4.6% from 1998-2008 (Wyatt & Byun, 2010). BLS projects investment in construction will grow annually between 2008 and 2018 by 5.1 percent for residential and 3 percent for nonresidential investments (Wyatt & Byun, 2010).

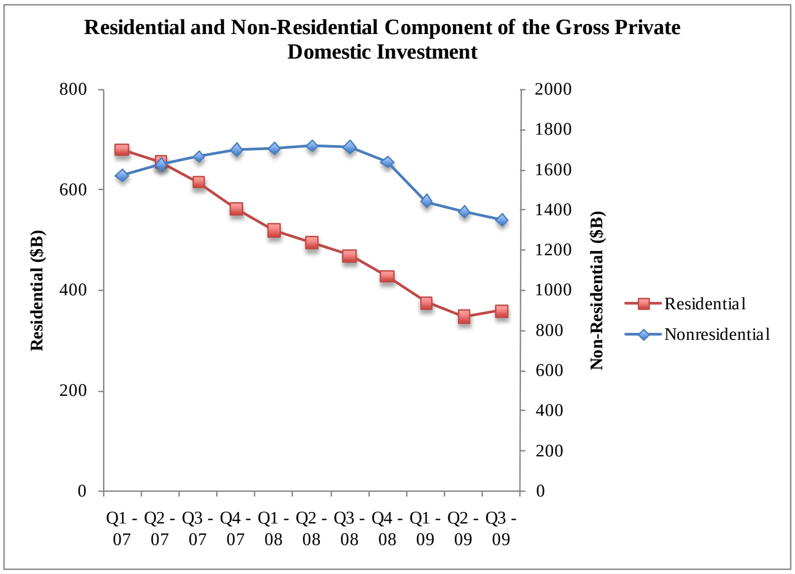


Figure 6 - Gross Private Domestic Investment (BEA, 2010)

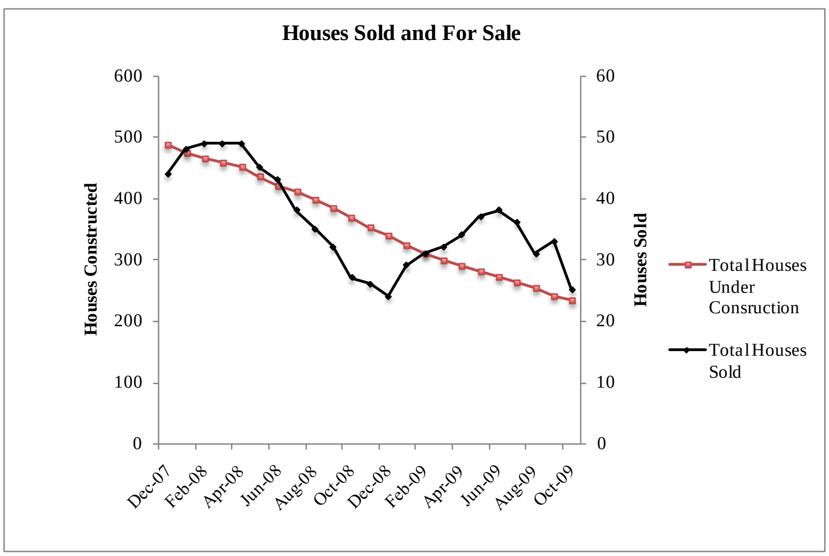


Figure 7 - House Sale Total (BEA, 2010)

1.9 Purpose of Research

The purpose of this research was to increase the understanding of the relationship between perceived and observed safety and productivity and to understand the variability in perception and behavior between crews working for the same general contractor in the homebuilding construction industry. Understanding this relationship will contribute to the design of safety interventions, and consequently, the reduction of injuries and fatalities.

1.10 Research Model

Cooper's (2002) adaptation of Bandura's (1977) model was adapted to understand the relationship between safety and productivity in construction. The model has three elements: person, job and organization. Each element in the model can also be broken down into the same reciprocal relationships. This research focused on the relationship between the internal psychological factors (attitudes and perception) and ongoing behaviors.

A two-phased data collection approach was used: Phase I) an evaluation of the relationship between perceived safety climate, risk behaviors, productivity, work ownership and variability among construction crews working for the same general contractor (Figure 8), and Phase II) an evaluation of the relationship between perceived safety climate, perceived productivity and observed safety behavior and labor productivity measures (Figure 9) among framers working for the same general contractor.

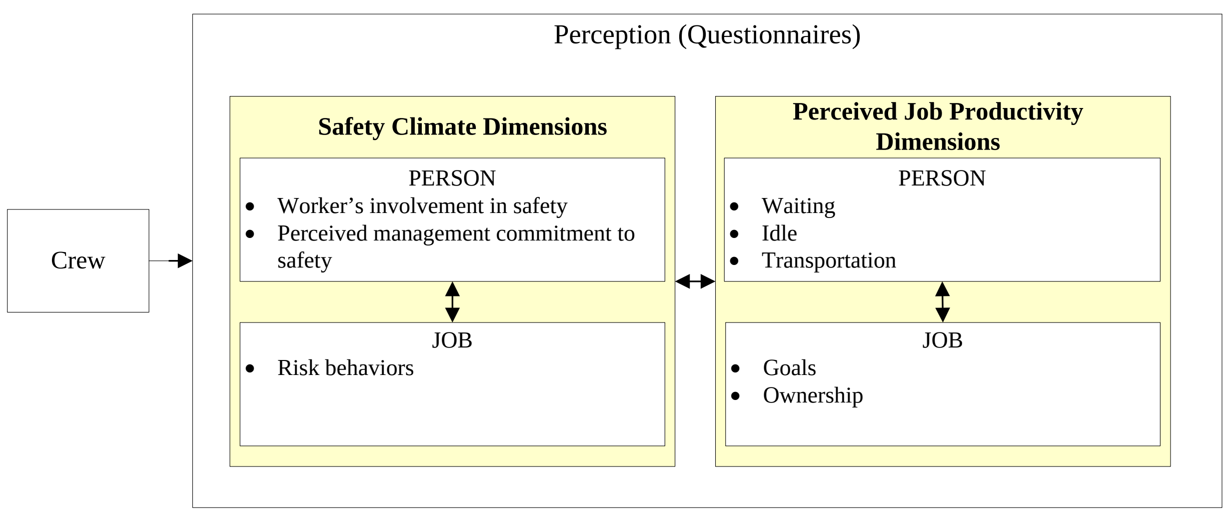


Figure 8 - Research Model Phase I

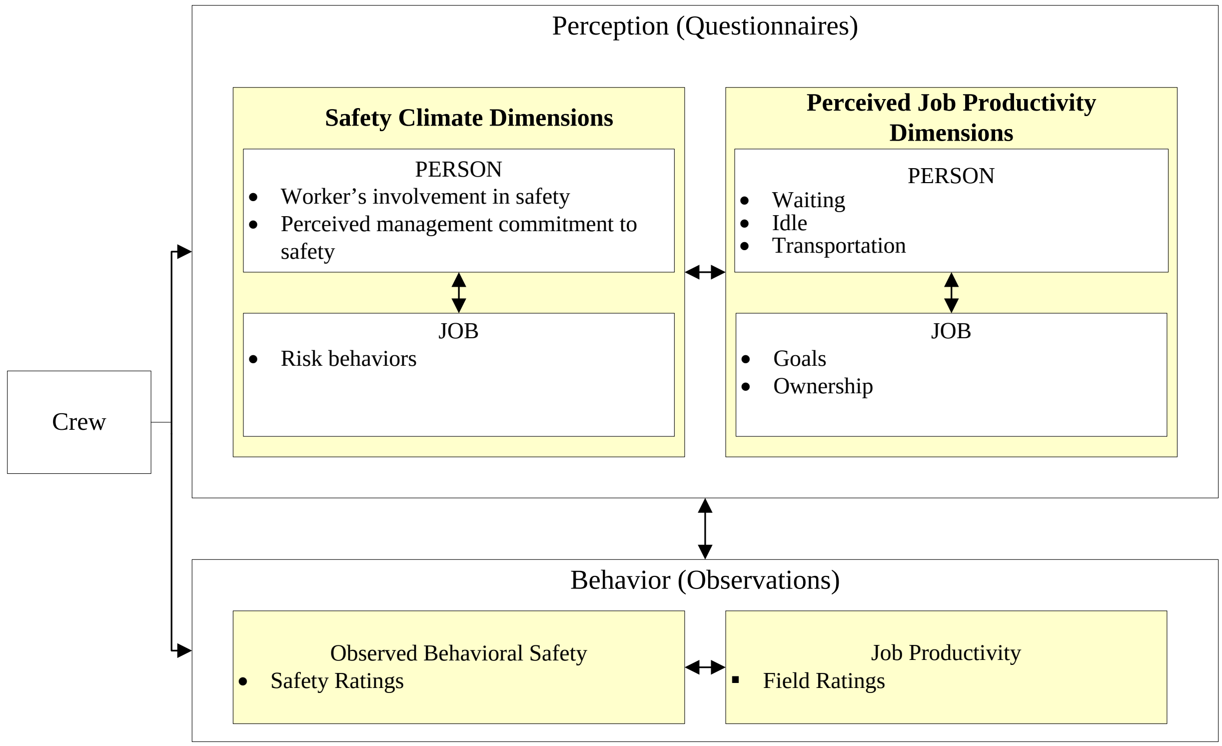


Figure 9 - Research Model Phase II

1.11 Research Objectives and Hypotheses

The construction industry leads the private sector with the most fatalities of any industry in the United States. With the employment changes expected in the next century, safe work environments will impact the bottom line of the construction industry. Literature supports variations in the housing production system. However, there are limitations to understanding these variations as related to safety.

It has long been assumed that people presume a tradeoff exists between productivity and safety. In the construction industry, it is critical to understand if a tradeoff actually exists between safety and productivity to avoid shortcut behaviors. This is specifically important due to the number of contractors, subcontractors and laborers that are hired for each job.

With these voids in consideration, the objectives for this research include:

- Evaluate the dimensions of perceived safety climate, risk behavior and productivity.
- Evaluate the relationship between workers' perception of safety climate, productivity, risk behavior, and work ownership.

- Evaluate if perceptions of safety climate, risk behavior, and productivity differ among crews working for the same general contractor.
- Evaluate the relationship between workers' perception of safety climate and observed safe behavior, workers' perception of risk behavior and observed safe behavior, and workers' perception of productivity and observed labor productivity.
- Evaluate the relationship between workers' perception of productivity, safety climate, observed labor productivity and observed safe behavior.

For this research, productivity will be defined as labor productivity. Labor productivity will be measured in the context of available materials, equipment, tools, information, safety equipment, rework, and material handling. The lack of these resources will be considered waste.

Measurements of productivity and waste can complement each other since the fundamental reasons for studying both are the same, to gather more information about the current state to achieve improvements (Forsberg & Saukkoriipi, 2007). Specifically, labor productivity, which is affected by human performance. Main sources of low productivity in construction include laborer's time spent on wasteful work or waiting for needed resources (Oglesby, Parker, & Howell, 1989), injuries and accidents (Wokutch & VanSandt, 2000b), and poor quality which requires time for rework (Zhang, Eastham, & Bernold, 2005). Therefore, one avenue for improving productivity is the elimination of the inefficient use of resources (Zhang et al., 2005). According to Forsberg and Saukkoriipi (2007), a better level of labor productivity will upgrade the level of value added activities and thereby can reduce waste and production cost.

It is hypothesized that perception of productivity will have a negative relationship with perception of safety (Evans, Michael, Wiedenbeck, & Ray, 2005; Hofmann & Stetzer, 1996). It is hypothesized that perceived safety will have a negative relationship with risk behavior (Rundmo, 1996) and a positive relationship with observed safety (Cooper & Phillips, 2004; Zohar, 2000). Additionally, it is hypothesized perceived safety and productivity will have a positive relationship with observed safety and productivity. It is also hypothesized that variability exists within the same construction company at the crew level relating to safety climate (Cox & Cheyne, 2000; Zohar & Luria, 2005), risk behavior, and productivity (Table 2).

The proposed research addressed five different goals relating to the relationship between perception and behaviors related to safety and productivity in construction workers. Previous studies have addressed the relationship between perceived and actual safety without considering the relationship to labor productivity. Understanding this relationship will provide opportunities for future research and interventions to reduce fatalities in the industry. Furthermore, this research provides an opportunity to evaluate waste in the construction field. Waste will be defined as causes that contribute to not useful or idle activities. Ineffective work includes being idle or doing something that is necessary to complete the job. This can include waiting for materials, carrying materials, waiting for a truck, or rework (Oglesby et al., 1989). This type of analysis provides a first step towards an evaluation of "lean waste".

This learning will contribute to the researcher's long-term goal of evaluating lean concepts in the home building industry as an improvement method for health and safety climate and culture. The study intends to make a contribution to the research of construction safety, through the evaluation of safety climate, risk behavior, labor productivity, and observed productivity and safety behaviors.

Table 2 - Hypotheses for Research

	Hypotheses	**Variables**
Phase I	H_1: There is a negative relationship between safety climate and perceived risk behavior. *Crews with high safety climate scores will have low perceived risk behavior scores.*	Risk Behavior, Safety Climate
	H_2: There is a negative relationship between work ownership and total productivity score. *Crews with high work ownership scores will have low perceived productivity loss scores.*	Work Ownership, Productivity
	H_3: There is a negative relationship between perceived safety climate and perceived productivity scores. *Crews with safety climate scores will have low perceived productivity loss scores.*	Safety Climate, Productivity
	H_4: There is a negative relationship among perceived risk behavior and safety climate, perceived productivity score, work ownership. *Crews with high safety climate and low risk behavior scores will have low perceived productivity loss scores.*	IV: Safety Climate, Productivity, Work Ownership DV: Risk Behavior
	H_5: There is a difference in perception of safety climate among construction crews.	IV: Crew DV: Safety Climate
	H_6: There is a difference in perception of risk behavior among construction crews.	IV: Crew DV: Risk Behavior
	H_7: There is a difference in perception of productivity loss among construction crews.	IV: Crew DV: Productivity (Time Loss)

	H_8: There is a difference in perception of presence of waste among construction crews.	IV: Crew DV: Productivity (Waste)
Phase II	H_9: There is a positive relationship between safety climate and safe behavior. *Crews with high safety climate scores will have high safe behavior scores.*	Safety Climate, Safe Behavior
	H_{10}: There is a positive relationship between work ownership and observed productivity. *Crews with high work ownership scores will have high-observed productivity.*	Work Ownership, Field Rating
	H_{11}: No relationship will be obtained among safety climate, perceived productivity, perceived risk behavior, safe behavior and observed productivity. *Crews with high task safety climate scores, low perceived productivity loss, low risk behavior, high safe behavior will have high-observed productivity.*	IV: Safety Climate, Productivity, Risk Behavior, Safe Behavior DV: Field Rating
	H_{12}: No relationship will be obtained among safety climate, perceived productivity, perceived risk behavior, observed productivity and safe behavior. *Crews with high task safety climate scores, low perceived productivity loss, low risk behavior, high observed productivity will have high safe behavior.*	IV: Safety Climate, Productivity, Risk Behavior, Field Rating DV: Safe Behavior

1.12 Document Overview

Chapter 2, a literature review, summarizes the current literature relevant to this research. It provides an overview including system safety, productivity, safety climate and culture, lean theory and several approaches to construction safety. Chapter 3 includes the study methodology for Phase I, questionnaires, and Phase II, questionnaires and videos.

Chapter 4 includes the analysis and results for Phase I and Phase II. This includes a descriptive analysis to review the demographic characteristics of the study participants. Additionally, climate and behavioral data was analyzed with several statistical methods. Chapter 5 concludes the results discussion, including limitations, recommendations and suggested future research.

Chapter 2. Literature Review

2.1 Health and Safety in Construction

2.1.1 System Safety

Chapanis (1996, p. 22) defines a system as an interacting combination, at any level of complexity, of people, materials, tools, machines, software, facilities and procedures designed to work together for some common purpose. Additionally a system can be a combination of smaller systems. Changes in one part of the system can possibly affect other parts and the system as a whole.

Hazard is defined as a source of danger (i.e. material, energy source or operation) with the potential to cause illness, injury, or death to a person or damage to a facility or to the environment (without regard to the likelihood or credibility of accident scenarios or consequence mitigation) (Stephans, 2004). Risk is defined as the chance of harm, in terms of severity and probability (Stephans, 2004). System Safety Analysis is a formal analysis of a system and the interrelationships among its various components to determine the real and potential hazards within the system and suggest ways to reduce and control those hazards (Stephans, 2004).

According to Stephans (2004), there is a difference between traditional compliance safety and system safety. Compliance safety focuses on 100% compliance with codes, standards and regulations while system safety approach focuses on optimum safety. The system safety philosophy uses a set of analytical tools compatible with the engineering hazard control process.

It is important to understand the causation of accidents. There are several theories of accident causation that attempt to explain why accidents occur. One such example is the Systems Theory of Accident Causation which views a situation in which an accident might occur as a system comprised of the following components: person (host), machine (agency), and environment. The likelihood of an accident occurring is determined by how these components interact (Goetsch, 1999).

Suraji et al. (2001) developed a model for the construction industry including the distal factors and their relationships to show the influence of the client, design team, project management team and the subcontractors in the construction management process. The model shows the working relationships between construction project participants who could potentially influence the health and safety in construction sites. It is intended as an accident model investigation and prevention tool.

A limitation of accident causation models can be the lack of social and organizational factors. According to Leveson (2004), event-based models are poor at representing systemic accident factors such as structural deficiencies in the organization, management deficiencies, and flaws in the safety culture of the company or industry since they don't understand the social and organizational criteria used to construct and operate systems.

Rasmussen (1997) has argued that court reports from several accidents such as Bhopal, Flixborough, Zeebrugge, and Chernobyl demonstrated that they were not caused by a coincidence of independent failures and human errors, but by a systematic migration of organizational behavior toward accident under the influence of pressure toward cost-effectiveness in an aggressive, competitive environment. It is, therefore, important to understand not just the elements of accident causation and system integration but also the socio-technical system as a whole.

System safety focuses on the complex combinations of sub-components acting together. The tasks required to establish, conduct and maintain an ongoing safety effort can be categorized as: planning tasks needed to initiate the program, primary system safety tasks that identify, analyze and control hazards to conduct the program and support tasks to maintain the program (Stephans, 2004). These tasks are completed throughout the life cycle of a project.

There are many system safety analysis methods, mostly industry based. Following are some of the systems that are unique to the system safety human system integration: Preliminary Analysis, Event Tree Analysis, Fault tree analysis (FTA), Failure modes and effects analysis (FMEA), Fault Hazard Analysis, Subsystem Hazard Analysis, System Hazard Analysis, Cause-consequence Analysis (Swallom, Lindberg , & Smith-Jackson, 2004). Selecting the appropriate system safety tool can be a comprehensive process.

2.1.2 Zero Accident Techniques

In the early 1990s, The Construction Industry Institute (CII) sponsored research in an effort to develop a zero accident approach to safety. The concept includes a commitment to "zero injuries" as a goal and objective. Five High Impact Zero Injury Safety Techniques were identified, as techniques that made the difference between good, Lost Workday Case Incident

Rate of 1.0-4.4, and excellent, Lost Workday Case Incident Rate of 1.0 or below (CII, 1993). The five techniques and most significant sub-elements, in no priority order, include (CII, 1993, pp. 5, Table 1): Safety Pre-Project/Pre-Task Planning, Safety Orientation and Training, Written Safety Incentive Program, Alcohol and Substance Abuse Program, and Accidents/Incidents Investigations. The zero accident technique is a belief that workplace accidents can be predicted, prevented and are unacceptable.

A follow up study by CII (2003) identified changes in safety for the construction industry and identified nine key areas for making zero accident a reality: 1) Demonstrated management commitment, 2) Staffing for safety to include the people, methods, and resources used to ensure safety on the project, 3) Planning: pre-project and pre-task, 4)Safety education: orientation and specialized training, 5) Worker involvement, 6) Evaluation and recognition/reward, 7) Subcontract management, 8) Accident and incident investigations, and 9) Drug and alcohol testing.

2.1.3 Safety in Design

A panel identified several "breakthrough" suggestions for improving safety in the construction industry including standardization of safety rules and practices and designer involvement in safety planning (Korman, 2001). Gambatese, Behm and Hinze (2005) defined designing for construction safety as addressing the safety of construction workers in the design of the permanent features of a project. This approach would incorporate safety awareness to eliminate or mitigate risks in the building process.

Safety in design is consistent with safety engineering steps for the control of hazards: 1) Evaluate process or operation and identify its harmful agents, 2) Eliminate the harmful agents by redesign or substitute a less harmful material, arrangement, and so on, 3) Shield, enclose, (guard) the hazard, 4) Isolate the hazard, 5) Dilute the harmful effect, and 6) If steps 2-5 do not give the appropriate level of control, provide personal protective equipment (Grimaldi, 1975, p. 136). The responsibility of safety for the workers in a construction site in the United States is often placed on the employer, or general contractor. The OSH Act places a general duty on the employer to maintain a hazard free environment. Building codes provide safety standards for the end user, or the dweller (USBC, 2003) but do not include any requirements for the builders. Typically, the designer is not involved in the safety aspect of the project. A common safety approach is reactive to the hazards resulting from decisions made during the preliminary design process.

A study of 500 accident records from the U.K. Health and Safety Executive showed that accidents in construction projects involved inappropriate construction operations (88%) as the most significant root cause. Additional root causes were found to be construction planning (28.8%), construction control (16.6%), site condition (6%) and operative action (29.9%)(2001).

A study which evaluated the role of designers in construction safety showed that less than one third of the design firms addressed construction worker safety in their designs (Hinze & Wiegand, 1992). Early efforts of safety through design were successful in several industries. Chrysler began their safety through design process in the 1980s for their industrial robots and General Motors implemented them in the design of their manufacturing tools (Thompson, 1999). The research shows a dichotomy in the construction industry: there exists an opportunity for safety improvement by incorporating safety from the design phase but still design firms do not assume accountability for improvements.

Weinstein, Gambatese, and Hecker (2005) analyzed the impact of a safety in design system named the Life Cycle Safety (LCS) implemented by Intel corporation in the design and build of a $1.5 billion dollar semiconductor fabrication and research facility. The LCS system extended the concept of safety-in-design to reflect safety concerns in all phases of the facility's lifecycle including programming, detailed design, construction, operations and maintenance, retrofit, and decommissioning. The researchers found the system was successful in eliminating or mitigating significant safety and health hazards during construction, surfaced and promoted design changes that otherwise might not have been implemented under the traditional technical design review process only (Weinstein et al., 2005).

Safety in design has been implemented outside of the United States through regulatory legislation (Gambatese et al., 2005). For example, in the United Kingdom, designers are accountable for the safety of their designs and in particular have to comply with the hierarchy of risk control under Regulation 13 of the Construction (Design and Management) (CDM) Regulations (Wamuziri, 2006). In Australia, OHS statutes of Western Australia, South Australia and Queensland establish the obligations of designers of buildings and structures to include the responsibility of safety of the constructor (Bluff, 2003). In the United States, studies researching the construction design in safety have summarized various reasons for the absence of its implementation to include regulatory safety ownership responsibility, safety knowledge/education of designers, process of design/build and awareness (Gambatese et al., 2005; Hecker, Gambatese, & Weinstein, 2005; Hinze & Wiegand, 1992; Schilder, 1999).

Designing for safety in construction is an intervention that attempts to expand the responsibility of safety to an additional stakeholder group, the designers. It is a reasonable approach, considering its implementation success in other industries (i.e. automotive). One such solution that supports this practice includes the “Design for Construction Safety Toolbox”, a computer repository of multiple project safety data, created through The Construction Industry Institute (Gambatese, Hinze, & Haas, 1997).

Gambatese et al. (2005) cites several keys to the implementation of a safety design for construction: a change in designer mindset toward safety, establishment of a motivational force to promote designing for safety, increase designer knowledge of the concept, incorporate construction safety knowledge in the design phase, utilize designers knowledgeable about design for safety modifications, make design for safety tools with guidelines available for use and reference and mitigate designer liability exposure. These recommendations suggest an increase in awareness, education, design tools and resources for the designers are necessary.

2.2 Safety Climate

Organizational climate refers to the formal and informal shared perceptions of organizational policies, practices and procedures (Reichers & Schneider, 1990). It is a molar concept indicative of the organization’s goals and appropriate goal attainment means. Multiple climates are thought to exist in organizations.

Safety climate relates to shared perceptions with regard to safety policies, procedures and practices and is considered a subset of organizational climate. Zohar (1980, p. 96) defined the term safety climate as, “a summary of molar perceptions that employees share about their work environments”. It is a snapshot of the state of safety providing an indicator of the underlying safety culture of a work group, plant or organization (Flin et al., 2000). Assessment can be complex. It is imperative to establish the difference between formally declared policies, procedures and practices and their enforced counterparts. Key features of a good safety culture that can be assessed by a climate measure need to be defined (Flin et al., 2000; Zohar, 2003).

Zohar’s (1980) original model for safety climate included a 40 item measure of organizational climate for safety and validated in a sample of 20 industrial organizations in Israel and included eight dimensions: (a) perceived importance of safety training programs, (b) perceived management attitudes toward safety, (c) perceived effects of safe conduct on promotion, (d) perceived level of risk at work place, (e) perceived effects of required work pace on safety, (f) perceived status of safety officer, (g) perceived effects of safe conduct on social status, and (h) perceived status of safety committee. The dimensions were created based on organizational characteristics that were found to discriminate between high and low accident-rate companies.

Brown and Holmes (1986) validated this model with an American sample of production workers and derived a smaller safety climate model with included the following dimensions: (a) employee perception of how concerned management is with their well being, (b) employee perception of how active management is in responding to this concern and (c) employee physical risk perception. Dedobbeleer and Béland (1991) attempted to validate Brown and Holmes' three factor safety climate model on construction workers and found a two factor model was more appropriate including: (a) management's commitment to safety and (b) workers' involvement in safety. In this two factor model, management commitment was indicated by workers' perceptions of management's attitude toward safety practices, management's attitude toward workers' safety, actions taken by supervisors to enforce safety, and management safety activities including safety instructions and availability of proper equipment; worker involvement was indicated by workers' perceptions of the presence of regular safety meetings, risk taking, likelihood of injuries, and control (Glendon, 2006).

2.2.1 Assessment

It is necessary to establish the difference between formally declared policies, procedures and practices and their enforced counterparts; key features of a good safety culture that can be assessed by a climate measure need to be defined (Flin et al., 2000; Zohar, 2003). The ultimate target of safety climate perception is the true priority of safety such that climate level reflects its consensually assessed priority by employees in a company (Zohar, 2008). Measures of safety climate should include items that refer to situations presenting competing operational demands involving safety (Zohar, 2008). Measures of safety climate can include mediated assessment of managerial commitment or priorities, which can be prompted by direct statements such as, "Management in this company cares about workers"(Zohar, 2008). It can also include mediated assessment through universal indicators and assessment based on industry-specific indicators.

In addition to the aforementioned models, safety climate has been measured form a wide range of features including, but not limited to, workforce perceptions of the current state of some organization facet, individual dispositions, personality, and self reported work behaviors (Flin et al., 2000). There are numerous safety climate self-completion questionnaire surveys (Brown & Holmes, 1986; Dedobbeleer & Béland, 1991; Zohar, 1980; Zohar & Luria, 2005). No consistent factor structure, however, has emerged for safety climate. A number of studies have found that safety climate mediates organizational factors and work behaviors (Barling et al., 2002; Neal, Griffin, & Hart, 2000; Zohar, 2002). Additionally, a number of studies have found a relationship between safety climate and behavioral safety measures (Brown & Holmes, 1986; Cooper & Phillips, 2004; Williamson, Feyer, Cairns, & Biancotti, 1997).

2.2.2 Safety Climate Multi-Level Model

Zohar (2000, 2003; 2005) suggests a multi-level model of climate based on climate as a convergent, level adjusted perceptions, appraisals of policies, procedures and practices as indicators of desired role behaviors. The core meaning of climate relates to socially constructed indicators of desired role behavior that originates from policy and procedural actions of top managers and from supervisory actions from frontline supervisors(Zohar, 2008). The redefinition of safety climate as a multi-level construct is intended to help discriminate between the priorities of senior management and those of individual supervisors (Zohar & Luria, 2004, 2005). Practices include strategic goals and procedures include tactical guidelines for these goals.

There are several assumptions underlying the concept of safety climate as a multi-level construct which include: (a) Policies and procedures which are established by senior management must be implemented or enacted by unit managers throughout the organizational hierarchy, (b) Policy implementation requires supervisory discretion such that supervisors make choices regarding how and which procedures to implement and (c) Individual employees can discriminate between procedures instituted by top management and those executed by unit managers (Zohar, 2008). Supervisory roles may include differences in implementation, which can potentially lead to between-group variations. These variations may or may not fall within the boundaries identified by the company policies. Between-group differences relating to different ways of implementing company policies and procedures can create a potential for distinct organization-level and group-level climate perceptions (Zohar & Luria, 2005). This is especially important in construction, where each contractor is expected to work within the safety practices established, often via contract, by the general contractor. In construction, projects draw upon separate contractors to complete the phases of the home building, creating a temporary organization for each particular project.

The framework of a multi-level construct of safety climate was tested in several studies resulting in significant-group level variation within the framework of a single organizational safety climate (Zohar, 2000; Zohar & Luria, 2004, 2005). Additional findings include the increase of the restraining effect of instituted procedures within the routinization of work and that among discrepant group climates, 84.2% were higher than the organizational climate (Zohar & Luria, 2005).

A multi-climate framework proposed by Zohar (2008) includes the co-existence of various climates associated with key facets of the organizational environment. High safety climate and high work ownership denotes “Safety Citizenship”; high safety climate and low work ownership denotes “Safety Compliance”; low safety climate and high work ownership denotes “Safety Defiance”; and low safety climate and low work ownership denotes “Safety Minimization”. Given the co-existing climates in organizations, it is important to understand whether specific climates interact to allow for better prediction of relevant outcome criteria, i.e. employee safety.

According to Zohar (2008), in the context of safety, such interaction or synergy is suggested by the distinction between compliance and commitment based safety systems. It is further suggested by Zohar (2008) that a complimentary climate must refer to a distinctive performance facet. Several studies have shown that safety commitment, instead of safety compliance, offers a better prediction of safety outcomes (Griffin & Neal, 2000; Hofmann, Morgeson, & Gerras, 2003; Neal & Griffin, 2006; Zacharatos, Barling, & Iverson, 2005).

2.2.3 Psychological Ownership

Psychological ownership is a construct that underlies employee commitment, satisfaction, citizenship, participation, and offers parsimony with a better discrimination between the safety and ownership facets (Van Dyne & Pierce, 2004; Zohar, 2008). Psychological ownership is conceptually defined as the state in which individuals feel as though the target of ownership or a piece of that target is theirs and includes three roots: 1) Efficacy and effectance, 2) Self identity, and 3) The need for having a place (Pierce, Kostova, & Dirks, 2001, 2003).

Work ownership climate includes the extent to which supervisory and/or senior leaders allow work issues to become ownership targets and their recognition of such ownership once it develops. This suggests that climate for safety and work ownership are likely to interact due to the two dimensional nature of safety behavior, i.e. compliance and citizenship resulting in divergent outcomes, within the context of safety (Zohar, 2008). Safety citizenship should develop with high work ownership climate and high safety climate. Employees are expected to consider the safety of operations as an ownership target, directing discretionary action towards this target. It is beneficial in organizations whose processes or technologies are little routinized (Zohar, 2008).

Safety defiance includes high work ownership and overrides health and safety consideration due to a low safety climate. Ownership targets are likely to exclude process safety, focusing on some other process or outcome facets. Can result in situations where safety is ignored and defied when it competes with owned facets (Zohar, 2008). Safety compliance occurs with low work ownership climate coupled with high safety climate. Workers are expected to follow rules and procedures in getting the work done. Employees are likely to consider safety a high-priority facet and safety behavior would be guided by the rules to the exclusion of discretionary extra-role activities (Zohar, 2008). Safety minimization occurs when employees only follow those safety rules associated with high or imminent danger, and overlooking the rules associated with low-likelihood or delayed risks (Zohar, 2008).

Two types of psychological ownership have been identified by the existing research, organization-based and job-based psychological ownership. Organization-based psychological ownership is concerned with individual members' feelings of possession and psychological connection to an organization as a whole. Job-based psychological ownership is related to individuals feeling of possession toward their particular jobs (Mayhew, Ashkanasy, Bramble, & Gardner, 2007). Both types are considered attitudinal (Van Dyne & Pierce, 2004) and use attitudinal measures using possessive vocabulary. Psychological ownership is context-specific and reflects the individual's current position regarding the present organization and existing job (Mayhew et al., 2007). Pierce et al. (2001) suggested that highly autonomous jobs create a greater degree of control and should increase the experience of psychological ownership. Mayhew et al. (2007) found that job autonomy had both direct and indirect effects on psychological ownership.

2.3 Safety Culture

The term safety culture was officially used in the initial report about the Chernobyl accident to refer to the safety regime that should prevail at a nuclear plant (INSAG, 1986). The Chernobyl accident occurred in 1986 at Unit 4 of the Chernobyl nuclear power plant in the former Ukrainian Soviet Socialist Republic. The accident resulted in 30 deaths and radioactive release to the atmosphere (World Nuclear Association, 2010).

Following Chernobyl, a number of other public inquiry reports quoted safety culture as an explanation for the way a combination of managerial, organizational and social factors contributed to the disasters, including the 1988 North Sea platform Piper Alpha explosion (Cullen, 1990). Most recently, a breakdown in safety culture was cited for the number of fatalities in Las Vegas strip construction. In the last two years, the 13 construction-related fatalities on the Las Vegas Strip are more than the city saw during the entire 1990s building boom (Illia, 2008). The vast scale of the construction projects in Las Vegas includes the gathering of disparate craft workers, ambitious schedules, and less than appropriate safety programs (Illia, 2008). In June 2008, CityCenter workers walked off the job demanding jobsite safety, prompting the owners to develop an action plan (Illia, 2008).

A variety of definitions have been proposed for safety culture. Guldenmund (2000) reported sixteen definitions for safety culture and climate, with nine referring to safety climate and seven referring to safety culture. Pidgeon (1991, p. 135) defined safety culture as, "the constructed system of meanings through which a given people or group understand the hazards of the world." Cooper (2000, p. 111) suggests that safety culture is, "a sub-facet of organizational culture, which is thought to affect members' attitudes and behavior in relation to an organization's ongoing health and safety performance."

To date, a universally acceptable model with which to formulate testable hypothesis that take into account antecedents, behaviors and consequences does not exist (Cooper, 2000; Glendon, 2006). Glendon and Stanton (2000) adopted a model of safety culture that is analogous to organizational culture. Cooper (2000, p. 118) defined safety culture as, "The product of multiple goal-directed interactions between people (psychological), jobs (behavioral) and organization (situational)." He further suggested that this definition reflects Bandura's (1977) model of reciprocal determinism derived from Social Cognitive Theory.

Bandura's model was adapted to reflect the concept of safety culture, where each element is measured via commonly used methods. Each element in the model can be further broken down into the same reciprocal relationship to systematically examine the multifaceted nature of the safety culture (Cooper, 2002).

Safety culture is, therefore, presented as the product of interactions between the safety climate, safety related behavior and safety management systems (Cooper, 2002; Glendon, 2006). Safety climate is the internal, psychological factors relating to the person, including attitudes and perceptions; this element of safety culture can be assessed using safety climate questionnaires. Safety-related behavior is ongoing and observable behavior, which can be measured through such techniques as behavior sampling and observation. Safety management systems can be measured with objective safety audits (i.e. organizational policies, practices, procedures, and management style).

Safety culture, according to the aforementioned model, is product of multiple goal-directed interactions between people (psychological), jobs (behavioral) and organization (situational). It includes the collective work practices, which are supported by management and workers.

2.4 Demographics - Latinos in Construction

A number of studies have been completed to help understand the significance of the Latino population growth in the construction industry. Data mapping the root cause of construction accidents mostly focuses on the type of accident (i.e. falls, struck-by). Worker characteristics are limited to age, gender, and ethnicity (based on regulatory reporting). Most of the research is in agreement that a disproportionate number of Latino construction workers are killed or injured on the job. There are two general categories established for root causes: 1) Hispanics tend to work in more hazardous occupations and 2) Ethnic cultural variables.

A study of occupational fatality injury and risk conducted using BLS data for a four year period from 1998 to 2001 showed that among sixteen building trades, ironworkers and roofers ranked the highest in terms of both nonfatal injury and fatality risks followed by electricians, brick masons, stonemasons, block masons, painters, paperhangers, carpenters, and insulation workers, who were also exposed to relatively high risks (Baradan & Usmen, 2006). As previously mentioned, the number of Latino workers in dry walling, concrete, carpentry, painting, masonry and roofing is high.

There are several studies that indirectly map the type of accident to the occupation of the employee. One such study evaluated aggregate data from 1998-2001 using BLS data and reported that Hispanic men have high relative risks in mining (7.54) and construction (4.76) (Richardson, Ruser, & Suarez, 2003). Another study showed findings that supported the proportion of fatalities occurring to Latinos is greater than the expected proportion corresponding to the percentage (10%) of Latino workers in the working civilian population (Moure-Eraso & Friedman-Jimenez, 2003).

A breakdown based on National Research Council Information resulted in "falls" being the primary fatal injury category in construction with 37 percent of all Latino construction fatalities. Additionally, the most frequent nonfatal work injury was found to be struck by objects with 38 percent (Vazquez & Stalnaker, 2004). Differences in injuries, illnesses and fatalities between Latinos and non-Latino construction workers (carpenters, construction laborers, painters, drywall installers, and electricians) were evaluated. The study found that among the five groups, Latinos showed a higher frequency of injuries and illnesses among dry wall installers (Goodrum & Dai, 2005).

A second category of the studies includes the differences in ethnic culture. Culture is defined as the shared way of life of a group of people, including their artifacts and their symbols (Berry, Poortinga, Segall, & Dasen, 2002, p. 477). Culture is defined by Hofstede (1991, p. 5) as the collective programming of the mind which distinguishes the members of one group or category of people from another. Culture, as a cognitive system, is a metaschema (global cognitive framework) that reflects beliefs, attitudes, and experiences that influence how individuals perceive risks and make decisions about precautions and compliance (Smith-Jackson, 2006, p. 363).

Common reasons to explain the disparity of accidents between Latino and non-Latino construction workers are differences in language, culture, and occupation (Goodrum & Dai, 2005). More than 71% of companies employed people whose native language was not English or who did not speak English (Vazquez & Stalnaker, 2004). For example, a study that evaluated data from the U.S Bureau of Labor Statistic's Current Population Survey from 1998-2001, showed that among the Hispanic carpenters and construction laborers in the analysis, about 34% indicated that they could only communicate in Spanish (Goodrum, 2004). CPWR (2008) reported that in 2005, one of four construction workers spoke a language other than English at home with 84% reporting they spoke Spanish. Among Latino construction workers, 42% reported they cannot speak English very well and 42% reported they couldn't speak English at all (CPWR, 2008).

The aforementioned conclusions show that many Latinos speak little to no English. Several studies have reviewed the safety training materials available for Latino construction workers. A workshop report of the National Academy of Science in 2003, reported a review on (then) existing training materials and it was concluded that the quality of existing materials was mixed, with some of it very poor; a need was identified to create a standardized approach for the development of training materials for the Latino workforce (Obadia, 2003).

The Center to Protect Worker's Rights in cooperation with OSHA sponsored the development and presentation of a ten-hour safety and health training in Spanish. Spanish-speaking trainers delivered the training and all materials were in Spanish. The follow up survey indicated that the majority of the participants indicated that they did not understand a substantial amount of their health and safety training when materials were delivered to them in English (Ruttenberg & Lazo, 2004).

A socioeconomic and cultural background summary for Hispanic workers from Latin America was outlined to include several points. Hispanic workers may have little or no experience with governmental enforcement of safety regulations due to their experience with the absence of the technical and social infrastructure in their countries of origin (Brunette, 2005). Workers may have little or no trust in governmental agencies' stated intentions to protect their rights due to the lack of occupational safety and health regulations and enforcement from their countries of origin (Brunette, 2005). Working conditions in their countries of origin may also influence Hispanics' level of safety awareness (Brunette, 2005). Hispanic workers bring with them varied histories, cultural sensibilities, strong health beliefs, and different cultural backgrounds (Brunette, 2005). For example, a study found that Latino farm workers believed that failure to comply with instructions to reenter a field (after pesticide spraying) or to not work fast enough could cost them their jobs (Quandt, Arcury, Austin, & Cabrera, 2001). Hispanic workers' immigration status may lead to fear and, consequently, affect whether they speak up about safety issues (Brunette, 2005).

Taking all these factors into consideration, Brunette (2004) led a design effort, which actively involved Hispanic workers in the design, development and validation of a safety and health repository of educational materials targeted for Hispanic construction workers. Some additional initiatives to design for language barriers include public sector resources like OSHA and NIOSH in Spanish. An example of this is the use of a "blue hardhat program" where the bilingual workers wear a blue hardhat (for easy identification) in construction sites and translate or enable communication between Spanish- and English-speaking workers. The program is a creative approach to translate or enable communication between Spanish- and English- speaking employees to facilitate safe job performance and minimize misunderstandings; workers in the program were provided a monetary incentive (Vazquez & Stalnaker, 2004).

A special training tool was developed by the Home Builders Institute and sponsored by Lowe's Corporation. The tool, "Sed de Saber, Construction Edition" utilized technology to help Spanish speakers learn English at their own time and space by teaching 500 words and 340 phrases. Piloted in Pulte Homes in Phoenix, the pilot group experienced a 51 percent gain in English language proficiency (NAHB, 2008a). Additionally, the development of a training tool for jobsite safety through the use of a participatory approach with Latino workers was completed for Pulte Homes (Evia, 2008).

Underreporting can also be associated with culture. Many Hispanic construction workers don't report unsafe working conditions because they are afraid of losing their jobs (Hopkins, 2003; Quandt et al., 2001). This data, however, is often anecdotal since no process exists for documenting this information.

Although the validity of methods used to establish the effects of culture variables (language, power distance) on accident causation can be challenged (source of data, underreporting, etc.), several studies have generated similar conclusions. If a worker does not speak English, they can't understand the safety training delivered in English. This observation, supported by the census numbers and accident statistics, has created awareness. This is particularly interesting in residential construction where safety training among smaller firms may vary from formal training to on the job training.

2.5 Productivity in Construction

Performance involves all aspects of the construction process. Performance consists of seven dimensions: effectiveness, efficiency, quality, productivity, quality of work life, innovation and profitability (Sink, 1985). Effectiveness encompasses the realization of the organization's objectives. Efficiency involves the utilization of resources. Quality is doing things correctly the first time. Productivity can be defined in various ways but it is typically defined as output/input. Quality of work life includes the response of organizational members to the socio-technical aspects of the work and the organization. Innovation is the use of creativity by members of the organization and profitability can be expressed in various ways to quantify the bottom line. A flexibility criterion was added due to the increasing need to manage and measure flexibility in systems (Kleiner, 1997). It is important to distinguish between performance and productivity. Productivity is treated as a separate dimension of performance because of the labor-intensive nature of the construction process (Maloney, 1990).

There have been several efforts to identify and determine the factors that affect construction productivity. Productivity can be defined as, "the effectiveness with which management skills, workers, materials, equipment, tools and working space are employed at or in support of work-face activities to produce a finished building, plant, structure or other fixed facility at the lowest feasible cost (Oglesby et al., 1989, p. 5)". A Department of Energy study identified the major factors as material availability, tool availability, work redone, overcrowded work area, inspection delays, foreman incompetence, crew interference, craft turnover and absenteeism and foreman changes (Borcherding & Garner, 1982; Borcherding, Sebastian, & Samelson, 1980). Productivity factors including tools, materials, engineering drawing management, construction equipment, supervisor direction, safety, communication, project management, labor, foremen and superintendent were identified in order of severity to productivity in the listed order (Dai, Goodrum, & Maloney, 2009).

Craft workers have a significant influence on labor productivity since they are the ones who execute the work (Maloney, 1983). Craftsmen or crews at work faces utilize methods, information, materials, equipment usually supplied by others (Oglesby et al., 1989). Therefore, craftsmen have significant knowledge and influence of factors that affect productivity (Oglesby et al., 1989). The knowledge is detailed and specific to the processes, procedures and roles that are existent in their day-to-day activities. In many construction organizations, enlisting ideas from craftsmen if rare because it takes time away from tasks or because it is considered as an infringement on management's right to control the work (Dai et al., 2009; Oglesby et al., 1989). There are many ways to request information from craft workers, two of which are asking and observing (Oglesby et al., 1989). A better understanding of the factors influencing labor productivity from the workforce's perspective can provide site management teams with valuable information to effectively allocate their limited resources, provide craft workers with better support, increase craft workers' motivation, and enhance craft workers' commitment to productivity improvement (Dai et al., 2009).

2.6 Lean Concepts

2.6.1 Toyota Production System

Lean applications to production systems have been successfully implemented in manufacturing. The Toyota production system was developed by the Toyota Motor Corporation in an effort to eliminate, through improvement activities, various kinds of waste lying concealed within a company (Monden, 1993). Taiichi Ohno is regarded as the founder of the Toyota Production System (TPS). Ohno (1988) described the evolution of TPS as one of necessity in post war Japan. Additionally, the contributions of W. Edwards Deming in quality helped influence the development of TPS.

Ohno (1988) identified the basis of TPS as the absolute elimination of waste based on two pillars needed to support the system, just in time (JIT) and autonomation. Just in time includes a flow process in which the right parts needed in assembly reach the assembly line at the time they are needed and only in the amount needed. Autonomation is the automatic control of defects, and is not limited to the machine processes; it can be used in conjunction with manual operation and is a technique for detecting and correcting production defects by incorporating a mechanism to detect abnormalities or defects and stop the line or machine when abnormalities or defects occur (Monden, 1993). Because autonomation always involves some type of automation, it can be categorized in the taxonomies of automation levels and operator roles developed by Kleiner and Shewchuk (2001) as Direct Performer (H), Manual Controller (Hm) Partner (HM), Supervisory Controller (Mh) or Executive Controller (M).

Monden (1983, p. 1) described the Toyota Production System as a system with three sub-goals needed to achieve the main goal of cost reduction, quality control, quality assurance and respect for humanity. Quantity control enables the system to adapt to daily and monthly fluctuations in terms of quantities and variety (Monden, 1983). Quality assurance assures each process will supply only good units to subsequent processes. Respect for humanity is cultivated while the system utilizes the human resource to attain its cost objectives.

Additionally, there are four main elements identified by Monden (1993) which are supported by systems such as Kanban, production smoothing methods, setup time reduction, standardization of operations, layout, and flexible workforces, among others. Just in time is to produce the necessary units in the necessary quantities at the necessary time. Autonomation is the autonomous control of defects. It supports JIT by never allowing defective units from a preceding process to flow into and disrupt a subsequent process. Flexible work force varies the number of workers to demand changes. Originality and ingenuity capitalizes on worker suggestions.

The Toyota production system reduces costs by completely eliminating wastes found in manufacturing. Monden (1993) identified four wastes that can be found in manufacturing including: 1) excessive production resources, 2) overproduction, 3) excessive inventory and 4) unnecessary capital investment. These wastes should be eliminated for cost reduction.

Waste can be described in terms of seven categories: Defects, Overproduction, Transportation, Waiting, Inventory, Motion and Processing (Shingo, 1992). The seven wastes can also be categorized into three main groups including man (motion, waiting, overproduction), machine (over processing), and materials (transportation, inventory and defects) (Rawabdeh, 2005). The process of identifying waste activities is difficult due to the overlap between the processes and sub-systems. There have been various approaches to understanding productivity in the construction industry. A meta-analysis found that 49.6% of construction operative time is devoted to wasteful activity, with the amount being very variable (Horman & Kenley, 2005).

Serpell et. al (1997) evaluated 17 building construction projects by seven construction companies in the Metropolitan Region of Chile and found, through work sampling and various qualitative methods, that about 53% of the total working time was dedicated to non productive activities. The work sampling results in the study included productive work, contributory work and non-contributory work. Non-contributory work indentified several wastes categories: waiting (9%), idle time (7%), traveling(6%), and transporting (14%) (Serpell et al., 1997) . Waiting behaviors included over manning (27%), lack of progress (18%), lack of equipment

(14%) and lack of materials (12%); Idle including lack of supervision (39%), over manning (27%), worker' attitudes (20%) and poor work allocation (9%); Travelling included over manning (22%), lack of supervision (19%); and Transporting included inadequate method (37%) and lack of equipment (27%) (Serpell et al., 1997). Although it is not possible to completely eliminate contributory work time, reduction will result in an increase in production time. Dennis' (2002) general categories of waste include motion, delay, conveyance, correction, over processing, inventory, overproduction and knowledge disconnection.

Over time, additional publications continue to highlight the Toyota methodology. Liker (2004) described the "Toyota Way" as a system designed to produce the tools for workers to continuously improve their work via fourteen principles organized in four categories: Philosophy, Process, People/Partners and Problem Solving.

2.6.2 Lean Concepts in Manufacturing

In 1990, results of a five year study of the automotive industry was published in a book called "The Machine that Changed the World" (Womack, 1990). The phrase of "Lean Manufacturing" was coined. Comparing the mass production techniques of the United States with those of Japan, the Toyota system was described as "lean" because, in comparison, Toyota used half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time, less than half the needed inventory on site with fewer defects and the production of a variety of products (Womack, 1990, p. 13).

According to the Lean Enterprise Institute (LEI, 2007) , the steps of lean implementation include: specify value, map, flow, pull and perfection. The first is specifying and defining the value from the perspective of the final customer in terms of a specific product, which meets the customer's needs at a specific price and at a specific time. Next the value stream should be identified. The creation of a map of the "Current State" and the "Future State" of the value stream follows. The identification, categorization, and elimination of waste in the "Current State" is the next step. The remaining steps in the value stream should flow. Functional barriers should be eliminated and a product-focused organization that dramatically improves lead-time should be employed. Internal customers should pull products as needed, eliminating the need for a sales forecast. There is no end to the process of reducing effort, time, space, cost, and mistakes.

According to Feld (2001, p. 4), five primary elements are required to support the manufacturing component of lean production: manufacturing flow, organization, process control, metrics and logistics. Manufacturing flow includes the physical changes and design standards deployed as part of each work cell, which are based on natural groupings of related tasks. Organization outlines people's roles and functions, including training. Process control includes the effort to monitor, stabilize and improve discrete manufacturing process steps. Metrics establish visible, result based performance measures, which determine improvement targets and recognize work teams for process improvement. Logistics define the operating rules for material flow planning and control.

Some research has shown the application of lean concepts in manufacturing has resulted in improved efficiency, productivity, and safety. Several programs used include 5S, Kaizen, cross training, and the empowerment of teams. For example, "5S"is a cleanup activity in the work place. "Sort, Straighten, Shine, Standardize and Sustain" provides an approach for housekeeping. Chapman (2006) cites several studies that achieved measurable improvements by integrating ergonomics and lean production activities. The TRW (Cookeville, Tenn., facility) utilized the kaizen approach and achieved a 90 percent reduction in severity rate while improving plant wide throughput by 15 percent over 2 years. Honeywell identified cost savings of $100,000 per year from a single ergonomics improvement project. DENSO achieved a 27 percent reduction in recordable injuries between 1998 and 2000 by applying ergonomic and kaizen methodologies and practices.

In general terms, lean and safety concepts share the goal of minimizing or eliminating risk and waste. At its root, lean relies on the human component, the worker. There is minimal research, however, on human performance practices and its impact on health and safety in the lean production environment. Genaidy and Karwowski (2003) propose lean production as a socio-technological system that can be used by manufacturing to achieve and maintain high productivity and quality. From a socio-technical perspective, if the lean processes and tools are defined as the technological sub-system, then it is imperative to understand the personnel system to ensure sub-optimization does not lead to safety incidents.

2.7 Differences in Manufacturing and Construction

Lean concepts have been introduced in additional industries including construction. The construction industry continues to reevaluate itself since the traditional building processes have been challenged by increasingly changing demands. There are existing differences between manufacturing and construction. Some differences that have been noted include large units that cannot be transported, on-site production, one of a kind projects, dynamic labor workforce and uncertainty produced by the different onsite production permutations (Salem, Solomon, Genaidy, & Minkarah, 2006). Most projects or their individual work phases are of relatively short durations with a final product that is unique in design (Oglesby et al., 1989).

These differences, however, are a result of the existing processes being used in the industry. They are temporary challenges, not a constraint to the evaluation of improvement approaches. An understanding of the complex construction system is necessary to understand hard versus soft differences. The Construction Industry Institute (2005, pp. 5-6) identified differences and similarities between the "manufacturing principles" and "construction principles" as a result of a study to determine lean applicability in the construction industry:

- Constructors do not control the entire supply chain.
- The largest constructors control only one percent of the market whereas in manufacturing largest manufacturers may control 20 percent or more.
- Owners are much more involved in product features, product configuration, cost, schedule and process.
- Responsibility for success is shared between producer and consumer in construction.
- High employee turnover results in less opportunity for training.
- Construction workers are craft skilled, in manufacturing they are process specialized.
- Production requirements, access, and schedules are governed by multiple contracts.
- Construction has a fluid organization at the project level.
- The configuration of the production environment changes all of the time. It is more difficult to maintain visual management systems.
- Production people move through product, not product through production people.
- Construction has more difficult supply change relationship, different suppliers/subs in different geographic regions.

- There are alternate ways of doing each task. Production methods are in the hands of the workers and not manufacturing engineers.
- The typical construction project is what manufacturers would consider a proto-type, generally construction only produce one-off products.
- To a large extent, the production sequence is discretionary.
- Material flow is not a steady state process. Supply lines vary at different project locations.
- Construction material storage location and amounts are not the same at different points in the project.
- Construction can change the execution time by adding or subtracting resources.
- Construction is resource paced and manufacturing is typically machine paced.
- Construction is impacted by the weather.
- High turnover provides less opportunity for training.
- Ability to develop a quality-tracking program is difficult.
- Production time is measured in hours, sometimes days in contrast to manufacturing where it is measured in minutes or second.

Although the aforementioned differences exist, both industries strive to deliver a quality product, in the shortest amount of time, with maximum productivity while saving money. Therefore, it is necessary to focus, not on the differences, but rather on the applicability of lean, evaluating one challenge at a time.

2.8 Lean Construction Principles

There have been several suggested approaches to introducing lean principles in the industry. Like Toyota's approach of starting the lean effort by concentrating on the shop floor, several research initiatives suggest change in the industry should start from the operational processes where the product is created. The operational level allows for visible results (Ballard, Harper, & Zabelle, 2003; CII, 2005; Koskela, Ballard, & Howell, 2003).

Koskela (1992) introduced the concept of construction as a production system. Eleven heuristic principles were summarized to guide the practice for improvements, when applying lean construction. Non-value adding activities, variability, and cycle times should be reduced. Output flexibility, process transparency and output value through the systematic consideration of customer requirements should be increased. The number of steps, parts and linkages should be minimized resulting in simplification. Control should be focused on the complete process. Continuous improvement and benchmarking should be built into the process.

A key to the lean philosophy in construction is identifying and driving out the waste (CII, 2005; Koskela, 1992) . According to CII (2005), only 3-20 percent of tasks add value with their share in total cycle time. Ballard's (2000) Last Planner System ® is based on the assumption that planning is the primary method for organizing activities in construction. Assignments are specific enough to ensure the right type and amount of materials can be collected, activities are aligned in the proper order and the capabilities of crews and sub crews are carefully considered (Ballard, 2000).

Due to the increase in lean construction research, several organizations exist including: International Group for Lean Construction (IGLC, 2007) and the Lean Construction Institute (LCI, 2007). The Lean Construction Institute (2007) defines lean construction as, "a production management approach to project delivery, a new way to design and build facilities extending from the objectives of a lean production system to maximize value and minimize waste to specific techniques applied in a new project delivery process". Additionally, CII (2005) researched the applicability of lean concepts to construction an defined it as, "the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream and pursuing perfection in the execution of the constructed project". Five major lean construction principles were generated (CII, 2005): Customer focus, Culture/people, Workplace Standardization, Waste Elimination, Continuous improvement/built in quality. Based on a combination of literature, interviews and case studies, lean construction principles and sub-principles were developed by CII (2005) to include customer focus, culture/people, workplace organization/standardization and waste elimination. Customer focus places the customer as part of the value generation process (CII, 2005). Culture (and people) encourages employee empowerment, training and management commitment (CII, 2005). Workplace organization and standardization includes the use of 5S, error-proofing devices, visual management , defined work processes and logistics and storage plans (CII, 2005). Finally, the employment of the use of lean tools to eliminate waste in the system is encouraged (CII, 2005).

Lean should not be used only as a set of tools. A system thinking approach is necessary, including commitment throughout the entire organization. Although projects claim safety improvements as a result of lean, the causal relationship between lean project delivery and safety lacks research. According to Wokutch et. al (2000a, 2000b), safety and health concerns are integrated throughout the production and planning systems in Japanese lean manufacturing environments. Accidents and associated injuries are an extreme form of inefficiency and must be avoided at all costs because of the nature of the system. Several suggested learnings from the Japanese system for managing health and safety include the integration of health and safety into the planning and production system, and application of Kaizen techniques for safety and health and training (Wokutch & VanSandt, 2000a).

Hazards, which can be "wastes" in terms of time, cost and human resources, should be recognized as such in the production planning process. The construction industry provides an opportunity to apply lean concepts with a systems approach, including safety as one of the elements, in addition to productivity, schedule, cost and quality.

2.9 Humans, Lean and Safety

The impacts of lean production on humans have received mixed results in the current research, sometimes even within the same study. Jackson and Mullarkey (2000) reported both positive and negative direct effects of lean production team working on aspects of autonomy, work demands and social climate, citing a relationship to the management choices in work designs, in a study conducted in the garment assembly area of a U.K. high fashion ladies wear manufacturer. A study of a process control equipment manufacturer found increased job satisfaction (Mullarkey, Jackson, & Parker, 1995) while another study of a large British manufacturer of printed circuit boards found the introduction of JIT resulted in decreased job satisfaction (Jackson & Martin, 1996). Several researchers have stressed the significant impact of lean production on workers due to the increased participation of the worker, which has been linked to improved manufacturing outcomes (Hayes, 1981; Monden, 1983, 1993; Womack, 1990).

An extension of the discussion including the human component of the lean equation includes safety management. Several studies have investigated safety concepts, though the correlation between safety performance and lean concepts has yet to be reported.

Saurin et al. (2006; 2004; 2002) researched safety management through production planning and control. In particular, Saurin et al. (2006) evaluated the commonalities and differences between safety management and lean production management, utilizing the cognitive systems engineering (CSE) perspective. The CSE perspective, which is concerned with the study of how joint cognitive systems perform rather than cognition as a mental process, was assumed due to two main factors: 1) it is adequate to dynamic and complex environments and 2) it provides high level guidelines on work system design (Saurin et al., 2006). Four guidelines were proposed by Saurin et al. (2006) for developing and monitoring procedures in the lean production approach. First is to consider worker's mental and physical capabilities. Next, is to stress workers involvement in procedure development and monitoring. Investigate reasons for successful performance rather than just causes of non-compliance with procedures. Adopt a broader view on the meaning of deviations from procedures.

Several new approaches have been suggested. Howell et al. (2002) reviewed traditional behavior based safety management best practices and recommended a new approach to construction safety based on a framework proposed by Jens Rasmussen (1994, 1997). Rasmussen's model (1994, 1997) assumes that efforts to improve safety by counteracting the human error sources tend to be ineffective. Safety improvements must be directed toward the control of performance in interaction with the boundary (of safe performance) and not with the control of errors. Rasmussen (1994, 1997) suggests a focus on the control of behavior by making the boundaries explicit and known and by giving opportunities to develop coping skills at boundaries, rather than fighting deviations from a particular pre-planned path.

Howell (2002, p. 9) proposed a new definition of hazard as, "a condition, which if released, can lead to injury unless the worker is able to detect and avoid it without increasing exposure to another hazard", which coupled with better planning can expand the zone of safety and increase the extent to which tasks are fail-safe. This strategy is within the context that organizational and individual pressures push people to work near the edge of loss control (or boundary of functionally acceptable performance in Rasmussen's model (1997). According to Howell (2002), training is a very important aspect so workers could always answer what zone they are in, what risk of hazard they face, what can be done to prevent releasing the hazard and what can be done to reduce the harm if the hazard was released.

Following the assumptions of this model, Abdelhamid et al. (2003) developed a signal detection methodology to assess a worker's occupational safety competency intended to help facility the evaluation of worker training on how to identify the zone in which they are working.

Mitropoulous et al. (2003) also aligned with the Rasmussen model and recommended the use of Crew Resource Management for more effective error identification and management techniques. A time-dependent risk evaluation strategy to predict risk levels on the basis of empirical data was proposed with a goal of supporting better planning of accident prevention measures (Sacks, Rozenfeld, & Rosenfeld, 2005). It is important to understand the interrelation between the STS subgroups to ensure sub-optimization does not lead to safety incidents.

The American National Standards Institute (ANSI, 2007) published a technical report that provides guidance to address lean manufacturing concepts and safety concerns of machinery in manufacturing. Safety is a critical element in the lean manufacturing effort to yield processes that are better, faster, less wasteful and safer. The intent of most lean programs will include and support strong safety performance. A process model outlines the inputs (machines, equipment, materials, humans and environment/culture), outputs (throughput, production cost, injury/illness, and defects) and design methods (lean and safety) used to achieve the leadership goals and objectives for safety and lean (ANSI, 2007).

Chapter 3. Methodology

3.1 Introductory Field Observation Pilot

The researcher conducted field observation pilot of a residential construction builder in May 2008. The purpose of the visit was for the researcher to become familiarized with the residential homebuilding process. The residential builder engaged with was one of America's leading homebuilders that serve homebuyers in several states including: Maryland, New York, North Carolina, Virginia, Ohio, South Carolina, Pennsylvania, Tennessee, Delaware, West Virginia, Kentucky and New Jersey.

Design is self-performed, allowing a fully integrated design and manufacturing process. Additionally, the company uses panelized construction that it manufactures. Panelization includes the construction of components offsite such as trusses, walls, stairs, doors, etc. before delivery to the building site or construction location. The homebuilder sub-contracts 99% of their field construction work.

During the two-day visit, the researcher observed field processes, focusing on the practices for framing. The researcher met with the builders' safety officer to learn stages of the home building process, material handling, quality controls and safety controls. The researcher conducted an informal discussion (Appendix B) with a safety officer.

During the introductory visit, the researcher visited several production sites, including projects under different brand names, different contractors and at different phases of the construction process. The researcher, through independent observation recorded observations (Table 3) including the following general categories listed by O'Brien et al. (2002, p. 19):

1. Points in the subcomponent production where errors where observed or noted by building personnel (Errors).
2. Points where the tools, facilities, or material handling processes limited productivity (Limiters).
3. Points of excessive complexity in formal production documents (Complexity).
4. Points where informal production documents were produced (Documents).
5. Points where excessive personnel inputs were required to complete a task (Inputs).
6. Observations of safety violations (Risk).

Table 3 - Observations for Framing Process Sample

Description	Categories
Material stacking is dependent on the production schedule, delivery schedule, stacking space availability, coordination, planning, etc.	☒ 1. Errors ☒ 2. Limiters ☐ 3. Complexity ☐ 4. Documents ☐ 5. Inputs ☒ 6. Risk
Operator shortcuts, such as the taping of the hook on the crane, are created for faster processes (faster release of rope).	☒ 1. Errors ☐ 2. Limiters ☐ 3. Complexity ☐ 4. Documents ☐ 5. Inputs ☒ 6. Risk
Facility limitations can create unnecessary motion, layout constraints, space and distances between stations.	☒ 1. Errors ☒ 2. Limiters ☐ 3. Complexity ☐ 4. Documents ☐ 5. Inputs ☒ 6. Risk
Change or addition of new component not communicated to contractor; consequently work was stopped to understand the component and installation process.	☐ 1. Errors ☐ 2. Limiters ☒ 3. Complexity ☒ 4. Documents ☐ 5. Inputs ☒ 6. Risk
Delivery of material is based on transportation efficiency (not assembly efficiency).	☐ 1. Errors ☒ 2. Limiters ☐ 3. Complexity ☐ 4. Documents ☐ 5. Inputs ☐ 6. Risk
Tool limitations such as the absence of a rope (expected to be included by the crane operator) can cause delays.	☒ 1. Errors ☐ 2. Limiters ☐ 3. Complexity

	☐ 4. Documents ☐ 5. Inputs ☒ 6. Risk
Schedule coordination can lead to conflicts, like removal of safety guards (windows) before arrival of components.	☐ 1. Errors ☐ 2. Limiters ☒ 3. Complexity ☐ 4. Documents ☐ 5. Inputs ☒ 6. Risk
Not understanding safety procedures can lead to unsafe acts.	☐ 1. Errors ☐ 2. Limiters ☐ 3. Complexity ☐ 4. Documents ☒ 5. Inputs ☒ 6. Risk
Manual material handling and housekeeping processes can couple to create risk.	☐ 1. Errors ☒ 2. Limiters ☐ 3. Complexity ☐ 4. Documents ☐ 5. Inputs ☒ 6. Risk

The pilot study observations revealed different approaches by subcontractors to the framing task of building homes. It was learned, however, that there are several contractual agreements that must be met by all the subcontractors that contribute to the work design. These are in the form of performance specifications that provide checklists defining the general standard for quality and professionalism. This is specifically important since it provides a constant in the supply chain. The difference in subcontractor approaches to framing creates variability for the project managers. The panelization structures and delivery process, however, is constant to all the subcontractors.

Based on the literature review and field pilot observations, simultaneous consideration of safety and productivity was applied by the researcher to a framing process to evaluate perceptions and behavior construction workers. This research was focused on the relationship between perception and behaviors of labor productivity and safety.

Unsafe behavior may not always result in an accident (Hofmann & Stetzer, 1996). The performance of unsafe behaviors or routines may not only be infrequently punished with the negative consequence (i.e. injury, accident) but may be perceived as having rewarding features such as enabling the worker to complete their work more quickly or comfortably (Hofmann & Stetzer, 1996). Over time, these unsafe behaviors may be considered "normal" and done by everyone (Wright, 1986), and the relationship between safety and productivity considered a tradeoff. If unsafe acts are built into the work, they can become routine and part of the safety culture. A study of off-shore installations showed that many of the witnesses interviewed during accident investigations referred to the dangerous practices with such phrases as 'common sense', 'everyone did it', and 'normal working conditions' (Wright, 1986, p. 281). This reinforces a culture that suggests construction is simply a risky industry.

Literature supports a positive relationship between performance pressure, in the form of role overload, and safety performance (Hofmann & Stetzer, 1996; Zohar, 1980) and a relationship between productivity emphasis and accidents (Evans et al., 2005), and safety climate and safety behavior (Cooper & Phillips, 1994; Cooper & Phillips, 2004; Zohar, 2000). Currently, empirical research addressing the relationship between perceived safety and productivity and observed safety and productivity is, however, lacking.

3.2 Phase I

3.2.1 Instruments

A total of three survey instruments, five open ended questions, and a demographics questionnaire, were used to create the Safety and Productivity Perception (SPP) tool (Appendix C and Appendix D). The instruments were selected to measure perceived safety climate, perceived risk behavior, perceived productivity and work ownership at the crew level in home building construction. Demographics data was collected to include age, experience, language proficiency, safety training, accident occurrence at work, and craft. The demographics questionnaire included twelve questions designed to help describe the characteristics of the sample population.

3.2.1.1 Safety Climate

The safety climate instrument for this study was a questionnaire designed by Dedobbeleer and Béland (1991). Two factors were included, management commitment and workers involvement. The first factor measured management's commitment to safety in terms of management's safety attitudes and practices. The second factor measured worker's physical risk perception and perception of control.

The questionnaire was created by Dedobbeleer and Béland (1991) in an effort to validate the three safety climate dimensions suggested by Brown and Homes (1986). Brown and Homes (1986) factors included, (a) employee perception of how concerned management is with their well being, (b) employee perception of how active management is in responding to this concern and, (c) employee physical risk perception. Brown and Homes' (1986) suggested dimensions were generated in an effort to validate Zohar's (1980) eight dimensions of safety climate. The study by Dedobbeleer and Béland (1991) was conducted on nine nonresidential construction sites in the Baltimore, MD Metropolitan Area, with 272 workers. A two-factor model resulted with a total coefficient of determination of 0.92. A systematic replication of the Dedobbeleer and Béland (1991) bifactorial structure was done using a sample of workers in different occupations by Oliver, Tomás, and Meliá (1993). The study found the two-factor model provided the best global fit and the climate structures did not differ between US construction workers and Spaniard workers from different types of industries.

For the scope of this dissertation, the safety climate questionnaire included all nine items (Table 4). Respondents were asked to rate each item based on their current job assignment. Responses for each item in the questionnaire were assigned values ranging from 1 to 5 to indicate level of agreement. The value of 5 was given for high agreement with a statement and the value of 1 was given for disagreement with a statement.

Table 4 - Safety Climate Questionnaire Factors and Items

Management Commitment	Worker's Involvement
- Management's attitude towards safety practices - Management's attitude toward safety - Foreman's behavior - Safety instructions - Proper equipment	- Safety meetings - Perceived control - Perception of risk-taking - Perceived likelihood of injuries

The questionnaire was modified for this study to include a 5-point Likert scale (1=strongly disagree, 5=strongly agree) for all the questions. The original questionnaire included multiple-choice responses with different scales for each question. The 5-point Likert scale was used for consistency in the response magnitude and direction for the questionnaire.

3.2.1.2 Perceived Risk Behavior

Perceived risk behavior was measured by a seven item questionnaire proposed by Rundmo (2000). Rundmo's study was conducted in Europe, the US, and Canada in the aluminum, magnesium, agricultural, energy and petrochemical divisions of the company Norsk Hydro and included a total of 13 plants and 730 respondents. The Cronbach's alpha for the behavior questionnaire in Rundmo's study was found to be 0.86. The original questionnaire included a 5-point frequency rating scale (1=very often, 5=never). Mearns et. al (2003) created a safety behavior instrument by deriving items from Rundmo (1996, 2000). Four out of the seven items were used verbatim from Rundmo's (2000) perceived safety risk scale, and the other three items were reworded. The Cronbach's alpha for Mearns questionnaire was found to exceed 0.70.

One finding from the questionnaire by Mearns et. al (2003) included the respondents having problems with discriminating the nuances between 'sometimes' and 'occasionally' expressed in the five point scale. Additionally the 'very often' point in the scale was never used. The authors suggest it was considered less confusing to use the anchor points 'never', ‘sometimes’ and ‘often’. In accordance with this finding, the perceived risk behavior questionnaire was adapted to include a 3-point interval frequency rating scale (1=Often, 2=sometimes, 3=Never).

3.2.1.3 Perceived Productivity and Work Ownership

Perceived productivity was measured using a modified version of the Craftsmen’s Questionnaire (Oglesby et al., 1989). The Craftsmen Questionnaire was intended to understand worker’s perception of their jobs and conditions surrounding them. The Craftsmen’s Questionnaire (Oglesby et al., 1989) was modified to include questions about the perception of delays and productivity time lost, excluding additional open-ended questions regarding other job aspects. The proposed job aspect categories were based on the findings by Serpell et al. (1997) of waste types, including waiting, idle, travelling and transportation, that affected productivity (Section 2.6.1).

Questions were included to address six themes: waiting, idle, transportation (Oglesby et al., 1989; Serpell et al., 1997), perceived lost production time, workable goals (Oglesby et al., 1989) and personal work ownership (Mayhew et al., 2007; Van Dyne & Pierce, 2004). Two scales were used, a 5-point Likert rating scale (1=strongly disagree, 5=strongly agree) and a quantitative interval frequency scale (1=<1 hour, 6=>5 hours). The 5-point Likert rating scale was used for questions that addressed materials, tools, production equipment, safety equipment, rework, job information, language translation, material location, material handling and daily task priorities. The frequency scale was used for questions addressing the amount of time spent waiting or handling the aforementioned categories. The original questionnaire used “yes” and “no” multiple-choice responses and open-ended questions.

The personal work ownership included modified items from the work ownership instrument suggested by Mayhew et. al (2007) based on Van Dyne & Pierce organizational psychological ownership instrument. This measure tested feelings of possession toward their job and a second question was reworded to test participants’ feeling of possession towards meeting their daily production goals. Mayhew et. al (2007) work ownership instrument showed a Cronbach’s alpha of 0.84.

3.2.2 Questionnaire Review

The “reading ease” of SPP was evaluated using the Flesch Reading Ease Score and the Flesch-Kincaid Grade Level score in Microsoft Word. The reading ease formula is (Flesch, 1948):

Flesch Reading Ease = 206.835 – 846 (word length) – 1.015 (sentence length)

The Flesch Reading Ease score is measured on a scale between 0 and 100. The higher the score, the easier it is to read. According to Flesch (1948) the scores roughly follow patterns: 0-30 very difficult, 30-50 difficult, 60-70 standard, 70-80 fairly easy, 80-90 easy, 90-100 very easy. The Flesch-Kincaid Grade Level score rates text on a United States grade school level.

The questionnaires resulted in a Flesch Reading Ease score of 69 and a Flesch-Kincaid Grade Level score of 7.0. This seventh grade reading level should be acceptable according to CPWR’s (2008) reported estimates of education level among construction workers to include: 27% of construction production workers had less than a high school diploma, 45% had a high school diploma, and 28% had some post-secondary education.

The questionnaires and informed consents were translated to Spanish to include workers who may not be proficient in English. Spanish was selected based on the estimate of foreign born workers in construction in 2005 to be 85% Latinos and among the languages spoken at home, Spanish represented 84% of the population (CPWR, 2008). A back-translation method was used to maintain equivalence between the original and translated versions of the questionnaires. Brislin’s (1970) classic back-translation model was used for instrument validation. This included an iterative process of repeated independent translation and back-translation by a team of translators. A native Spanish speaker (the researcher) translated the instrument from English to Spanish. A second native Spanish speaker independently back-translated the instrument from Spanish to English. The documents were compared for discrepancies.

3.2.3 Questionnaire Industry Validity

The questionnaires were tested for industry content validity. Content validity is the extent to which an empirical measurement reflects a specific domain of content (Carmines & Zeller, 1979, p. 20). Although these questionnaires were validated previously (Dedobbeleer and Béland

(1991); Rundmo (2000); Oglesby et. al(1989); Mayhew et. al (2007)), the content review was completed to ensure their relevance to construction.

A total of six experts in safety, construction, productivity or homebuilding reviewed the questionnaire for relevance and clarity (Lynn, 1986). The experts included a general contractor custom homebuilder, a construction superintendent, an assistant professor in construction management and safety, a homebuilding corporate safety officer, a quality manager and an Industrial and Systems Engineering PhD candidate. A Content Validity Index (CVI) was calculated (Lynn, 1986). The Content Validity Index is a proportion agreement procedure which allows two or more raters to independently review and evaluate the relevance of a sample of items to the domain of content represented in an instrument (Wynd, Schmidt, & Schaefer, 2003). The proportion of cases in which the raters agree are tallied to determine the stability of their agreement (Lynn, 1986).

A Likert type, ordinal scale was used which included a rating of *1=not relevant, 2=somewhat relevant, 3=quite relevant* and *4=very relevant*. The results for ratings of 1 and 2 were considered content invalid and ratings of 3 and 4 were considered content valid (Lynn, 1986). Experts were provided with the questionnaires and a relevance rating scale (4-point ordinal scale) to quantitatively rate the items' relevance to the domain of the content about safety factors. The amount of proportion that was considered sufficient included values higher than 70% (Hartman, 1977; Wynd et al., 2003).

The content validity review resulted in the deletion of nine questions. Each item was reviewed. Items for which 5 (out of 6) experts allocated a rating of three or four (CVI > 83%) were retained. Ratings of three or four assigned a "Quite Relevant" or "Very Relevant" value to the question. Deleted items included nine items, one question from the risk behavior scale, four open-ended questions, two questions about crew scheduling and two questions about supervisor presence on the field (Table 5). After the questions were deleted, the safety climate questionnaire remained with nine items, the risk behavior questionnaire was reduced to six items, the craftsman's questionnaire was reduced to 24 items and the work ownership questionnaire remained with two items.

The average CVI for the questionnaire resulted in 91.1%, rendering the modified questionnaire content valid (Lynn, 1986). Additionally, feedback was received on the wording of two questions. First, a question from risk behavior was reworded and the "I turn a blind eye" phrase was replaced with “I ignore”. This change was suggested based on the translatability of the phrase. Additionally, a language clarification was added to a translation question in the Craftsman’s Questionnaire.

Table 5 - Deleted Questions

Category	Question
Risk Behavior	• I break rules and instructions because they don’t describe the safest way of working.
Craftsman’s Questionnaire	• In your opinion, please list materials that are often short in supply. • In your opinion, please list the tools that are often short in supply • In your opinion, please list the production equipment that is often short in supply. • I have to stop work and wait or move to another task because another crew was not finished or was moved in ahead of your crew? • How many hours per week do you think you lose because you are waiting or moving from one spot to another because of another crew? • Please list type of information you are missing. • I have to stop work and wait or move to another task because my supervisor is not available at the jobsite? • How many hours per week do you think you lose because you are waiting for your supervisor?

3.2.4 Participants

Participants were recruited from construction workers employed by a homebuilder. The researcher received locations of homebuilding communities from a project manager. The researcher visited the job sites and spoke with the foreman of each jobsite, explaining the research. If the foreman agreed to participate, the researcher approached the workers. If the foreman did not agree to participate, the researcher would leave the jobsite. The foreman was not previously aware of the researcher’s visit. The homes were at different stages of build. Therefore, crews from different crafts were recruited. The researcher did not know the stage of build of the homes prior to arriving at the jobsite.

Questionnaire administration was limited to field production workers. Crews of two or more workers reporting to a foreman were recruited. Workers reporting to the same foreman were categorized under the same group. Questionnaires were in paper and pencil format. Questionnaire administration was limited to production workers working in The Northern

Virginia Area (Loudoun, Falls Church, Fairfax, Manassas). Participants had to be at least 18 years of age, not be in supervisory or management positions and be able to understand English or Spanish.

Questionnaires were administered throughout the workday. The researcher supervised the completion of the questionnaires. Participants were asked if they preferred to complete the questionnaire on their own or if they preferred to have the items read to them. This was intended to help participants who may have lower reading levels. The researcher, who is bilingual, was available to supervise the administration of the Spanish version of the questionnaire.

Participants were assured of the confidentiality of their responses. The questionnaires were anonymous, including only a code to identify the work group (crew). Institutional Review Board (IRB) approval was received prior to the data collection effort. This was communicated to the participants by the inclusion of an informed consent. Participants were asked to read and sign the informed consent prior to the questionnaire being distributed (Appendix F and Appendix G). A copy of the consent form, including the researcher contact information, was provided to all participants. All questionnaires and forms were available in English and Spanish.

3.3 Phase II

3.3.1 Instruments

3.3.1.1 Questionnaires

Phase II included the use of the Safety and Productivity Perception (SPP) questionnaire used in Phase I and observational studies documented by videotapes and complemented by field data observations. The participants in Phase II completed an informed consent and a questionnaire. The questionnaire was the same one used in Phase I (Appendix C and Appendix D).

The researcher ensured no participants from Phase I participated in Phase II by 1) recruiting in different communities and, 2) by asking the worker if they had previously participated in the research. If the worker had participated in Phase I, that particular crew was excluded from Phase II. This occurred once (one crew member) and the crew was excluded from Phase II.

3.3.1.2 Videos

Phase II focused on the framing of the first floor of a single family home. The homes in the sample size were approximately 2800 ft^2 of living space. The framing of a first floor single family home was videotaped for eight hours. Videotaping was used to provide availability for careful viewing and accurate sampling techniques. The framing task was selected since laborers and carpenters ranked as the top two occupations with the most fatalities in homebuilding.

A "rapid ethnography" field data collection approach was used (Millen, 2000). Rapid ethnography is a collection of field methods intended to provide a reasonable understanding of users and their activities given significant time pressures and limited time. It includes core elements such as: limiting or constraining the research focus and scope, using key informants, capturing rich field data by using multiple observers, interactive observation techniques and collaborative qualitative data analysis (Millen, 2000).

Ethnography describes and interprets a cultural, social group primarily through observations and interviews with additional artifacts during extended time in the field (Creswell, 1998). The ethnographic approach emphasizes "natives' point of view, holism, and natural settings provides a unique perspective to understanding users' work activities (Blomberg, Giacomi, Mosher, & Swenton-Wall, 1993). Ethnographic work's natural setting includes a commitment to study the activities of people in their every day settings (Blomberg et al., 1993). This requires the study be conducted in a field setting instead of a laboratory or experimental setting. Holism emphasizes the belief that particular behaviors can only be understood in everyday context in which they occur. The description is of how people actually behaved and not how they ought to behave. Understanding the members' point of view of the world is crucial. With the realization that one can never truly get inside the head of another or see the world exactly as another does, the research methods attempt to get as close to the insider's view of the situation as possible (Blomberg et al., 1993).

Two stationary video cameras were positioned on the right and left side of the job site (Figure 10). A Canon ZR10 Digital Camcorder was positioned on the left and a Panasonic PV-GS300 Digital Video Camcorder was positioned on the right. JVC Digital Video Cassettes were used on LP mode (90 minutes) to record up to eight hours of a first floor home framing task. A Quantaray QSX-9500 Heavy-Duty Tripod with Fluid Head was used with the Canon. A Velbon VideoMate-607 Heavy-Duty Tripod was used with the Panasonic.

The data collector wore a camera mounted on her hardhat (Figure 11). This allowed additional footage, specifically in locations that were hard to reach by the stationary cameras. The head mounted camera was a $V.I.O_{TM}$ POV.1. The POV.1 was a fully integrated point-of-view video system. It included a wide-angle camera head, which recorded with 720X480 resolution at 30 fps. A 2GB SD card was used for up to four hours of video recording capabilities. The camera uses four AA batteries, which could record up to four hours of video and sound.

Figure 10 - Stationary Video Cameras at Field (Left and Right)

Figure 11 - Field Data Collection Instrument

3.3.2 Framing Task

Framing included the joists, studding, sheathing, and trusses of the house. A panelization framing system was used by the General Contractor. Contractually, the General Contractor expected the Framing Contractor to supply all labor, tools, nails and equipment used to erect beams, stanchions, floor systems, wall systems, roof systems, porches, decking and exterior wood trim. All material handling was the responsibility of the Framing Contractor.

The eight hours of video captured the floor and first floor wall systems framing. Before the framing started, the framers checked the foundation and slab to make sure they were squared. The foundation was swept to eliminate any debris. A sill plate was attached to the foundation by anchor bolts or straps. Floor joists and exterior ring joist rested on the sill plate. Steel I-beams were used to provide support to the joints at the midpoint. Beams were shimmed to correct for beam pocket imperfections. A shim is a piece of material inserted between building materials for the purpose of straightening or making surfaces flush at a joint (Simpson, 2007). The beams rested on stanchion posts which went through the foundation floor and rested on a concrete footing. Stanchions should be plumb and set on solid bearing, with adjustable end down. The sub-flooring was nailed and glued to the floor joists.

Plate insulation was installed along the perimeter of the foundation. Plates were anchored to the foundation. Joists and hangers were installed. Sub-flooring was installed. Adhesive was applied and sheets were glued, screwed and placed one at a time. Nailing patterns was contractually defined by the General Contractor. Exterior walls and partitions were set and plumbed.

Material for floor framing was delivered before the framing started. Panels were delivered either the day before or the same day as the framing start. The drop off location for the materials depended on the available space. Panels were delivered as needed but there was a certain amount of batching from the manufacturing facility for production and transportation efficiency (not field task efficiency). Panels were sorted several times upon arrival based on batching, stacking space availability, and delivery time.

3.3.3 Participants

Participants were recruited from framers contracted by a general homebuilder. The researcher received the locations of homebuilding communities from the general contractor project manager. The researcher arrived at the jobsite at six in the morning the day of the job and spoke with the foreman of the jobsite (Appendix E). Upon agreement by the foreman, the researcher addressed the workers for their participation in the study. The crews were not notified beforehand of the research. Upon the crew's agreement for participation, the researcher provided the workers with the informed consent and questionnaires (Appendix F and Appendix G).

Questionnaire administration was limited to framers and laborers. Workers reporting to the same foreman were categorized under the same crew. Questionnaires were in paper and pencil format. Questionnaire administration was limited to production workers working in Northern Virginia Loudoun, Falls Church, Fairfax, and Manassas areas. Participants were required to meet the following guidelines: must be at least 18 years of age, must not be in supervisory or management positions and must be able to understand English or Spanish.

The researcher supervised the completion of the questionnaires. Participants were asked if they preferred to complete the questionnaire on their own or if they preferred to have the items read to them. This was intended to help participants who may have had lower reading levels.

The researcher, who is bilingual, was available to supervise the administration of the English and Spanish version of the questionnaire. Participants were assured of the confidentiality of their responses. The questionnaires were anonymous, including only a code to identify the work group. Institutional Review Board (IRB) approval was received prior to the data collection effort. This was communicated to the participants by the inclusion of an informed consent. Participants were asked to read and sign the informed consent prior to the questionnaire being distributed and the video camera being set up. A copy of the consent form, including the researcher contact information, was provided to all participants.

After the completion of the questionnaires, the video cameras were set up. Workers were asked to continue their work. The researcher did not interfere with the task. Video cameras were moved when necessary to not interfere with worker travel paths and/or material delivery. The researcher was present for the entire eight-hour period of filming. Filming was only stopped to change the cassettes or camera battery. The researcher documented times of cassette changes (start and stop) and battery changes (start and stop) (Appendix H).

A total number of fourteen trips were completed to collect the data for Phase I and Phase II. The trips for Phase I averaged four days each while the trips for Phase II averaged three days each. For Phase II, six research trips were successful and resulted in videos of the crews. Four trips resulted in repeat crews that either had previously been taped before or had participated in Phase I. Refer to Table 6 for trip details.

Table 6 - Listing of Research Trips

Phase	Trip Date	Average Duration per Trip (Total)	Approximate Miles to Location (one-way)
Phase I	5/19/08-5/21/08 11/19/08-11/22/08 12/9/08-12/12/08 1/7/09-1/10/09	4 days (15)	240 miles
Phase II–Crew Videos	3/24/09-3/26/09 4/18/09-4/20/09 5/4/09-5/6/09 7/12/09-7/14/09 7/20/09-7/22/09 8/19/09-8/21/09	3 days (18)	240 miles
Phase II – No video	5/19/09-5/20/09 7/6/09-7/7/09 8/6/09-8/7/09 8/11/09-8/12/09	2 days (8)	240 miles

The videos were downloaded using the same video camera used for taping. The videos were converted to MPEG-1 digital media file format. The videos were kept in their original time format. Naming of each video included *Date Video#* (i.e. Mach25 Video1). Videos were saved on an external hard drive for portability.

3.4 Video Review

3.4.1 Coder Recruiting and Training

The videos were prepared for analysis in the lab based on predefined activity categories. Two coders were recruited through verbal requests and emails to undergraduate and graduate students in existing industrial engineering and psychology labs at Virginia Tech. The researcher interviewed the coders to understand their experience level in construction. Coders were recruited and interviewed separately. Coder A had a Bachelor of Arts in Interdisciplinary Studies with minors in Sociology, History and International Studies. Coder B was a senior in Psychology. Both coders had no experience in the construction industry. Both coders were blinded to the objectives of the study. Additionally, both coders were blinded to the scoring results of the other coder.

The coders performed three general tasks for this project. They reviewed the construction videos to code them for predefined behavior categories of productivity, safety and waste. The researcher trained the coders individually on how to access the data from an external drive and operate the Noldus Observer® XT 8.0 software. The process of coder training is important since it helps to ensure acceptable levels of inter-rater reliability (Kendall & Butcher, 1982).

A three phased approach was used to complete the coder training, (a) training of the coders to use the software and understand the behaviors, (b) evaluation of the coders' performance at the end of the training and, (c) determination of the extent to which the training was maintained throughout the study (Castorr et al., 1990). The training was standardized through the use of a coding manual, predefined behaviors and decision rules. The researcher trained each coder through the use of a coding manual (Appendix I) to guide them in learning the software and coding procedures. A hard copy of the coding manual was provided to the coders for reference. The coders were trained and performed the observational analysis individually.

The researcher first trained the coders on the software (approximately 1.5 hours) and productivity field ratings. The trainee practiced data coding with the researcher prior to coding independently. After each coder felt comfortable with the process, the coder completed (on their own) coding for a training video. The training video consisted of 49 random times to code. After the practice video was completed, results were compared to a baseline evaluation completed by the researcher. If at least 70% agreement existed, on the total number of codes categories, the coder proceeded to begin the video observation (Castorr et al., 1990).

The coders were provided with a hard copy of the random times (Appendix J) and decision guidelines. The coders were trained to circle the random time if the analysis requirements were not met for that particular time. After the productivity videos were complete, the same training and coding process, including, decision rules, was followed for safety and waste analysis (Figure 12). Decision rules were provided as verbal instructions to aid the coders in completing the observations.

3.4.2 Coding Scheme

Activity sampling was used to evaluate labor productivity, safety behavior and the presence of waste. Field observations were recorded with videos and analyzed to understand the activity level of framing operations with the use of a field rating technique. Field ratings required the behaviors of workers be grouped at the moment of observation into classifications. This research focused on the classifications: working-not working, safe-not safe, waste-no waste.

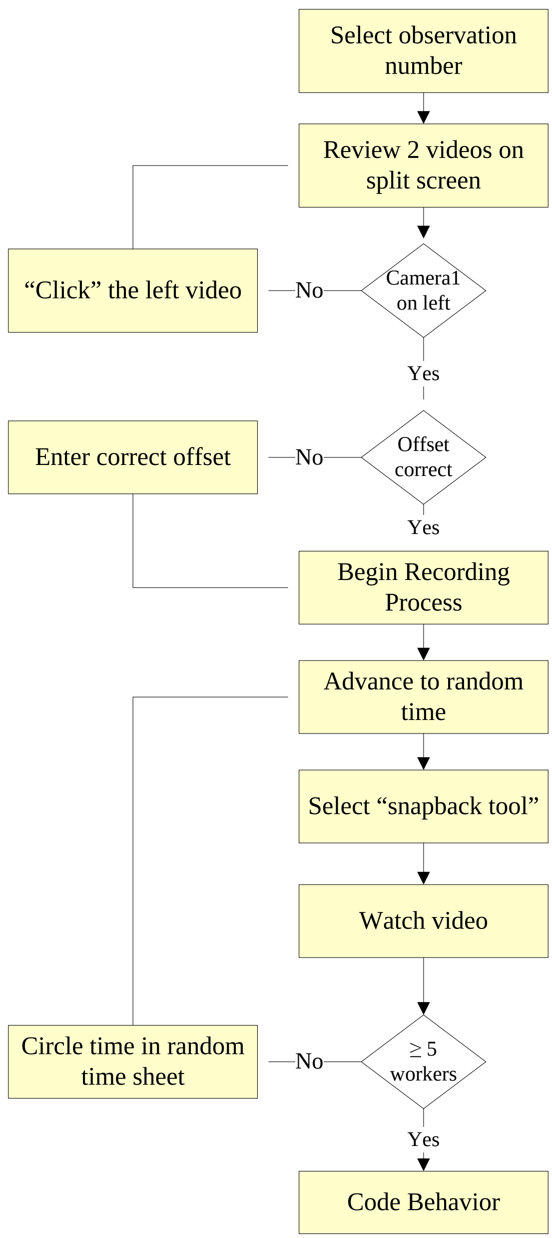


Figure 12 - General Process for Video Coding

Two coders evaluated the videos based on the predefined activity categories using Noldus Observer® XT 8.0 Software. The Observer® XT is an event logging software used for video analysis. A *Coding Scheme* was created for the productivity, safety and waste events. The coders observed crews of construction workers during various stages of a single family home framing and entered observations of the workers' behavior in the form of predefined codes. The program created a space for each individual that performed an action (Subject) and a space for the action itself (Behavior). Each record is mapped to a time stamp. All files were scored from two media files (MPEG-1). The media files, left and right cameras, were shown in a dual-split image and played simultaneously. The camera-1 video was always on the left side of the screen.

The *Coding Scheme* included subjects and behaviors. The behaviors were grouped based on categories. For productivity, group categories included working and not working. For safety, group categories included, safe and not safe. For waste the categories included waiting, idle time, traveling time, transportation and no waste. The videos were synchronized to allocate for any differences in recording starting times of the camera. The researcher kept field observation logs to document synchronization times. The researcher validated the differences through video observations (Appendix H).

The behaviors were coded as "state" or mutually exclusive. When one behavior was active, the other behaviors within the same group were not active. Subjects were defined as Worker 1 – Worker 7 (Figure 13). Each worker was identified with a subject number. The subject number stayed constant throughout that current observation (to not double count between the left and right cameras). Notes could be added about specific characteristics of the worker to help identify them (i.e. Worker 1 - yellow hard hat, Worker 2 - Red Sweatshirt) in the comment section. The subject number did not necessarily stay constant between observations. This was due to the difficulty of identifying specific characteristics to differentiate between workers. At least five different workers had to be observed between the two different cameras (Oglesby et al., 1989). Each observation was viewed by the coder for six seconds (Oglesby et al., 1989) at ½ playback speed using the *Quick Review Function*. The Quick Review Function allowed the coder to automatically rewind the six seconds to play the tapes at ½ the speed.

Coders selected the behavior from a predefined list (Figure 14). If an observation did not include at least five workers (couldn't identify their actions or worker not seen in the screen), the observation was not recorded and the time was circled in the random observation sheet.

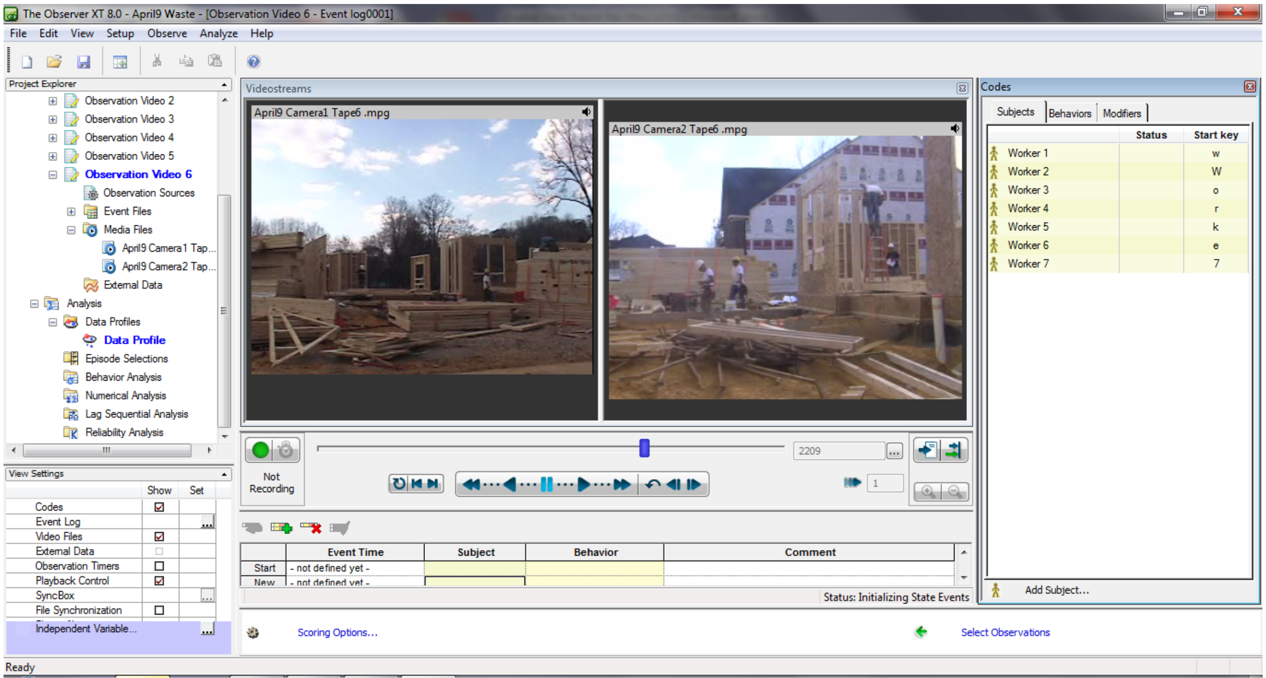


Figure 13 - Noldus Observer® 8.0 XT Worker Recording Screen

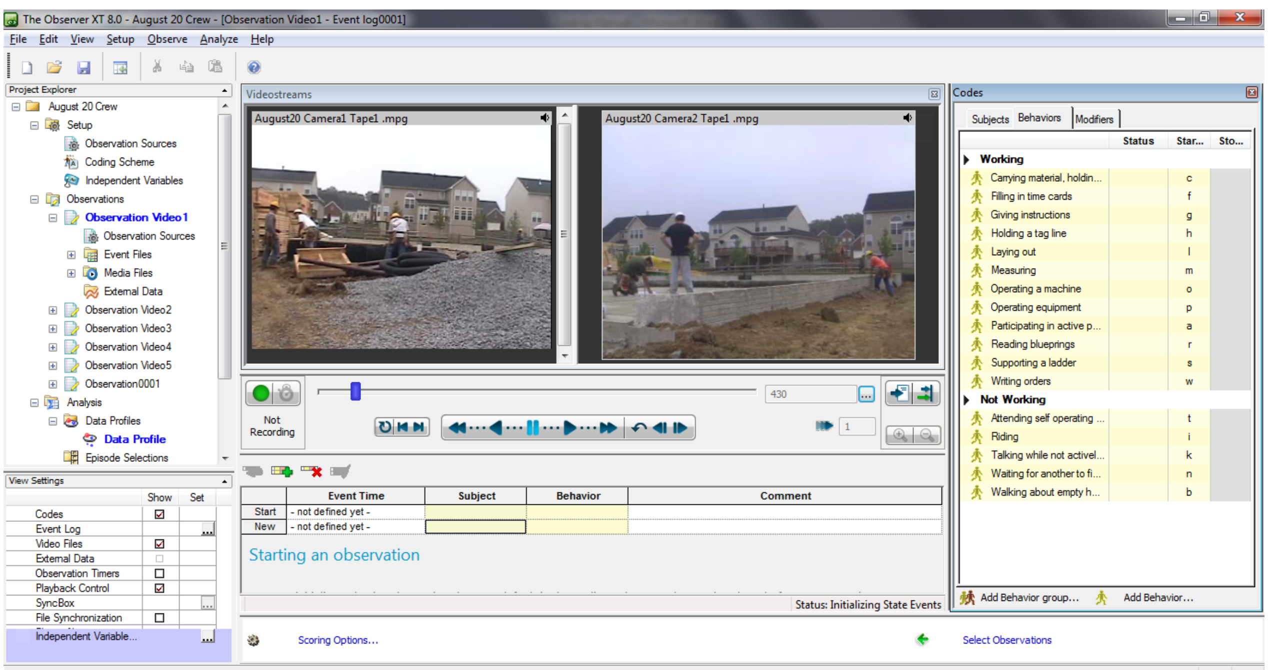


Figure 14 - Noldus Observer® 8.0 XT Behavior Recording Screen

Observations were recorded from left to right on the screens. Observations were collected at random times. An Excel random number generator was used to generate the random observation times. The random numbers were generated for the total amount of video time per date. They were sorted and scrubbed for start times, breaks, lunch and quitting time. Observation times excluded ½ hour after starting work, ½ hour before lunch, lunch time, ½ hour after lunch and ½ hour before quitting time (Oglesby et al., 1989).

Coders recorded observations using 5-6 videos per date until 400 observations were completed. Each worker behavior recorded represented one observation. Once the count reached 400 observations, the existing time slot was finished and the coding was stopped. There was not a time cap for the coders to complete the observations.

3.4.2.1 Productivity Ratings

Sampling, as used for productivity improvement applications, involved observing and classifying a percentage of some whole to obtain a representation via a statistically valid sample (Oglesby et al., 1989). Field rating activities for productivity (Table 7) included working and not working.

Table 7 - Productivity Behaviors

Working	Not Working
- Carrying material or holding or supporting material - Participating in active physical work - Measuring - Laying out - Reading blueprints - Filling in time cards - Writing orders - Giving instructions - Holding a tag line - Supporting a ladder - Operating a machine - Operating equipment	- Waiting for another to finish work - Talking while not actively working - Attending self-operating machines - Walking about empty handed - Riding

Guidelines were used for appropriate productivity rating techniques (Oglesby et al., 1989). At least 75% of the personnel needed to be in the video sample. This was established as at least five workers present in both screens. The coder devoted full time to the count and the rating was taken at the first instant of observation. The coder was asked to not speculate about whether or not the subject was or will be active a moment before or after the observation. Random times excluded ½ hour after the worker started, lunch and ½ hour before quitting time (lunch or end of day). Additionally, no counts were discarded (Oglesby et al., 1989).

The statistically valid sample size calculation included assumptions of confidence level, margin of error and the unknown fraction to be estimated (*Handbook of Industrial Engineering*, 1992):

$$N = \frac{Z^2 * p(p-1)}{I^2} = \frac{1.96^2 * 0.5^2}{0.05^2}$$

N=number of observations
Z=normal probability distribution factor, based on confidence level
P=unknown fraction to be estimated
I=desired margin of error in estimation

The range of percentage of productive work usually found in construction-labor sampling is between 40 percent productive and 60 percent productive, with a recommended 50 percent category proportion requiring the maximum sample size to attain a stated confidence limit and limit of error (Oglesby et al., 1989). For sampling construction operations, a general industry consensus included a confidence level of 95% and a limit of error of plus or minus five percent (Oglesby et al., 1989). Coders worked to complete a sampling size of 400 (Figure 15). Decision rules were established so the process of coding followed observer-independent rules (Krippendorff, 2004). The same procedure and sample size was used for coding safety and waste observations.

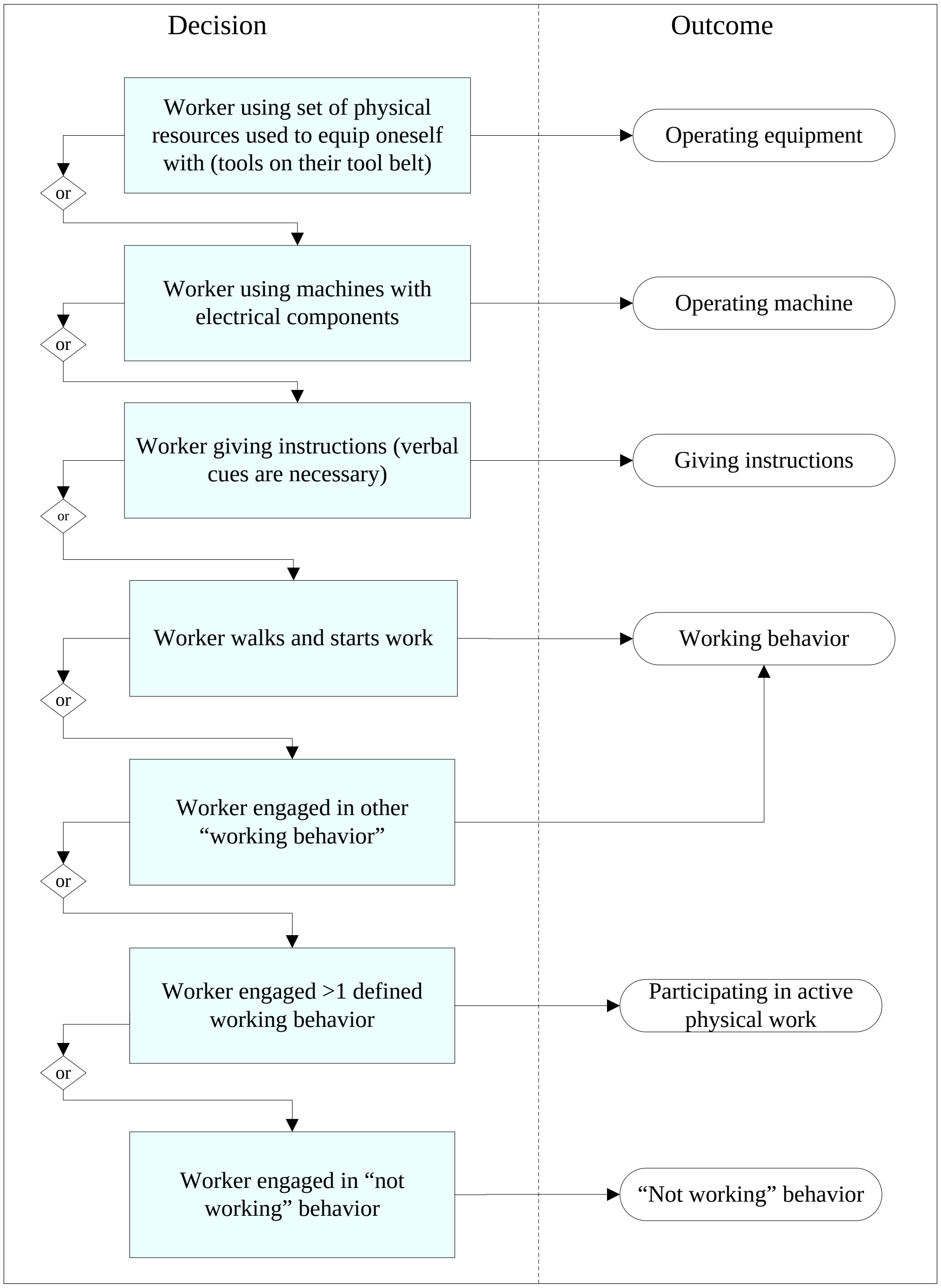


Figure 15 - Productivity Rating Coding Decision Guide

3.4.2.2 Safety Behavior

The safety behavior was analyzed using a behavior sampling technique. Behavior sampling, as used for safety improvement applications, is based on randomly sampling observations of workers' behavior to evaluate whether the observed behaviors are safe or unsafe (Tarrants, 1980). Types of behaviors that can be observed include the use of personal protection equipment, manual material handling, and proper tool use. The behaviors were predefined for the trained coder to be able to systematically identify safe and unsafe behaviors.

Behavior sampling has been recommended as a reliable method for evaluating safety performance (Cooper & Phillips, 1994; Fitch, Hermann, & Hopkins, 1976; Glendon & Litherland, 2001; Reber & Wallin, 1983; Tarrants, 1980). Observations were recorded and analyzed to understand the percent work safe behaviors (Table 8). The suggested safe behaviors were based on a road construction safety behavior study (Glendon & Litherland, 2001), a jobsite safety inspection checklist (Oglesby et al., 1989), and the National Association of Home Builders and U.S. Occupational Safety and Health Administration Jobsite Safety Handbook (NAHB-OSHA, 2007).

The final list of key behaviors from the road safety behavior study was determined from discussion with a Occupational Health and Safety Coordinator and the principal construction technician based on frequency and range of accidents with the company (Glendon & Litherland, 2001). The jobsite safety inspection checklist was developed by a large building contractor (Oglesby et al., 1989). Behaviors were selected if they were observable, applicable to the first floor framing task and included in the NAHB-OSHA Jobsite Safety Handbook. Video recordings were used to for the sampling techniques.

A percent safe behavior was calculated for each crew. Observations were collected at random times and in different sequences. An Excel random number generator was used to determine the observation times.

$$\%\, Safe\ Behavior = \frac{Total\ Safe}{Total\ Safe + Total\ Unsafe} x100\%$$

The safe and unsafe observations were tallied to generate each total. The same aforementioned field sampling guidelines were used for coding the safety observations (Oglesby et al., 1989). At least 75% of the personnel needed to be in the video sample. This was established as at least five workers present in both screens. The coder devoted full time to the count and the rating was taken at the first instant of observation. The same random times were used. The coders, however, were given unmarked random time sheets and asked to follow the same procedure as the productivity ratings. Additionally, no counts were discarded (Oglesby et al., 1989). The process is listed in Figure 16.

Table 8 - Safety Behaviors

	Safe	**Not Safe**
Personal Protective Equipment	- Wearing appropriate personal protective equipment (PPE) - Wearing eye protection where damage can result to the eyes (including nail guns)	- Not wearing hard hat or wearing it incorrectly (i.e. backwards) - Not wearing boots - Not wearing hard hats (or wearing incorrectly) or boots - Not wearing eye protection where damage can result to the eyes (including nail guns)
Equipment	- Tools are used for their intended purposes - Tools are stored away when not being used - Ladders are used properly - Both hands must be used when climbing extension ladders	- Tools used for alternative purposes (other than their intended function) - Tools are not stored away after use - Ladders used for other than their intended function - Both hands are not used when climbing extension ladders
Tools	- Power saws have blade guards - Saws turned off before leaving them unattended - Tools are raised and lowered by their handles	- Power saws do not have blade guards - Saws kept running while unattended - Tools are raised and lowered by their cords
House-Keeping		- Workers slips due to trash, debris, materials - Worker trips due to trash, debris, materials - Ramps don't have cleats
Material Handling		- Lifting panels while climbing ladder
Vehicles	- Worker stays clear of backing and turning vehicle - Backup warning systems are functioning properly - Flaggers are used when the operator is unable to see	- Worker does not stay clear of backing and turning vehicles - Backup warning systems are not functioning properly - Flaggers are not used when the operator is unable to see

3.4.2.3 Waste

Waste was analyzed using the same sampling technique and process as the productivity ratings and the safety ratings (Figure 17). The behaviors were pre-coded.

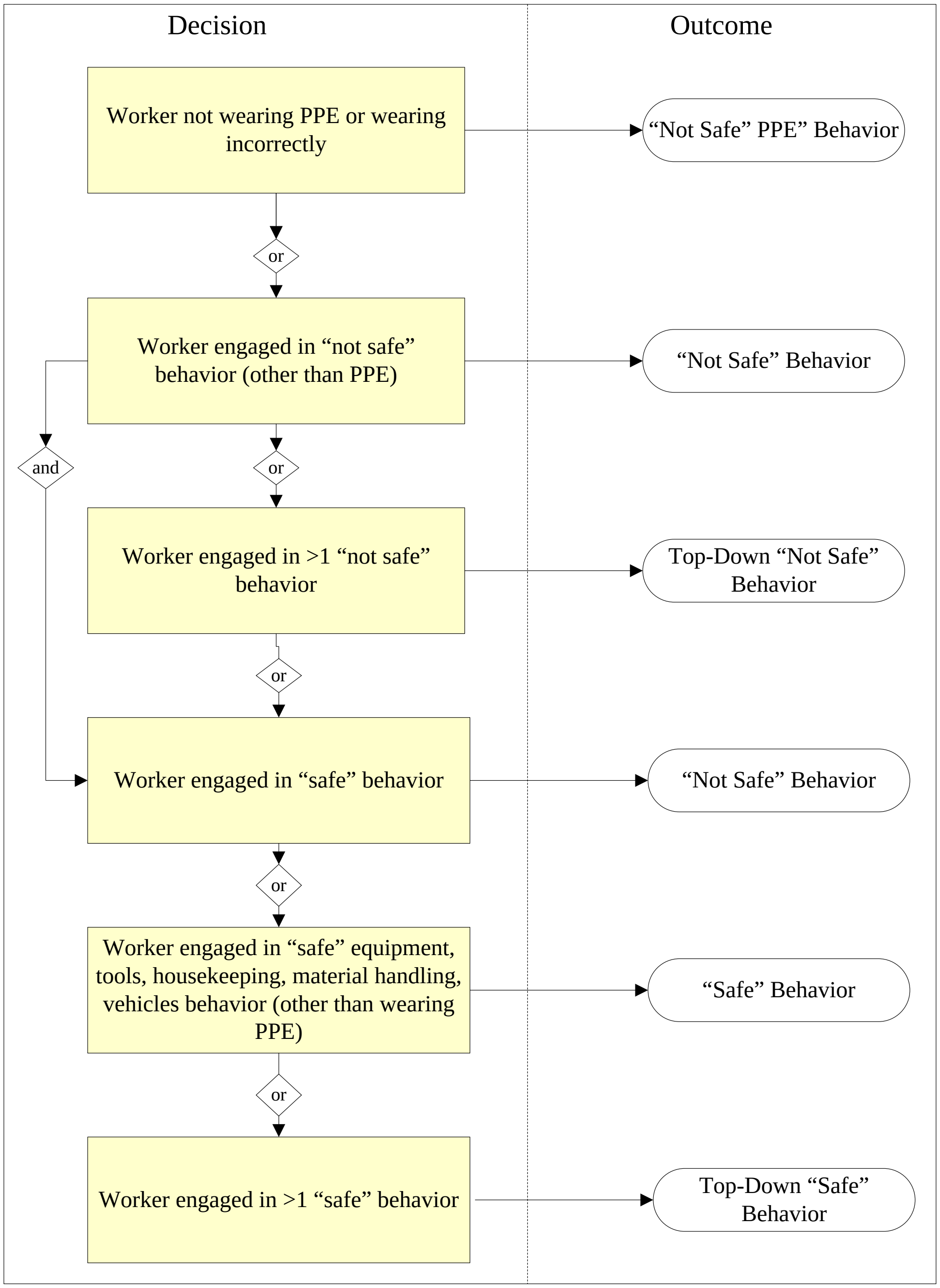


Figure 16 - Safety Video Coding Decision Guides

Waste comes from flow activities, conversion activities and management activities and it’s generally manifested by two common construction situations: work inactivity and ineffective work (Serpell et al., 1997). Subcategories of waste included waiting, idle time, traveling, and transportation. Additional description of coding can be found in coding manual (Appendix I).

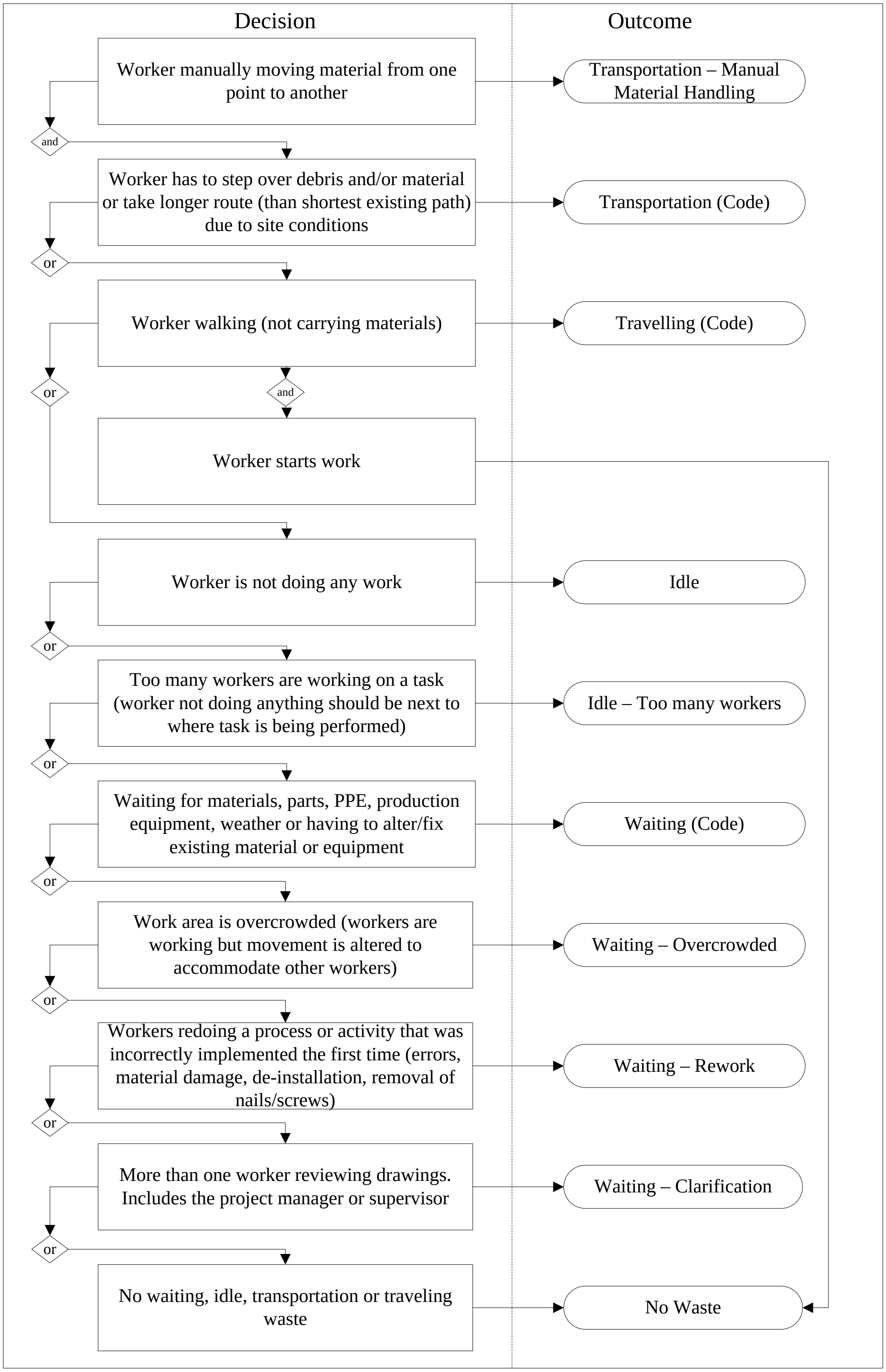


Figure 17 - Waste Video Coding Decision Guide

3.4.2.4 Video Data Collection and Analysis

The use of videotaped recordings for observational analysis offered the ability to capture non-verbal and verbal behaviors and interactions which were observed and analyzed in a lab setting. Videotaping provided the ability to review as many times as necessary by replaying the data. This can, in turn, enhance rater reliability.

Videotaping provided an alternative to real-time observations since the multilevel systems comprised behavioral units (Kopenhaver Haidet, Tate, Divirgilio-Thomasm, Kolanowski, & Happ, 2009). Additionally this method allowed for the implementation of training of naïve observers without construction knowledge which facilitated coding to be done without any preconceived judgments (Kopenhaver Haidet et al., 2009). Observations using videotapes allowed for multiple coders to view and analyze the same data.

Videotaping, however, required resources to collect and analyze the data. The data, although rich in depth of analyzability, required time as a resource. For this research, the data collection and analysis time was plotted in Figure 18. As the depth of the richness of data increased, the time to collect and analyze the data increased.

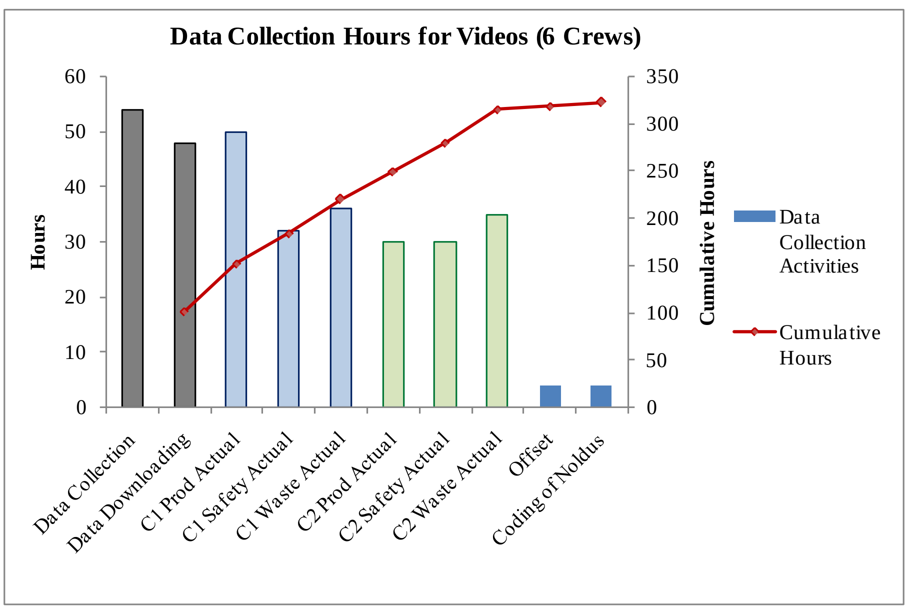


Figure 18 - Data Collection Time for Video Analysis

Chapter 4. Results and Discussion

4.1 Phase I and II

One hundred and fifty seven construction workers participated in Phase I. Four participants' responses were discarded due to incompleteness. Three additional responses were discarded since they did not meet the group requirement of at least two group members. One additional response was discarded due to age guidelines (18 years of age); this was discovered after the fact. The total participants included for Phase I analysis was one hundred and forty nine (39 crews) workers.

Forty-one construction workers (6 crews) participated in Phase II. No responses were discarded. Since the questionnaires were administered via hard copies, a data electronic file was created for data analysis. Two surveys from each group, including both English and Spanish, were randomly selected and rechecked by the researcher to ensure accuracy of data entry.

4.2 Phase I & Phase II Questionnaires

Questionnaires from Phase I and Phase II were combined for analysis (n=190, 45 crews). The variables of interest in this study were conceptualized both at the individual and crew level of analysis and required aggregation of the data collected from individuals. Workers reporting to the same foreman were grouped. Each worker's perception of safety climate, risk behavior, presence of waste, labor productivity lost, and work ownership were summed.

The crew safety climate, the perceived risk behavior, the perceived presence of waste, the perceived labor productivity lost, and work ownership were determined by averaging the score (for each questionnaire) of all workers who completed the questionnaire for that crew (Table 25, Appendix L). This procedure of representing climate by a single score is based on the theoretical consideration whereby all climate dimensions describe conditions and procedures, affecting the effectiveness of the safety program (Zohar, 1980). They are considered additive in nature. A high safety climate score indicates more favorable conditions and procedures (Zohar, 1980).

The conditions determining the appropriate level of analysis include, (a) within-group homogeneity (the degree to which group members equally share perceptions about the climate) and (b) between-group variance (the degree to which climates differ significantly between crews in the same organization) (Zohar, 2000). Intraclass correlation coefficients (ICC) provide measures of reliability. Intraclass correlation coefficients, ICC1 and ICC2 were used to justify aggregation of data to a higher level of analysis (Bartko, 1976; Fleiss, 1971). ICC1 compared the variance within units of analysis using the individual ratings of respondent and ICC2 assessed the relative status of between and within variability using the average ratings of respondents within each unit (Schneider, White, & Paul, 1998).

Results for ICC1 and ICC2 were, 0.04, 0.68 respectively for safety climate, 0.04, 0.66 respectively for risk behavior, 0.10, 0.81 respectively for perceived presence of waste, 0.10, 0.80 respectively for the perceived labor productivity lost and 0.10, 0.80 respectively for work ownership. Between-group variance was tested with one-way analysis of variance (ANOVA). The ANOVA was conducted with the unaggregated data, using work-group affiliation of each respondent as the independent variable. The results suggested a significant difference for safety climate, $F(44,145) = 3.09$, $p < 0.0001$, risk behavior, $F(44,145) = 2.92$, $p < 0.0001$, perceived presence of waste, $F(44,145) = 5.4$, $p < 0.0001$, perceived labor productivity lost $F(44,145) = 4.92$, $p < 0.0001$, and work ownership, $F(44,145) = 5.18$, $p < 0.0001$. These results indicated enough within-crew homogeneity and between-group variance for a crew level of analysis (Bartko, 1976; Fleiss, 1971; Zohar, 2000). The combined total (n=190, 45 crews) included crews which ranged in size with a minimum of 2 and a maximum of 8 workers per crew (Table 9).

4.2.1 Questionnaire Reliability

Cronbach's (1951; 1955) coefficient alpha was measured for the internal consistency of each scale (Table 10). Cronbach's alpha measures how well a set of variables measures a single unidimensional latent construct. Reliability coefficients of 0.70 are recommended (Nunnally, 1978).

For the raw value calculations, items with more variability contribute more to the variability of the resulting scale while the standardized value distributes weight equally. Since the productivity questionnaire employs different scales (for waste and loss), the standardized Cronbach's values were used for the Craftsman's Questionnaires. For the safety climate, risk behavior and work ownership questionnaires, the same scale was used, therefore, the raw Cronbach's values were used. All raw and standardized values resulted in values above 0.70 for the combined questionnaires, which was in accordance with the recommended values of 0.70 (Nunnally, 1978). No items were discarded.

Table 9 - Description of Crews

Crew	Workers	Description	Crew	Workers	Description
1	6	Electrical	25	5	Brick Masonry
2	3	Electrical	26	4	Concrete/Foundation
3	3	Carpentry	27	2	Painting &Wall Covering
4	7	Painting &Wall Covering	29	4	Landscaping
5	3	Insulation	30	4	Drywall and Insulation
6	4	Gutters	31	6	Framing
7	3	Painting &Wall Covering	32	6	Electrical
8	2	Electrical	33	3	Concrete/Foundation
9	2	Plumbing, heating &A/C	34	7	Framing
10	2	Concrete/Foundation	35	4	Plaster
11	3	Plumbing, heating &A/C	36	2	Cabinets
12	2	Laborer	37	3	Plaster
13	4	Painting &Wall Covering	39	3	Siding
14	3	Painting &Wall Covering	40	2	Painting &Wall Covering
15	3	Concrete/Foundation	41	2	Carpentry
16	4	Plaster	42	4	Painting &Wall Covering
17	6	Landscaping	43	7	Framing
18	2	Tiling	44	6	Framing
20	7	Carpentry	45	7	Framing
21	5	Cleaning	46	7	Framing
22	5	Roofing	47	8	Framing
23	6	Piping	48	6	Framing
24	3	Plaster			

Table 10 - Cronbach's Alpha Results

	Phase I		Phase II		Combined	
Scale	Raw	Standard	Raw	Standard	Raw	Standard
Safety Climate	0.65	0.75	0.75	0.79	0.70	0.77
Risk Behavior	0.72	0.73	0.68	0.70	0.71	0.73
Craftsman Questionnaire	0.81	0.83	0.66	0.75	0.79	0.81
Work Ownership	0.96	0.96	0.99	0.99	0.94	0.94

4.2.2 Demographics

The mean age of participants (n=182) was 31.7 (*SD* = 9.30) with a range from 18-61 years of age. Participants responded to their ethnicity as Latino 92.10% (175), White 6% (12), and Asian 2% (3). In Phase I, 90% (134) of the participants and in Phase II, 100% (41) of the participants responded to their ethnicity as Latino. Participants were given the option to complete the questionnaires in English or Spanish and 92% (174) opted to complete the questionnaire in

Spanish. During Phase I, 89% (133) of the participants and in Phase II, 100% (41) of participants opted for the Spanish form.

Three questions addressing participant's fluency with speaking, reading and writing English were included (Figure 19). Participants (n=190) indicated 36% speak English, 24% read English and 19% write English. Thirty-five workers (18%) indicated that they speak, read and write English. This included eight electrical workers, six painters, six framers, four gutter workers, three landscapers, two plasterers, two laborers and one carpenter, drywall, concrete and tiling workers.

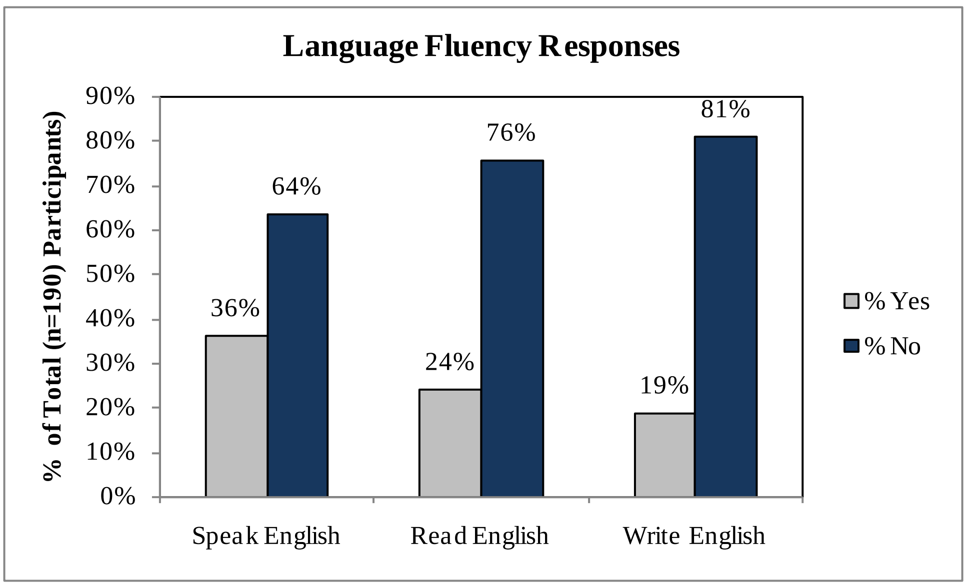


Figure 19 - Responses to Language Fluency by Participants

Participants (n=189) responded to their experience in the construction industry as 14% with less than one year experience, 47% with 1-5 years experience and 39% with more than 5 years experience. When responding (n=189) to their experience with the current employer, 15% had less than one year experience, 55% had 1-5 years experience and 30% had more than 5 years experience.

Participants (n=190) responded that 59% (112 participants) had received safety training. A total of 10% (19 participants) indicated they had an accident at work, with 13 of the 19 being participants who responded they had received safety training. The accident questionnaire item did not specify level of severity. Participants reported their trades as framers, painters, electrical, plaster and concrete (Figure 20).

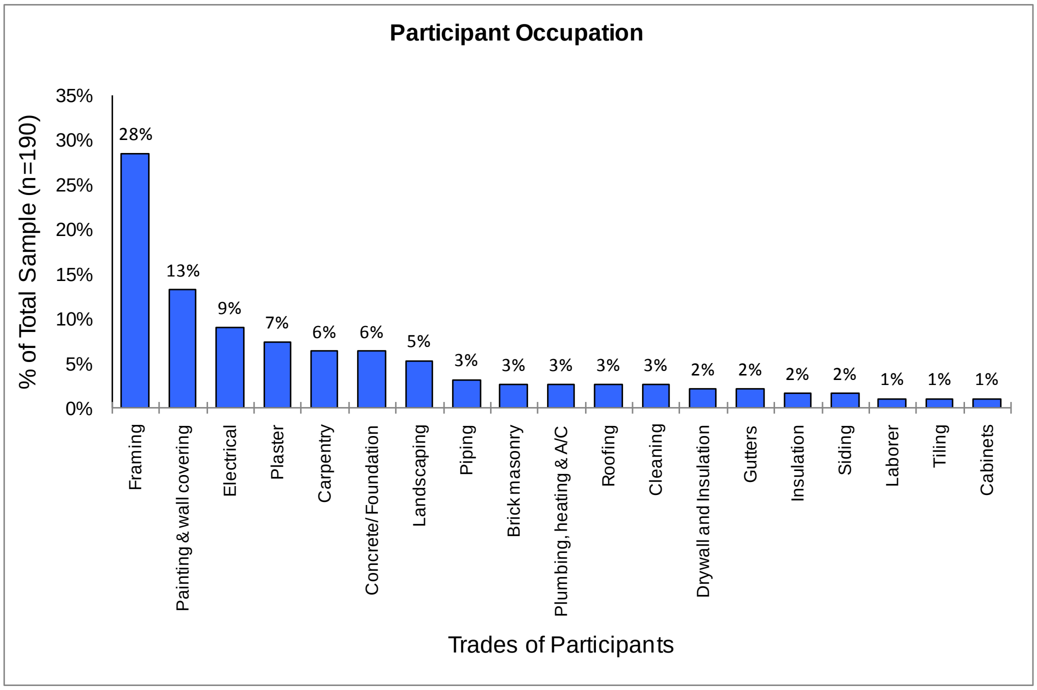


Figure 20 - Trades of Participants

4.2.3 Normality

Normality tests were run to determine whether the data set, at the worker level, was normally distributed. A graphical and non-graphical approach was selected.   Q-Q plots (quantile) are probability plots that provide a graphical method for comparing ordered variable values with quantiles of a specific theoretical distribution. If the data matches the normal distribution, the points form a linear pattern. A Shapiro-Wilk test was applied to test for a normal distribution (α=0.05). Safety climate (0.94, $p < 0.0001$), risk behavior (0.96, $p < 0.0001$), craftsman's questionnaire waste (0.98, $p = 0.0026$), craftsman's questionnaire loss (0.96, $p < 0.0001$) and work ownership (0.69, $p < 0.0001$) violated the normality assumptions (Appendix K) . Log and Boxcox transformations were performed but did not result in normal data. Due to the non-normality results, non-parametric statistical tools were used where appropriate.

Normality tests were additionally run, at the crew level, to determine whether the data set was normally distributed. A Shapiro-Wilk test was applied to test for a normal distribution (α=0.05). Safety climate (0.96, p = 0.1128), risk behavior (0.95, p = 0.07), craftsman's questionnaire waste (0.97, p = 0.34), and craftsman's questionnaire loss (0.98, p = 0.83) did not violate the normality assumption. Work ownership (0.80, $p < 0.0001$) violated the normality assumption.

4.2.4 Safety Climate

To obtain safety climate scores, each safety climate questionnaire was assigned a single score. The score was calculated as the sum of the values for all items (9 total items) in the questionnaire, which indicated the safety climate level for that individual worker. Crew safety climate score was calculated by averaging the individual scores across the crew.

Questions eight and nine were reverse coded. Question eight, "Taking risks is part of the job" and question nine, "I think I am likely to be injured on the job in the next 12 month period" were reverse coded to retain the direction of the scale. Higher safety climate scores indicated a perception of a safer work environment. The scores ranged from 26-40.50 (Table 25, Appendix L) with a mean of 32.90 (*SD* = 2.67).

The safety climate scale's Cronbach's (raw) alpha for internal consistency was 0.65 for Phase I (n=149, 39 crews), 0.75 for Phase II (n=41, 6 crews) and 0.70 (n=190, 45 crews) for the combined total. The "high" value of alpha suggests that the questionnaire items did measure the underlying safety climate construct.

The results of the safety climate scores for crews 1-48 are shown in Figure 21. The bottom and top edges of the box show the 25^{th} and 75^{th} percentile of the sample. The median is shown as a line and the mean is shown by the diamond. The boxplot graphically shows the differences between the scores of the crews. An extreme point of 19 existed for crew 1. The extreme point was retained since it is important to understand how it affected the overall crew score. Additionally, crews 2, 9, 20, 21, 24, 27, 35 and 36 had the same total score for each participant in the crew. For the eight crews, three had two crew members, two had three crew members, and one had four, five and seven crew members.

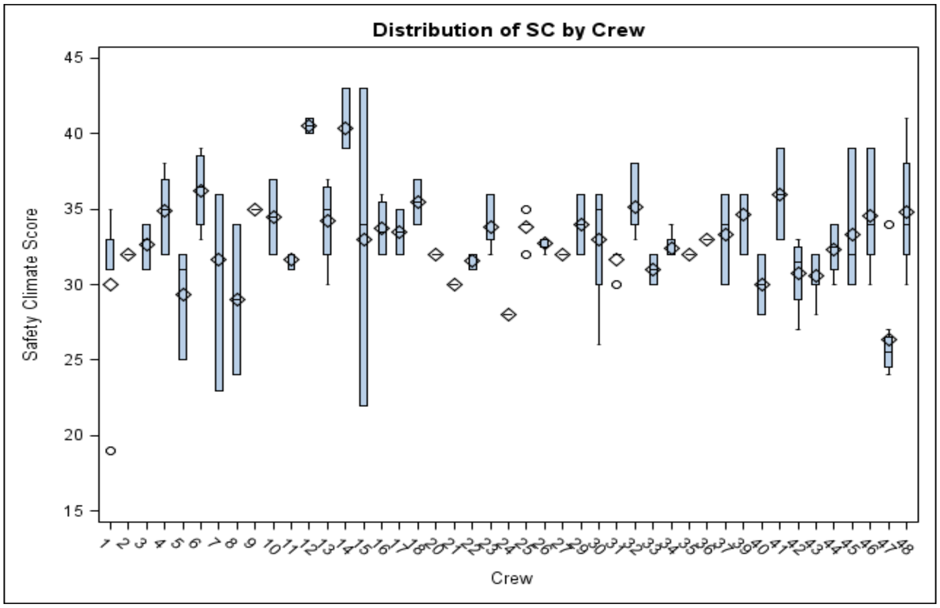


Figure 21 - Boxplot for Safety Climate

4.2.5 Risk Behavior

To obtain risk behavior scores, each risk behavior questionnaire was assigned a single score. The score was calculated as the sum of the values (6 total items) for all items in the questionnaire, which indicated the risk behavior level for that individual worker. Crew risk behavior score was calculated by averaging the individual scores across the crew. High risk core indicated a low frequency of perceived risk taking behavior. The scores ranged from 7-18 (Table 25, Appendix L) with a mean of 13.80 (*SD* = 1.92).

The risk behavior scale's Cronbach's (raw) alpha for internal consistency was 0.72 for Phase I (n=149, 39 crews), 0.68 for Phase II (n=41, 6 crews) and 0.71 (n=190, 45 crews) for the combined total. The values resulted in values above 0.70, which is in accordance with the recommended values of 0.70 (Nunnally, 1978). The results of the risk behavior scores for teams 1-48 are shown in Figure 22.

Extreme points existed for: crew 1, extreme point of 8, crew 24, extreme point of 7, crews 43 and 44, extreme point of 10, crew 48, extreme point of 9. Interestingly, from the five crews that had extreme (low) risk points, three were framing crews. Additionally, crews 2, 9, 14, 24, 26 and 36 had the same total score for each participant in the crew. For the eight crews, two had two crew members, three had three crew members, and one had four crew members.

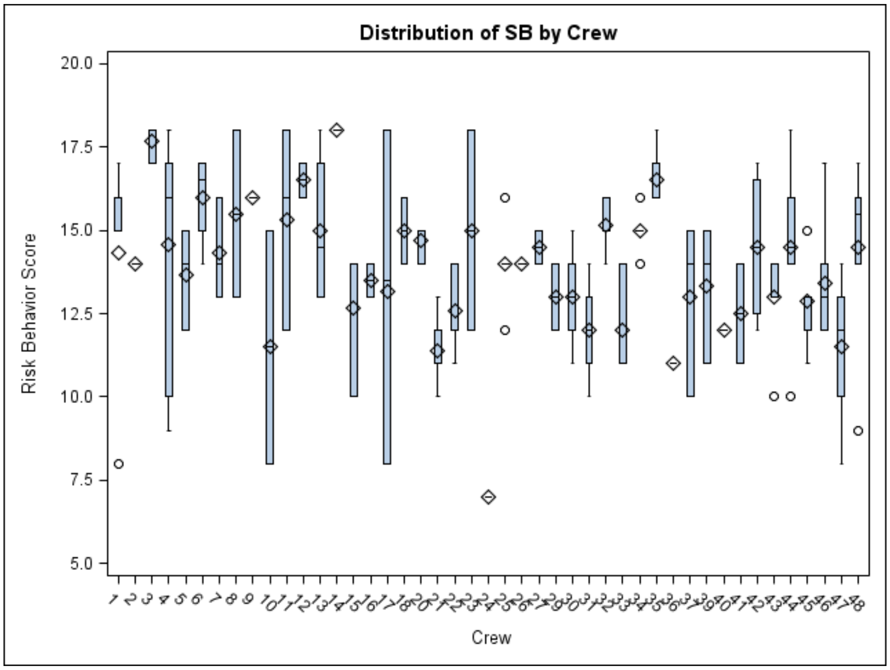


Figure 22 - Boxplot for Risk Behavior

4.2.6 Craftsman's' Questionnaire

To obtain craftsman's questionnaire scores, responses for each item were grouped into one of two categories, CQWaste and CQLoss. The craftman's scale's Cronbach's (standard) alpha for internal consistency was 0.83 for Phase I (n=149, 39 crews), 0.75 for Phase II (n=41, 6 crews) and 0.81 (n=190, 45 crews) for the combined total. The values resulted in values above 0.70, which is in accordance with the recommended values of 0.70 (Nunnally, 1978). The CQWaste (10 total items) included questions that addressed the availability of materials and equipment. The CQLoss (12 total) addressed the perceived time lost in one week due to CQWaste.

The scores were calculated as the sum of the values for the grouped items, which indicated the waste and loss level for that individual worker. Crew scores were calculated by averaging the individual scores across the crew. The results of the Craftsman's Questionnaires scores for teams 1-48 are listed in Figure 23 and Figure 24. The scores for CQWaste ranged from 11-32 (Table 25, Appendix L) with a mean of 19.7 *(SD* = 4.64). The scores for CQLoss ranged from 12-38 (Table 25, Appendix L) with a mean of 23.8 *(SD* = 4.90).

An extreme point existed for crew 17 for CQLoss value of 45. Additionally, crews 12, 21, 26, 27, 31, and 41 had the same total CQWaste score for each participant in the crew. Crews 9, 12, 21, 24, 27, 35 and 41 had the same total CQLoss score for each participant in the crew. For the nine crews, four had two crew members, one had three crew members, two had four crew members and one had five and six crew members each.

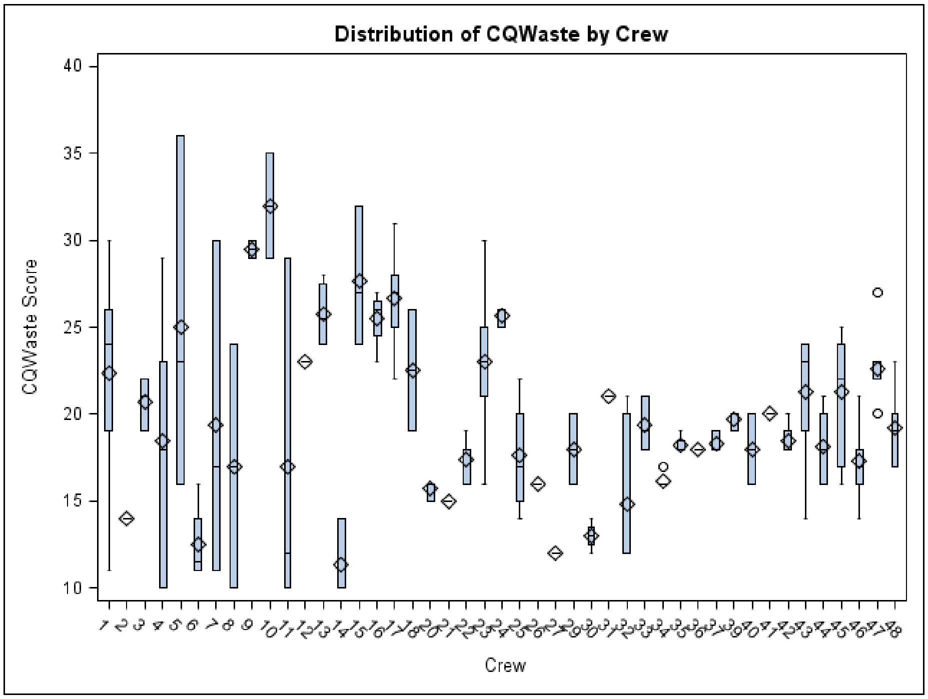


Figure 23 - Boxplot for Perception of Waste

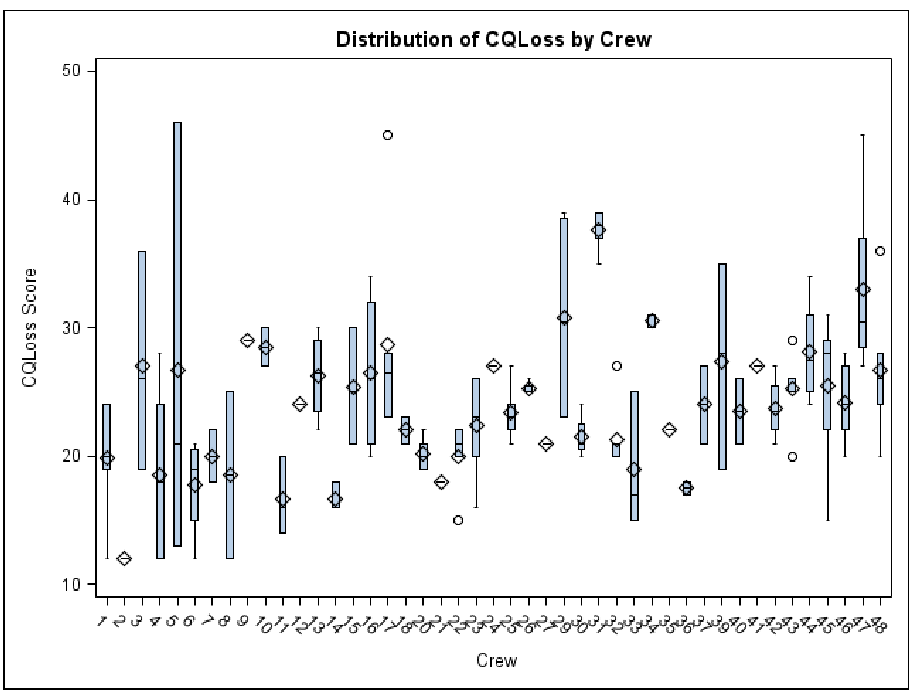


Figure 24 - Boxplot for Perception of Time Loss

4.2.7 Work Ownership

To obtain work ownership scores, each work ownership questionnaire was assigned a single score. The score was calculated as the sum of the values for all items (2 items) in the questionnaire, which indicated the ownership value for that individual worker. Crew work ownership scores were calculated by averaging the individual scores across the crew.

The work ownership scale's Cronbach's raw alpha for internal consistency was 0.96 for Phase I (n=149, 39 crews), 0.99 for Phase II (n=41, 6 crews) and 0.94 (n=190, 45 crews) for the combined total. The values resulted in values above 0.70, which is in accordance with the recommended values of 0.70 (Nunnally, 1978). The scores for work ownership ranged from 2-10 (Table 25, Appendix L) with a mean of 8.38 *(SD* = 2.06).The results of the work ownership scores for teams 1-48 are listed in Figure 25. Extreme points existed for: crew 1, extreme point of 10, crews 44, extreme point of 2, and 45 and 48, extreme points of 4. Interestingly, from the four teams with extreme points, three were framing crews. Additionally twenty one crews had the same total score for each participant in the crew.

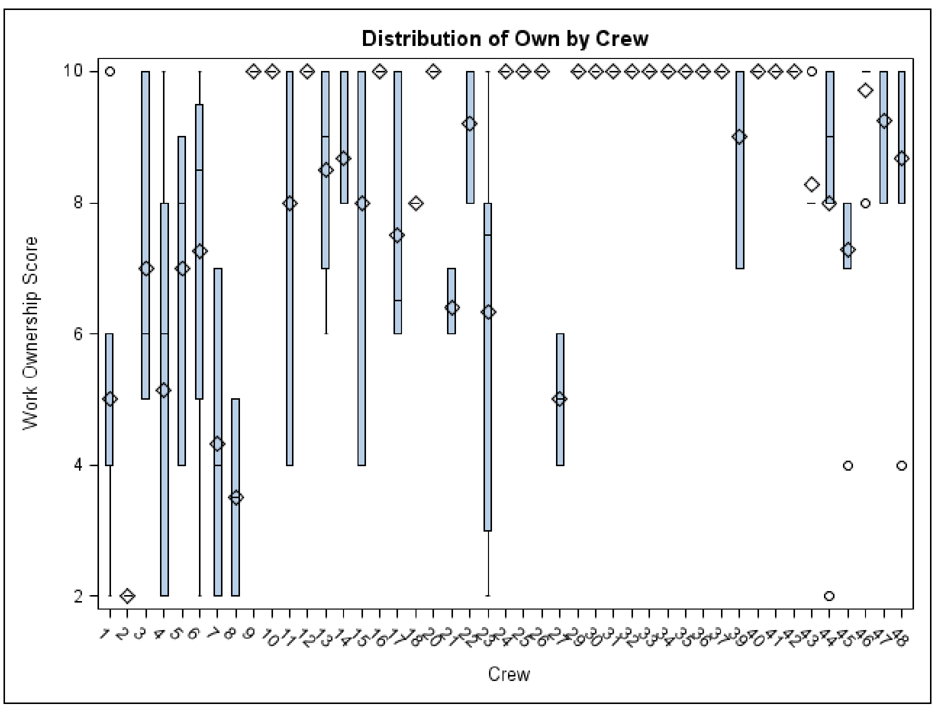


Figure 25 - Boxplot for Work Ownership

4.2.8 Correlation (Worker Level)

The assumption of multivariate normality is an underlying assumption for determining the type of correlation test to run. A first step for this procedure is the analysis of univariate normality for each variable. If non-normality is indicated for one or more of the variables, the multivariate normality assumption can be rejected. All univariate marginal distributions of a multivariate normal distribution are themselves univariate normal (Johnson, 1998, p. 16; Looney, 1995). All the variables violated the univariate normality assumption (Johnson, 1998), thereby violating the multivariate normality assumption.

Relationships among safety climate, risk behavior, waste presence, waste loss and work ownership were examined using nonparametric correlation analyses. Spearman's correlation was used to test the relationship between the variables (Table 11). Spearman's correlation is used when one or both of the variables are not assumed to be normally distributed. The values of the variables were converted in ranks and then correlated. Guidelines for designating the strength of a correlation coefficient include, $|r| \geq 0.70$, a correlation is considered to be strong; $0.30 \leq |r| < 0.70$, a correlation is considered to be moderate; and $|r| < 0.30$, a correlation is considered to be weak (Sheskin, 2004, p. 956). The aforementioned guidelines (Sheskin, 2004, p. 956) were used to interpret significant correlation results.

Table 11 - Spearman Correlation Coefficients, n=190

	Safety Climate	Risk Behavior	CQ Waste	CQ Loss	Work Ownership
Safety Climate	1.0				
Risk Behavior	0.40 *p* < 0.0001 *	1.0			
CQ Waste	-0.11 *p* = 0.1416	-0.23 *p* = 0.0012 *	1.0		
CQ Loss	-0.10 *p* = 0.1882	0.20 *p* = 0.0061*	0.54 *p* < 0.0001 *	1.0	
Work Ownership	0.02 *p* = 0.7798	-0.07 *p* = 0.3647	0.05 *p* = 0.4749	0.30 *p* < 0.0001 *	1.0

*Significant *(p<0.05)*

Spearman's correlation resulted in $r_s = 0.54$ ($p < 0.0001$), a significant moderate relationship between CQWaste and CQLoss. Spearman's correlation resulted in $r_s = 0.40$ ($p < 0.0001$), a significant moderate relationship between safety climate and risk behavior. A weak significant correlation was found between CQWaste and risk behavior, r_s= -0.23 (p = 0.0012), CQLoss and risk behavior, r_s = 0.20 (p = 0.0061) and work ownership and CQLoss, r_s = 0.30 (p < 0.0001).

4.2.9 Correlation (Crew Level)

Relationships among safety climate, risk behavior, waste presence, waste loss and work ownership were examined at the crew level using nonparametric correlation analyses. Spearman's correlation was used to test the relationship between the variables (Table 12). Spearman's correlation is used when one or both of the variables are not assumed to be normally distributed. Spearman's correlation was used; the multivariate normality assumption was rejected since all univariate marginal distributions of a multivariate normal distribution were not themselves univariate normal (Johnson, 1998, p. 16; Looney, 1995). The values of the variables were converted in ranks and then correlated.

Spearman's correlation resulted in r_s = 0.57 (p < 0.0001), a significant moderate relationship among CQWaste and CQLoss. Spearman's correlation resulted in r_s = 0.37 (p = 0.0123), a significant moderate relationship between safety climate and risk behavior. A significant moderate correlation was found between CQLoss and work ownership, r_s = 0.35 (p = 0.02).

Table 12 - Spearman Correlation Coefficients, Crew Level, n=45

	Safety Climate	Risk Behavior	CQ Waste	CQ Loss	Work Ownership
Safety Climate	1.0				
Risk Behavior	0.37 p = 0.0123 *	1.0			
CQ Waste	0.03 p = 0.8673	-0.21 p = 0.1700	1.0		
CQ Loss	0.08 p = 0.5843	-0.23 p = 0.1216	0.57 p < 0.0001 *	1.0	
Work Ownership	0.16 p = 0.2698	-0.23 p = 0.1200	0.03 p = 0.8637	0.35 p = 0.02 *	1.0

*Significant ($p<0.05$)

4.2.9.1 Discussion

It was hypothesized (H_1) that safety climate would have a negative relationship with risk behavior (Rundmo, 1996). Crews with high safety climate scores were expected to have low risk behavior scores (or infrequency in risk behaviors). The results supported the hypothesis. Spearman's correlation showed a significant moderate positive relationship between safety climate and risk behavior at the crew level and a significant moderate positive relationship between safety climate and risk scores at the worker level. The safety climate mean was 32.9 (*SD* = 2.67), with the maximum possible score of 40.50 on the safety climate questionnaire. The risk score mean was 13.8 (*SD* = 1.92). The maximum possible score for risk was 18. The risk scale measured frequency with a "3" indicating "never". Therefore, a score of 18 would indicate a worker who perceived their actions as risky to be very infrequent.

These results indicate that higher safety climates compliment a low frequency of perceived risk taking, at both the crew and worker level. This is important since risk behavior could also be evaluated at the individual level. The risk taking of one worker can be influenced by the degree to which workers are involved with the risk taking of their co-workers.

A frequency count was calculated for the questionnaires (Appendix M). Although the safety climate and risk behaviors were aggregated and analyzed at the crew level, certain questionnaire items were points of interest. A total of 146 (n=190) participants responded to "Agree" or "Strongly Agree" when asked if taking risks was part of their job (safety climate). A total of 92 (n=190) participants responded to "Agree" or "Strongly Agree" when responding to the likelihood of them being injured in the next twelve months (Figure 26).

Additionally, the risk behavior questionnaire addressed frequencies of risk taking (Figure 27). A total of 142 (n=190) participants responded to "Sometimes" and "Often" when asked if they took chances or risks to get a job done. A total of 117 (n=190) responded to "Sometimes" and "Often" when asked about bending the rules to achieve a production target. A total of 108 (n=190) participants responded to "Sometimes" and "Often" when responding to job stress stopping them from working to the rules.

In June 2008, CityCenter workers walked off the job demanding jobsite safety, prompting the owners to develop an action plan (Illia, 2008). The Center for Construction Research and Training (CPWR) conducted a worksite assessment of the CityCenter and Cosmopolitan construction projects to understand, among other objectives, safety climate (Gittleman et al., 2009). Among the results of the safety climate questionnaire item frequency count, it was found that 25% of 2,802 workers agreed that sometimes they ignored a safety rule or policy in order to carry out an assignment or meet the schedule and 16% of 2,796 workers disagreed that they would not suffer a lost time injury on the job site (Gittleman et al., 2009).

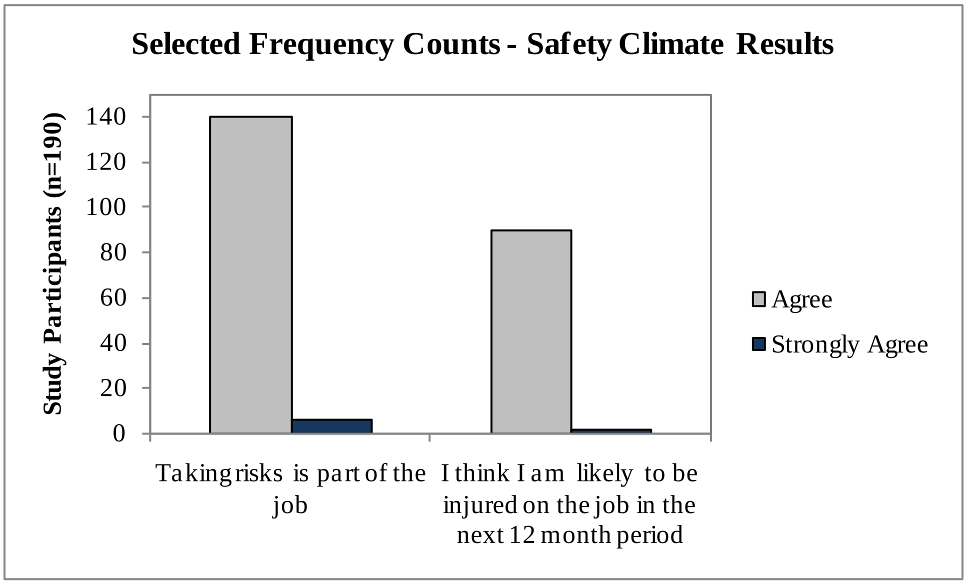


Figure 26 - Selected Frequency Counts for Safety Climate Results

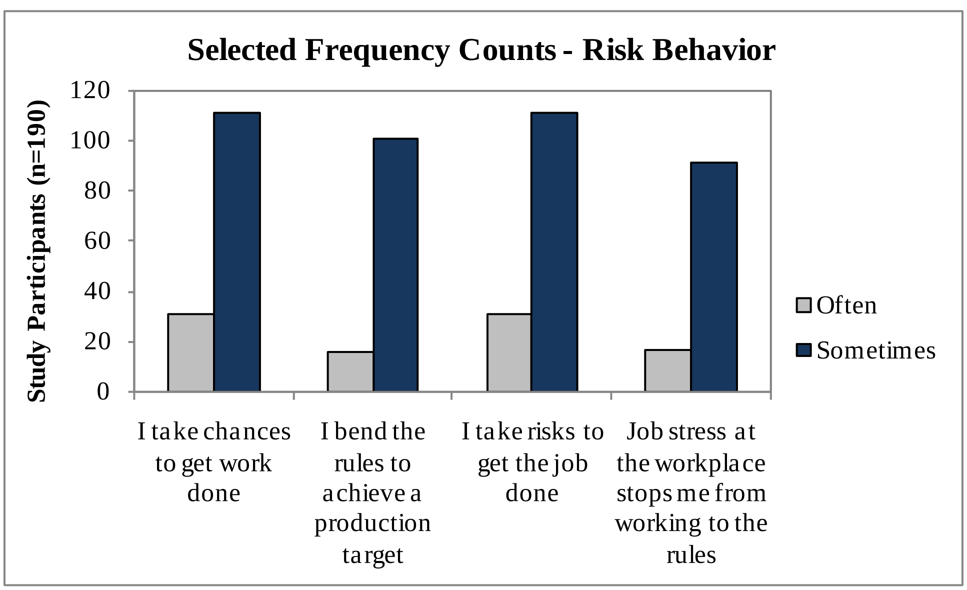


Figure 27 - Selected Frequency Counts for Risk Behavior Results

It was hypothesized (H_2) that work ownership would have a negative relationship with productivity loss. The results did not support the hypothesis. A moderate correlation was found between CQLoss and work ownership at the crew level and a weak correlation between work ownership and CQLoss at the worker level. The work ownership mean was 8.38 (*SD* = 2.06) and the productivity loss mean was 23.80 (*SD* = 4.90). The highest work ownership score possible was a 10, indicating a very high perception of work ownership. The highest possible productivity loss score was a 64.

It was hypothesized (H_3) that perception of productivity would have a negative relationship with perception of safety (Evans, Michael, Wiedenbeck, & Ray, 2005; Hofmann & Stetzer, 1996). The results did not support the hypotheses. Spearman's correlation did not result in significant relationships between safety climate and perceived productivity (waste or loss) at the worker or crew level.

Two relationships of interest for future exploration were observed only at the worker level. A weak negative correlation was found between CQWaste and risk behavior. A weak positive correlation was found between CQLoss and Risk Behavior. It is important to explore this relationship further since low risk frequency is represented by a high risk score in this research. Therefore, a negative correlation between risk behavior and waste shows high waste, low risk score (high risk behavior frequency) or low waste, high risk scores (low risk behavior frequency). No significant relationship was observed at the crew level.

An additional relationship of interest was the significant moderate correlation observed between CQWaste and CQLoss at the worker and crew level. This validated the complementary nature of the variables. CQWaste measured the presence of a particular type of waste and CQLoss measured the loss due to the waste. Although these statistical relationships are important to understand, they do not show cause and effect.

4.2.10 Risk Behavior Model

Multiple regression analysis was applied to evaluate whether safety climate, waste, loss and work ownership were predictors of risk behavior. Multiple regression analysis helps to learn more about the relationship between several predictor variables and a criterion variable. The analysis was performed at the crew level. Values were averaged for each crew. Forty-five crews were evaluated. All values were added to the model simultaneously.

There are several underlying assumptions for a multiple regression model. Normality tests were run to determine whether the residuals were normally distributed. A Shapiro-Wilk test was applied to test for a normal distribution (α= 0.05), resulting in normality, $W = 0.98$ (p = 0.77). Linearity assumptions were tested by plotting the residuals and the predicted values. The value in the plot is symmetrically distributed around the horizontal line, showing linearity (Appendix N, Figure 41).

The variables were evaluated with an $\alpha = 0.05$. The model was significant $F(4, 44)$ = 7.03, $p = 0.0002$. Two independent variables were significant, safety climate and work ownership. Waste was a variable of interest, with $p = 0.12$ *(Parameter estimate -0.09)*. Refer to Table 13 for parameter estimates.

Risk Behavior = 0.41 * *(Safety Climate)* - 0.33 * *(Work Ownership)*

Table 13 - Parameter Estimates for Risk Behavior Model

Variable	DF	Parameter Estimate	Standard Error	t-value	*p*
Intercept	1	-3.83	3.25	1.18	0.24
SC	1	0.41	0.09	4.56	< 0.0001
CQWaste	1	-0.09	0.06	-1.58	0.12
CQLoss	1	0.04	0.06	0.61	0.54
Work Ownership	1	-0.33	0.13	-2.42	0.02

The fitted model, resulted in an $R^2 = 0.41$, which shows that 41% of the variation of risk behavior is explained by the regressors (Allen, 1971). Multicollinearity was tested using variance inflation factor. Multicollinearity occurs when two or more predictor variables are highly correlated. Variance inflation factors statistics show how multicollinearity has increased the instability of the coefficient estimates (Freund, 2000). Dividing one by the variance inflation factor generates a tolerance value to indicate the severity of multicollinearity. The tolerance values included safety climate (0.92), waste (0.71), loss (0.54) and work ownership (0.70). Variance inflation factors included safety climate (1.1), waste (1.41), loss (1.86) and work ownership (1.43). Generally, variance inflation factors exceeding ten may be cause for concern (Freund, 2000). The results for the variance inflation for this study did not approach ten.

A PRESS statistic was run in SAS. The PRESS statistic provided a measure of the external predictive power of the model. In this approach, the *y* value for each subject was excluded and a prediction equation was derived on the remaining data. Therefore, *n* prediction equations were derived and *n* true prediction errors were found. The i^{th} observation was deleted, the regression model was fit to the remaining *n-1* observations, the predictive value of y_i corresponding to the deleted observation generated a corresponding prediction error (Montgomery, 2006):

$$e_{(i)} = y_{(i)} - \hat{y}_{(i)}; \hat{y}_{(i)}\ predicted\ value\ of\ ith\ observed\ response\ based\ on\ model\ fit\ n-1$$

A PRESS statement was used in SAS to generate the PRESS residuals (Appendix N), or the prediction error sum of squares (Allen, 1971). The statistic was used to compute an R^2 like statistic to give an indication of the predictive capability of the regression model (Montgomery, 2006):

$$R^2_{Prediction} = 1 - \frac{PRESS}{SS_T} = 1 - \frac{123}{163} = 0.25$$

It is expected that this model will explain about 25% of the variance in predicting new observations, as compared to 41% of the variability in the original data explained by the least-squares fit. The PRESS residual indicated that observations similar to Crew 24 may not be predicted well (the largest value).

4.2.10.1 Discussion

It was hypothesized (H_4) that crews with high safety climate and productivity scores would have high risk scores (or low risk frequency scores). A model was observed for predicting risk scores that partially supported the hypothesis. Two independent variables were significant, safety climate and work ownership. Productivity scores were not significant in the model. The model from this research suggests that safety climate and work ownership are predictors of risk behavior, or perceived frequency of risk behaviors. The safety climate parameter of 0.41 indicates the expected change in risk behavior per unit change of safety climate when the work ownership variable is held constant. Similarly, the work ownership parameter of -0.33 measures the expected change in risk behavior per unit change in work ownership when safety climate is held constant. The parameter for work ownership resulted in a negative value; it was expected to be positive.

Both safety climate and work ownership were measured by a scale of 5, where 5 indicated the most agreement for safety climate and the most frequency for work ownership. It is expected the model will explain about 25% of the variance in predicting new observations, as compared to 41% of the variability in the original data explained by the least-squares fit.

A multi-climate framework proposed by Zohar (2008) suggests the co-existence of various climates associated with key facets of the organizational environment. Given the co-existing climates in organizations, it is important to understand whether specific climates interact to allow for better prediction of relevant outcome criteria, i.e. employee safety. Such interaction can help distinguish between compliance and commitment based systems. One such interaction is between work-ownership and safety climate. In this study, both safety climate and work ownership contributed to predicting risk behavior.

The negative value of ownership provides an interesting result since it suggests that higher ownership values may contribute to lower risk behavior values, or higher frequency of perceived risk taking behavior. This provides a different conclusion than that generated by safety citizenship research. Safety citizenship research suggests that safety citizenship should develop with high work ownership climate and high safety climate (Zohar, 2008). Employees are expected to consider the safety of operations as an ownership target, directing discretionary action towards this target (Zohar, 2008). Zohar (2008) suggests that safety compliance will develop in organizations with low work-ownership and high safety climate since workers are only expected to follow rules and procedures in getting the work done.

Results for this model propose high safety climate and high work ownership will have lower risk behavior scores (higher risk behavior frequency) than high safety climate and low work ownership. Safety citizenship research has shown drivers to include safety communication, early hazard identification, and responsibility to include other's safety (Griffin & Neal, 2000; Hofmann et al., 2003; Neal & Griffin, 2006; Zacharatos et al., 2005; Zohar, 2008). The frequency count for the risk behavior question, "I ignore when safety rules are broken" showed that 41% of the participants (n=190) responded, "Often and Sometimes". These results may have contributed to the results of the model (Figure 28).

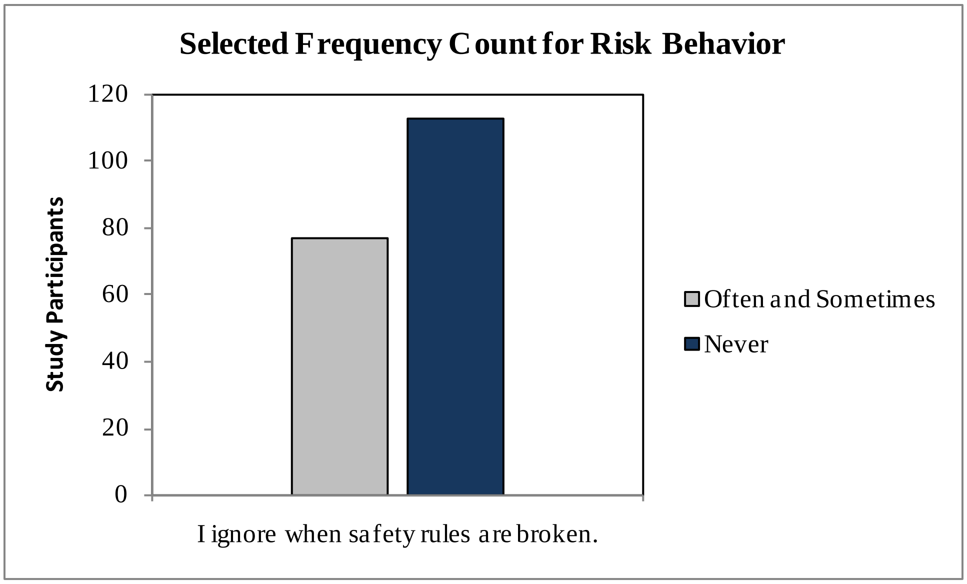


Figure 28 - Frequency Count for Risk Behavior Question (Ignoring When Rules are Broken)

4.2.11 Differences Among Crews

A Wilcoxon signed-rank test was used to test the difference between crews in perception of safety climate, risk behavior, presence of waste, loss due to waste, and work ownership. A PROC NPAR1WAY code was used in SAS. The Wilcoxon option in PROC NPAR1WAY displays a one-way ANOVA statistic, which is known as the Kruskal-Wallis test.

The Kruskal-Wallis test is a non-parametric statistical hypothesis test. The Kruskal-Wallis test was used for comparisons of differences between measurements. The Kruskal-Wallis test was run to test the differences between crews (45 crews). Safety climate, $\chi^2 = 95.73$, $p < 0.0001$, risk behavior, $\chi^2 = 90.85$, $p < 0.0001$, waste $\chi^2 = 122.4$, $p < 0.0001$, loss $\chi^2 =122$, $p < 0.0001$ and work ownership $\chi^2 = 122.8$, $p < 0.0001$. All tests were significant.

The critical path of construction for a single family home was used to reduce the analysis crews for evaluation. A critical path of a project is the sequence of critical activities (and critical events) that connect the project's start event to its finish event and which cannot be delayed without delaying the project (Meredith & Mantel Jr., 2009). This is the longest duration path through the work plan. The critical path was selected as a grouping mechanism due to its effect on the schedule and its validated use within the construction domain. If the critical path is delayed, the project completion time will slip.

The homebuilding critical path for a single family home was provided by a safety officer of the homebuilding corporation where the study was conducted. Due to the sample distribution, not all critical path stages were populated. The evaluation was conducted at the critical path level since productivity and safety are a factor in the schedule of the building of a home (Table 27, Appendix L). Crafts were aggregated at the critical path activities to understand differences in perception among groups who populate the schedule during shared times (Table 14).

The Kruskal-Wallis test was performed to test the differences between crews grouped by activities in the critical path plan (6 crews). Safety climate, $\chi^2 = 9.30$, $p = 0.0973$, risk behavior, $\chi^2 = 14.73$, $p = 0.0116$, waste $\chi^2 = 3.88$, $p = 0.5670$, loss $\chi^2 = 34.23$, $p < 0.0001$ and work ownership $\chi^2 = 20.54$, $p = 0.001$. A significant difference existed for risk behavior, loss and work ownership.

The Kruskal-Wallis test was performed to test the differences between crews for risk behavior, loss and ownership (Table 15). A Bonferroni adjustment was done on $\alpha = 0.05$ significance level. The Bonferroni adjustment resulted in $\alpha = \frac{0.05}{15} = 0.003$. The Bonferroni adjustment helps protect against multiple test of statistical significance giving the appearance of significance, or Type I error.

Table 14 - Construction Critical Path for a Single Family Home

Wk	Activity (Group)	Grouped (From Sample)	n
< 1	Stake-out		
1	Excavation		
1	Footing		
2&3	Foundation (100)	Foundation/Concrete, Piping, Gutters	22
4&5	Framing (200)	Framing, Carpentry, Roofing, Brick Masonry, Siding	80
6&7	Mechanical Systems (300)	Plumbing, Heating and A/C, Electrical	22
7	Insulation		
7&8	Drywall (400)	Insulation, Plaster, Drywall/Insulation	21
9	Ceramic/Resilient		
9	Trim		
10	Paint (500)	Painting and Wall Covering	25
11	Final Trades (600)	Cabinets, Tiling, Landscaping, Laborers, and Cleaning	21
12	Carpet/Wood		
13	Pre-Settlement Demo		

Table 15 - Differences between Crews (at the Critical Path Level) at α=0.003

		Risk Behavior	Loss Perception	Work Ownership
Description (Group #)	DF	X^2, *p*	X^2, *p*	X^2, *p*
Foundation (100) Framing (200)	1	0.6276, *p* = 0.4282	7.8200, *p* = 0.0052	0.8590, *p* = 0.3540
Foundation (100) Mechanical (300)	1	2.6762, *p* = 0.1019	4.1300, *p* = 0.0420	1.3109, *p* = 0.2522
Foundation (100) Drywall (400)	1	0.8533, *p* = 0.3556	0.3430, *p* = 0.5581	4.1801, *p* = 0.0409
Foundation (100) Paint (500)	1	4.1801, *p* = 0.0409	1.0324, *p* = 0.3096	2.0249, *p* = 0.1547
Foundation (100) Final Trades (600)	1	1.4528, *p* = 0.2281	0.0037, *p* = 0.9513	0.4558, *p* = 0.4996
Framing (200) Mechanical (300)	1	9.1939, *p* = 0.0024 *	20.6050, *p* < 0.0001 *	6.6215, *p* = 0.0101
Framing (200) Drywall (400)	1	0.1421, *p* = 0.7062	3.7574, *p* < 0.0526	3.1074, *p* = 0.0779
Framing (200) Paint (500)	1	4.6399, *p* = 0.0312	15.9263, *p* < 0.0001 *	9.8777, *p* = 0.0017 *
Framing (200) Final Trades (600)	1	1.2363, *p* = 0.2662	5.2356, *p* = 0.02	4.7908, *p* = 0.0286
Mechanical (300) Drywall (400)	1	5.8843, *p* = 0.0153	8.2117, *p* = 0.0042	7.7164, *p* = 0.0055
Mechanical (300) Paint (500)	1	0.0005, *p* = 0.9828	1.2905, *p* = 0.2559	0.0611, *p* = 0.8048
Mechanical (300) Final Trades (600)	1	5.7749, *p* = 0.0163	3.0939, *p* = 0.0786	1.8204, *p* = 0.1773
Drywall (400) Paint (500)	1	3.4850, *p* = 0.0619	2.9924, *p* = 0.08	10.7291, *p* = 0.0011 *
Drywall (400) Final Trades (600)	1	0.1168, *p* = 0.7325	0.1344, *p* = 0.7139	7.0761, *p* = 0.0078
Paint (500) Final Trades (600)	1	4.5890, *p* = 0.0322	1.3055, *p* = 0.2532	0.9943, *p* = 0.3187

**Significant*

A significant difference was observed for risk behavior between group 200 (Framing) and 300 (Mechanical Systems) at α = 0.003. A significant difference was observed for loss perception between: group 200 (Framing) and 300 (Mechanical Systems), group 200 (Framing) and 500 (Painting, Wall Covering) at α = 0.003. Additionally, a significant difference was observed for ownership between group 200 (Framing) and 500 (Painting, Wall Covering) and between group 400 (Insulation, Plaster, Drywall) and 500 (Painting, Wall Covering) at α=0.003 (Figure 29).

4.2.11.1 Discussion

It was hypothesized that there would be a significant difference among crews in perception of safety climate (H_5), perception of risk behavior (H_6), perception of loss due to waste (H_7), and perception of presence of waste (H_8). The differences among crews were evaluated at two levels, individual crews and critical path groups.

The Kruskal-Wallis test was run to test the differences between crews. All tests were significant for differences among crews, supporting hypotheses H_5, H_6, H_7, and H_8. The Kruskal-Wallis test was run to test the differences between crews grouped by activities in the critical path (6 crews). A significant difference existed for risk behavior, loss and ownership, supporting hypotheses H_6 and H_7.

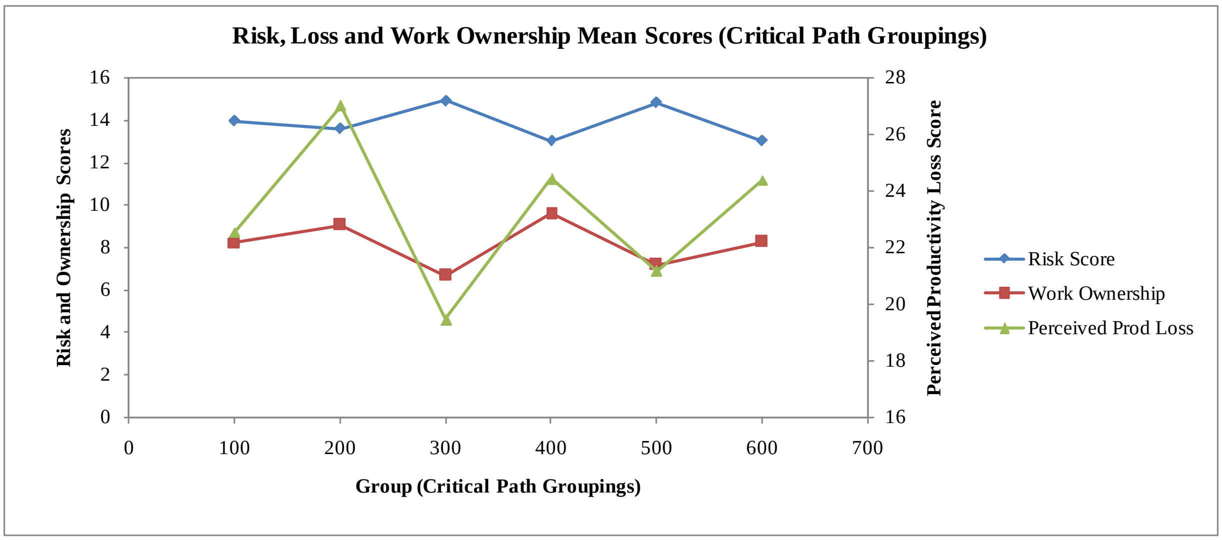


Figure 29 - Mean Scores for Risk, Loss and Work Ownership (Critical Path Groupings)

A significant difference was observed for risk behavior between group 200 (Framing) and 300 (Mechanical Systems). Participants in group 200 (Framing) had a mean risk score of 13.60 (*SD* = 2.10) which was less than participants in group 300 (Mechanical Systems) with a mean of 14.90 (*SD* = 2.11).

A significant difference was observed for loss perception between: group 200 (Framing) and 300 (Mechanical Systems), group 200 (Framing) and 500 (Painting, Wall Covering). Participants in group 200 (Framing) had a mean loss perception of 27.00 (*SD* = 6.13) which is greater than participants in group 300 (Mechanical Systems) with a mean of 19.50 (*SD* = 5.50). Participants in group 200 (Framing) had a mean loss perception of 27.00 (*SD* = 6.13) which is greater than participants in group 500 (Painting, Wall Covering) with a mean of 21.20 (*SD* = 4.74).

Additionally, a significant difference was observed for work ownership between group 200 (Framing) and 500 (Painting, Wall Covering) and between group 400 (Insulation, Plaster, Drywall) and 500 (Painting, Wall Covering). Participants in group 200 (Framing) had a mean work ownership perception of 9.05 (*SD* = 1.62), which is greater than group 500 (Painting, Wall Covering) with a mean of 7.2 (*SD* = 3.0). Participants in group 400 (Insulation, Plaster, Drywall) had a mean work ownership perception of 9.6 (*SD* = 1.36) which is greater than participants in group 500 (Painting, Wall Covering) with a mean of 7.2 (*SD* = 3.0).

Overall, the framing group had a higher perception of loss due to waste and a lower risk score (higher frequency of risk behavior) when compared to the mechanical systems group. The framing group had a higher perception of loss due to waste and a higher ownership value when compared to painting and wall covering group. Finally, insulation/plaster/drywall group had a higher work ownership value when compared to painting/wall covering group.

4.2.12 Open-ended Questions

A total of five open ended questions were included in the questionnaires. The open ended questions addressed age, safety equipment that was short in supply, causes of rework, type of safety training completed and type of work accident (if in occurrence). One response, “Proper ladders” was recorded for the safety equipment that was short in supply. Nine responses were received for the causes of rework (Table 16). Among the responses were lack of information, careless work and mistakes.

Participants (n=190) responded that 59% (112 participants) had received safety training. A total of 10% (19 participants) indicated they had an accident at work, with 13 of the 19 being participants who responded they had received safety training. A total of 10 participants included the type of accident they had experienced (Table 17).

Table 16 - Summary of Open Ended Responses for Causes of Rework

Causes for Rework	Count
Someone breaks it and it has to be fixed for free	1
Careless work	1
Measurement errors or doing the work without blueprints	1
Lack of info	3
Weather	1
Weekend schedule	1
Mistakes	1
Total	9

Table 17 - Summary of Open Ended Responses for Types of Accidents

Type of Accident	Count
Bad Back	1
Broke foot	1
Cut finger with a chain	1
Cut foot with debris	1
Eye cut, nail through hand	1
Fall from roof	1
Fall from ladder	1
Lifting motor	1
Piece of drywall in eye	1
Traffic	1
Total	10

A Wilcoxon signed-rank test was used to explore the difference between participants who indicated they had received safety training and those who had not. The Kruskal-Wallis test was run to test the differences between groups who responded "yes" (n=112) and "no" (n=78) to safety training, for safety climate and risk behavior. A significant difference existed for safety climate, $\chi^2 = 12.47$, $p < 0.0004$, and risk behavior $\chi^2 = 4.72$, $p = 0.0297$. Participants who responded "yes" to having received safety training had a higher safety climate mean 33.55 (*SD* = 2.78) compared to those who indicated they had not received safety training, 31.45 (*SD* = 4.29). Additionally, participants who responded "yes" to having received safety training also had a higher risk behavior mean, 14.25 (*SD* = 2.16) compared to those who had not received safety training, 13.2 (*SD* = 2.8).

Participants (n=92) responded to the type of safety training received by completing an open ended question. All response counts were documented and response categories were created by the researcher based on themes seen in the responses. Nine response categories were created to group the 34 different types of training types received (Table 18).

Table 18 - Safety Training Categories Based on Open Ended Responses for Training

Category	Type of Training	Total
Guidelines and Procedures	Work guidelines, procedures, practices, instructions, explanations	32
Verbal Instruction	Classes, seminars, lectures	22
Documentation	Documents, manuals, binders, books, pamphlets	10
OTJ Training	Training, instructions, procedures on the job	9
Mix of verbal and handout	Classes, information, instructions, videos, talks	5
Videos	Videos	5
Safety	Safety, safety groups	4
Training	Training, inspections	3
Meetings	Meetings	2
	Total	92

4.2.12.1 Discussion

The categories with the highest count included "Guidelines and Procedures" and "Verbal Instructions" with 32 and 22 occurrences, respectively. Guidelines and procedures included work guidelines, procedures, practices, instruction and explanations. Verbal instructions included classes, seminars and lectures.

These results are consistent with the training approaches in the construction industry today. Construction companies often use safety training, toolbox talks, inspections, incentives and citation programs to prevent accidents (Mitropoulos et al., 2003). Most construction knowledge, however, is learned on the job or as part of special courses, licensing or certification requirement and apprenticeships (CPWR, 2008). Training towards these levels may not specifically include or focus on safety. This may be supported by the 59% response rate (112 participants out of 190) that indicated they had received safety training and the 48% (92 participants out of 190) who indicated the type of safety training. This results in a total of 41% (78 out of 190) participants who indicated they did not have safety training.

Participants who responded "yes" to having received safety training had a higher safety climate mean when compared to those who indicated they had not received safety training.

Additionally, participants who responded "yes" to having received safety training also had a higher risk behavior mean compared to those who had not received safety training.

4.2.13 Factor Analysis

A factor analysis was completed to evaluate the dimensions of the combined questionnaires. Factor analysis is a statistical technique used to derive, create or develop a new set of uncorrelated variables, called underlying factors that will provide a better understanding of the data being analyzed (Johnson, 1998). In safety climate research, the "factors" are used to represent relationships among the sets of inter-related perceptual questions about safety (Cooper & Phillips, 2004).

The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was 68%, indicating that the data was appropriate for this analysis (Kaiser, 1974). The Kaiser-Meyer-Olkin measure of sampling adequacy tests whether the partial correlations among variables are small. It tests whether the correlation matrix is an identity matrix, which would indicate that a factor model is inappropriate. The sampling adequacy should be greater than 0.5 for a satisfactory factor analysis to proceed (Kaiser, 1974).

The "Kaiser criterion" was used to determine the appropriate number of dimensions necessary to describe the data structure. According to this criterion, factors are retained if they posses eigenvalues greater than or equal to 1 (Kaiser, 1960). This maintains that a factor must explain at least as much variance as any single variable contributing to the analysis. The eigenvalue for a given factor measures the variance in all the variables accounted for by that factor. Eleven factors were retained and explained a cumulative variance of 71.6% (Table 19). Although there are no clear criteria for cumulative variance evaluation, a guide for the behavioral sciences includes 60% (Child, 2006, p. 63).

4.2.13.1 Discussion

Factor 1, Safety Climate, included seven of the nine questionnaire items under the safety climate dimension. This included management's commitment to safety in terms of management's safety attitudes and practices and workers' perception of control over their safety on the job. Management commitment was indicated by workers' perceptions of management's attitude toward safety practices, management's attitude toward workers' safety, actions taken by supervisors to enforce safety, and management safety activities including safety instructions and availability of proper equipment; worker involvement was indicated by workers' perceptions of the presence of regular safety meetings, and control. Factor 2, Equipment Tools, included items from the Craftsman's Questionnaire, which addressed the availability and time spent waiting for safety equipment, tools and production equipment. Factor 3, Work Ownership, included four items. The first two items addressed the degree of ownership for the worker's job and tasks. The second two items addressed task priorities and completion dates.

Factor 4, Risk Behaviors, included five of the six items included in the risk behavior dimension. Items included taking risks to get a job done, bending the rules to achieve a production target and the effect of job stress and management pressure on safety rules. Factor 5, Material Handling, included the availability of equipment for moving materials. Factor 6, Rework, included items from the Craftsman's Questionnaire, which addressed the occurrence and time spent doing work that had previously been completed before. Factor 7, Materials, included items from the Craftsman's Questionnaire, which addressed the availability and time spent waiting for materials. Factor 8, Risk Acceptance, included the additional two items from the Safety Climate questionnaire, which addressed the workers' perception of risk taking and control.

Factor 9, Information, included items from the Craftsman's Questionnaire, which addressed the availability and time spent waiting for information to complete their job. Factor 10, Translation, included items from the Craftsman's Questionnaire, which addressed the availability and time spent waiting for language translation. Factor 11, Material delivery, included items from the Craftsman's Questionnaire, which addressed the availability and time spent moving materials to different location than where they were delivered.

Table 19 - Factor Analysis Results

	Scale	Factor	Loading	Factor Name
My foreman emphasizes safety practices on the job.	SC	F1	88	
Supervisors and other top managers seem to care about my safety.	SC	F1	82	
I think worker's safety practices are important to my managers.	SC	F1	81	
I was given instructions on the safety policy and safety requirements of the company when I was hired by my direct employer.	SC	F1	77	
There are regular job safety meetings at my present job site.	SC	F1	48	
There is proper equipment for our tasks available at this job site.	SC	F1	61	
I feel I have control over what happens to my safety on the job.	SC	F1	65	Safety Climate
How many hours per week would you estimate you spend waiting for safety equipment, getting safety equipment, or moving to a different area because the safety equipment is not available?	CQ	F2	87	
How many hours per week would you estimate you spend waiting for suitable tools, getting tools, or moving to a different area because the appropriate tools are not available?	CQ	F2	83	
I have to stop work and wait or move to another task because I don't have the safety equipment needed to complete the job.	CQ	F2	71	
I have to stop work and wait or move to another task because I don't have the tools needed to complete the job.	CQ	F2	71	
How many hours per week would you estimate you spend waiting for production equipment, getting production equipment, or moving to a different area because the production equipment is not available?	CQ	F2	66	
I have to stop work and wait or move to another task because I don't have the production equipment needed to complete the job.	CQ	F2	53	Equipment/ Tools
I feel a high degree of personal ownership for meeting daily task goals.	Own	F3	87	
I feel a high degree of personal ownership for this job.	Own	F3	85	
I receive clear daily task priorities.	CQ	F3	81	
I receive clear job completion dates.	CQ	F3	73	Work Ownership
I bend the rules to achieve a production target.	SB	F4	69	
I take risks to get the job done.	SB	F4	67	
I take chances to get work done.	SB	F4	66	
Job stress at the workplace stops me from working to the rules.	SB	F4	61	Risk Behavior

I break rules due to management pressure.	SB	F4	51	
I have to stop work and wait or move to another task because I don’t have the equipment to move materials.	CQ	F5	75	
How many hours per week would you estimate spend looking for the appropriate equipment to move materials.	CQ	F5	68	Material Handling
I spend time doing completed work over again (rework).	CQ	F6	83	
How many hours per week would you estimate you spend doing completed work again (rework)?	CQ	F6	78	
If I can't find the appropriate equipment, I will move the materials manually	CQ	F6	53	Rework
I have to stop work and wait or move to another task because I don’t have the materials needed to do the job	CQ	F7	55	
How many hours per week would you estimate you spend waiting for materials, getting materials from somewhere else or moving to a different area because materials are not available?	CQ	F7	55	Materials
Taking risks is part of the job.	SC	F8	79	Risk Acceptance
I think I am likely to be injured on the job in the next 12 month period.	SC	F8	68	
I often spend time waiting for someone to give me the information that I need to do my job.	CQ	F9	79	
How many hours per week would you estimate you lose because you are waiting to get information you need to do your job?	CQ	F9	61	Information
How many hours per week would you estimate you lose because you are waiting for translations (language) that you need to do your job?	CQ	F 10	80	
I often spend time waiting for someone to translate (language) the information that I need to do my job.	CQ	F 10	60	Translation
Materials often have to be moved to a different location than where they were delivered.	CQ	F 11	86	
How many hours per week would you estimate you spend moving materials to a different location than where they were delivered.	CQ	F 11	75	Material Delivery

4.3 Video Analysis

4.3.1 Demographics

Videos for six crews (n=41) were coded (Phase II). A total of 4,859 productivity, 4,807 safety and 4,836 waste observations were recorded by two coders for six framing crews (Table 20). Refer to Appendix M for the summary ratings of random times.

Table 20 - Number of Video Observations

	Number of Productivity Observations		Number of Safety Observations		Number of Waste Observations	
Crew (Date)	Coder A	Coder B	Coder A	Coder B	Coder A	Coder B
43 (March 25)	410	402	402	405	400	401
44 (April 9)	404	402	405	399	403	406
45 (May 5)	403	401	388	401	405	407
46 (July 13)	400	400	403	399	403	402
47 (July 21)	396	404	404	400	404	401
48 (August 20)	431	406	401	400	400	404

In Phase II, 100% (41) of the participants responded to their ethnicity as Latino. Participants were given the option to complete the questionnaires in English or Spanish and 100% (n=41) of participants opted for the Spanish form during Phase II. These results highlight the changing demographics of the construction workforce. When considering Latino employees as a percentage of each industry, 39% were laborers and 24% were carpenters (CPWR, 2008). Additionally, in 2005, 34% of the Latino construction workers resided in the District of Columbia (CPWR, 2008).

The mean age for the workers in Phase II (n = 41) was 28 (*SD* = 7.90*)*, with a minimum age of 19 and a maximum age of 52. Three questions addressing participant's fluency with speaking, reading and writing English were included. Participants (n = 41) indicated 20% speak English, 15% read English and 15% write English (Figure 30).

Participants (n = 41) indicated 37% had received safety training and 15% had an accident at work. Participants indicated that 12% has less than 12 months experience with the current employer, 61% had 1-5 years experience with the current employer, 24% has 5-10 years experience with the current employer and 2% had more than 10 years experience with the current employer. When responding to the amount of time working in the construction industry, 7% indicated less than 12 months, 56% had 1-5 years, 34% had 5-10 years and 2% had more than 10 years experience in the construction industry.

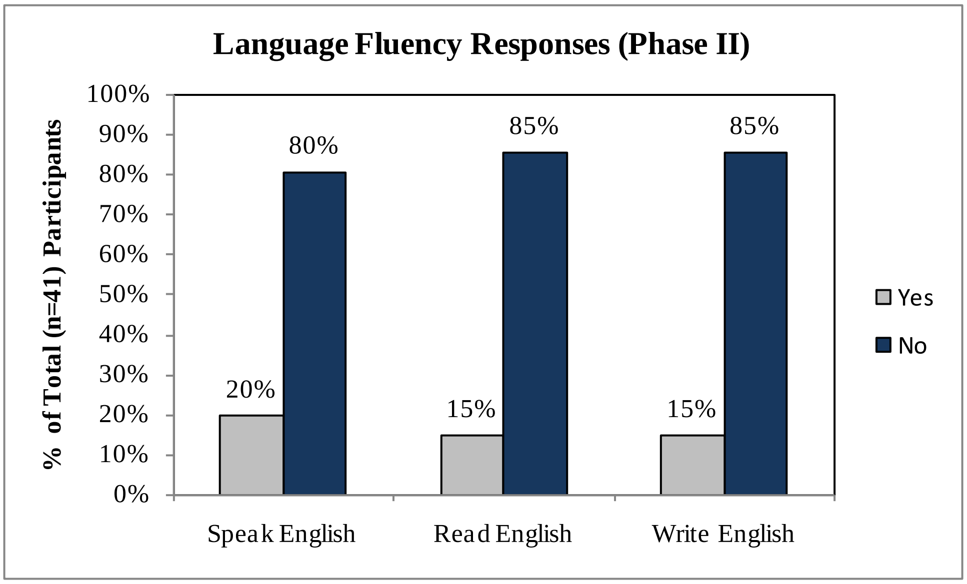


Figure 30 - Response to Language Frequency (Phase II)

4.3.2 Proportion of Agreement

Reliability analyses evaluate the extent to which coding is consistent across coders. In an event, consistency indicates the extent to which repeated measurements of the same event produce the same results. The video analysis was evaluated for consistency of responses between coders for the predefined behaviors and at the behavior groups. The consistency was tested using the reliability analysis function in the Noldus Observer® XT 8.0 software.

A frequency based approach was used for tallying instances of behaviors and classifications. For each behavioral category, the number of instances were counted (Jansen, Wiertz, Meyer, & Noldus, 2003). Each video (5-6 per date) was analyzed in pairs (Coder A-Coder B) of observations. Observations consisted of events in a time series, defined by the generated random times. Classifications were the behavior groups. For productivity, the classifications were “Working”, “Not Working”. For safety the classifications were “Safe” and

“Not Safe”. For waste the classifications were “Waiting”, “Idle Time”, Traveling Time”, Transportation” and “No Waste”.

The program considered each event on both data files (of comparison) and searched for a matching event in the other file within a defined tolerance window of six seconds. The six seconds was the coding duration of each observation. If the same event was found within the tolerance window of six seconds (time from the starting points of observation 1 to observation 2), it was scored as an agreement; otherwise it was scored as a disagreement.

Synchronization was used to establish how the observations were aligned. The videos were aligned by the start times, the point in the video from which the observations were started. This option was selected since the coders may have started the observations from a video file at a different starting point (i.e.0:00:00 video 1, 0:01:01 video 2). Synchronization was based on researcher field observation logs and validation (by the researcher) through video observations.

To account for an observation where no comparison events were available (only one coder analyzed that time event), only time based intersections were selected. This option allowed for only the events the time period shared by both observations to be considered an agreement. A time slot where one coder evaluated that time and the other did not was considered a disagreement.

The Noldus Observer® XT 8.0’s algorithm for reliability found agreements by linking behavioral records that overlap in time and then linked identical records within the tolerance window of six seconds. The algorithm identified disagreements by finding any unlinked records to the nearest unlinked record within the tolerance window of the other dataset (Jansen et al., 2003).

The events were analyzed in two ways, at the crew level with a proportion of agreement and at the classification level with a Cohen’s Kappa. The crew level was selected to understand the frequency of behaviors by crew. The classification level was selected to provide a comparison reliability point for the field ratings generated. For the proportion of agreement, the workers were categorized as a crew so the agreements/disagreements were based on total specific behaviors for each crew, and not individual worker number. The proportion of agreements was calculated based on:

$$Proportion\ of\ Agreement = \frac{Total\ Number\ of\ Agreement}{Total\ Number\ of\ Agreement + Total\ Number\ of\ Disagreement}$$

The proportion of agreement (Table 21) was calculated for productivity, safety and waste video observations. The average for the productivity proportion of agreement was 23% (*SD*=4%) with a range of 18-27. The average for the safety proportion of agreement was 45% (*SD*=5%) with a range of 36-49. The average for the waste proportion of agreement was 37% (*SD*=7%) with a range of 29-40.

Table 21 - Proportion of Agreement for Video Coders

Crew Number (Date)	Productivity Proportion of Agreement (%)	Safety Proportion of Agreement (%)	Waste Proportion of Agreement (%)
43 (3/25)	24	48	30
44 (4/9)	26	49	47
45 (5/5)	20	43	29
46 (7/13)	27	36	40
47 (7/21)	23	48	37
48 (8/20)	18	46	39

Additionally, the reliability between coders was tested at the classification levels, using Cohen's Kappa (Table 22). Cohen's Kappa is a statistical method used to measure inter-rater agreement. It measures the agreement for two raters and takes into consideration the amount of agreement that could be expected to occur by chance (Cohen, 1960). A result of 1 shows perfect agreement, -1 shows perfect and consistent disagreement and 0 shows a random level of agreement/disagreement. Benchmarks provided by Landis & Koch (1977), suggest values from 0.21-0.40 indicate "Fair" agreement, values from 0.41-0.60 indicate "Moderate" agreement values from 0.61-0.80 indicate "Substantial" agreement and values >0.81 indicate "Almost Perfect" agreement. Using the aforementioned guidelines, reliability for productivity coding indicated results of "Fair" for crews 45, 46, 47 and 48 and results of "Moderate" for crews 42 and 43. Results for safety coding indicated values of "Moderate" for all crews. Results for waste coding indicated values of "Fair" for all crews.

Table 22 - Results for Cohen's Kappa

Crew Number (Date)	Productivity (%)	Safety (%)	Waste (%)
43 (3/25)	42	50	35
44 (4/9)	43	57	40
45 (5/5)	30	52	30
46 (7/13)	38	42	34
47 (7/21)	32	47	30
48 (8/20)	21	59	35

4.3.3 Discussion

A standardized training procedure and evaluation process was used to train the coders to achieve acceptable levels of inter-rater reliability. The reliability for productivity coding indicated results of "Fair" for four crews and results of "Moderate" for two crews. Results for safety coding indicated values of "Moderate" for all crews. Results for waste coding indicated values of "Fair" for all crews.

A limitation of the coding process included the number of videos each coder completed to generate 400 observations. Proportion of agreement and reliability was analyzed by pairing videos from each coder. Only the common videos were included in the calculations when the total number of videos differed by coder. Common videos were determined by the number of observations per video required by the coders to reach 400 observations. For productivity, Coder A coded one more video for crew 43 and 48 than Coder B. For safety, Coder A coded one more video for crew 47 than Coder B. For waste, Coder A coded one more video for crew 46 and 47 than Coder B and one less video for crew 43.

4.3.4 Ratings

The coding ratings were evaluated at two classifications of productivity, safety and waste. The two classifications for productivity were working, not working; for safety, safe, not safe and for waste, presence of waste, no waste (Table 23). Each behavior was labeled according to these classifications. The result of the count was the total number of workers observed and the total number classified as working, safe and no waste. The behaviors were summed over the total number of observations to generate a total percent (Appendix O).

The two levels for classification were in accordance with the aforementioned sampling approach. Sampling, as used for productivity and safety improvement applications, involves observing and classifying a percentage of some whole to obtain a representation via a statistically valid sample (Oglesby et al., 1989).

$$\% \, Behavior = \frac{Total \; Behavior \; Category}{Total \; Category1 + Total \; Category2} x100\%$$

Table 23 - Field Rating Results for Productivity, Safety and Waste

	Coder 1		Coder 2		Diff	Coder1		Coder2		Diff	Coder1		Coder2		Diff
Crew (Date)	W (%)	NW (%)	W (%)	NW (%)	(1-2)	S (%)	NS (%)	S (%)	NS (%)	(1-2)	NE (%)	EW (%)	NE (%)	EW (%)	(1-2)
43 (3/25)	90	10	71	29	19	75	25	79	21	-4	68	32	47	53	21
44 (4/9)	91	9	90	10	1	80	20	79	21	1	71	29	53	47	18
45 (5/5)	93	7	71	29	22	94	6	97	3	-3	74	26	49	51	25
46 (7/13)	89	11	70	30	19	86	14	79	21	7	74	26	50	50	24
47 (7/21)	79	21	60	40	19	81	19	83	17	-2	58	42	41	59	17
48 (8/20)	79	21	61	39	18	95	5	98	2	-3	63	37	46	54	17

**Note: W=Working, NW=Not Working, S=Safe, NS=Not Safe, EW=Existing Waste, NE=No Existing Waste*

Both coders allocated field productivity ratings of greater than 70% for four crews. Two crews, crews 47 and 48 received field ratings of 60% and 61% respectively from Coder 2. Although Coder 1 allocated 79% for the crews 47 and 48, they were the lowest allocations for all the crews from Coder 1. This was the same pattern found in the field ratings of Coder 2. Both coders allocated safety ratings greater than 70% for all crews. The waste allocation was similar for crews 47 and 48.

The difference between observers' classifications was calculated (Coder 1- Coder 2). Coder 1 consistently allocated higher values to "working" behaviors than Coder 2. The minimum difference was 1% for crew 44, and the maximum difference was 19% for crew 43, 46 and 47. Coder 1 had higher allocations than Coder 2 to "safety" for crew 44 and 46 and lower allocation for crew 43, 45, 46 and 48. The highest absolute difference was 7% and lowest 1%. Coder 1 had higher allocation to "no presence of waste" for all six crews. The maximum absolute difference was 25% with a minimum of 17%. Refer to Table 23 for differences.

4.3.5 Behaviors

A Pareto analysis was used to understand behavior counts for productivity, safety and waste. The behaviors were summed for all dates for each coder. The total for each coder was summed to generate the total counts of behaviors. The total counts were used to create Pareto charts and descriptive charts. The behaviors that accounted for approximately 80% were identified for each coder and included in the descriptive charts.

For productivity, six behaviors contributed to the top 84% of the total (Figure 31). The behaviors included, 1) Participating in active physical work (23%), 2) Carrying material, holding or supporting material (21%), Walking about empty handed (12%), Operating equipment (10%), Waiting for another to finish work (10%) and Measuring (8%). Two from the six top behaviors were considered "Not Working" or unproductive behaviors (Figure 32). All six behaviors, albeit in slightly different order, accounted for approximately 80% of the behaviors, calculated for each coder individually. This individual coder results are consistent with aggregated results included in the analysis.

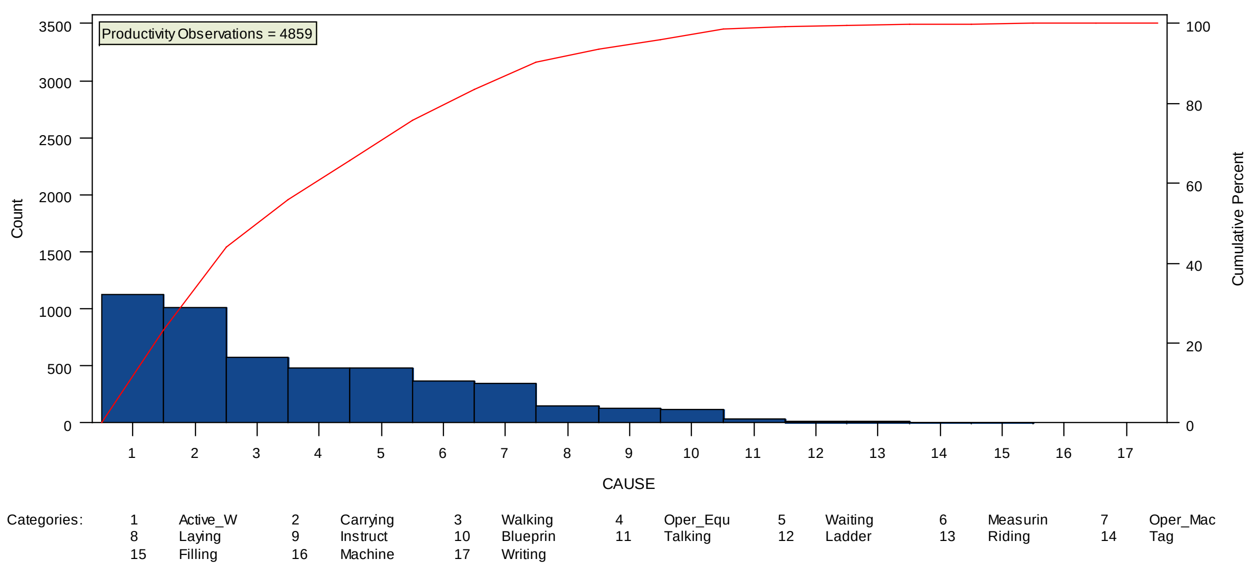


Figure 31 - Pareto for Productivity

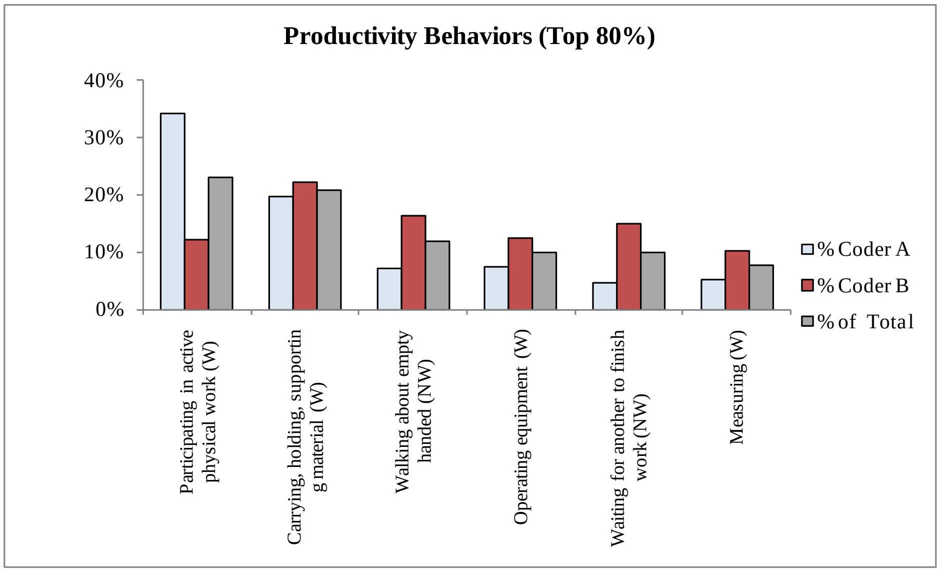


Figure 32 - Productivity Behaviors (Top Cumulative >80% of total)

For safety, three behaviors contributed to the top 87% of the total (Figure 33). The behaviors included, 1) Wearing appropriate personal protective equipment (52%), 2) Using tool for intended purpose (29%) and 3) Not wearing a hard hat or wearing it incorrectly (7%) (Figure 34). Additional behaviors to note include 4) Not wearing boots (4%), 5) Using ladders properly (3%) and 6) Not wearing eye protection where damage could result to the eye (1%). Three of the top six behaviors were "not safe". All three behaviors were the top behaviors calculated for each coder.

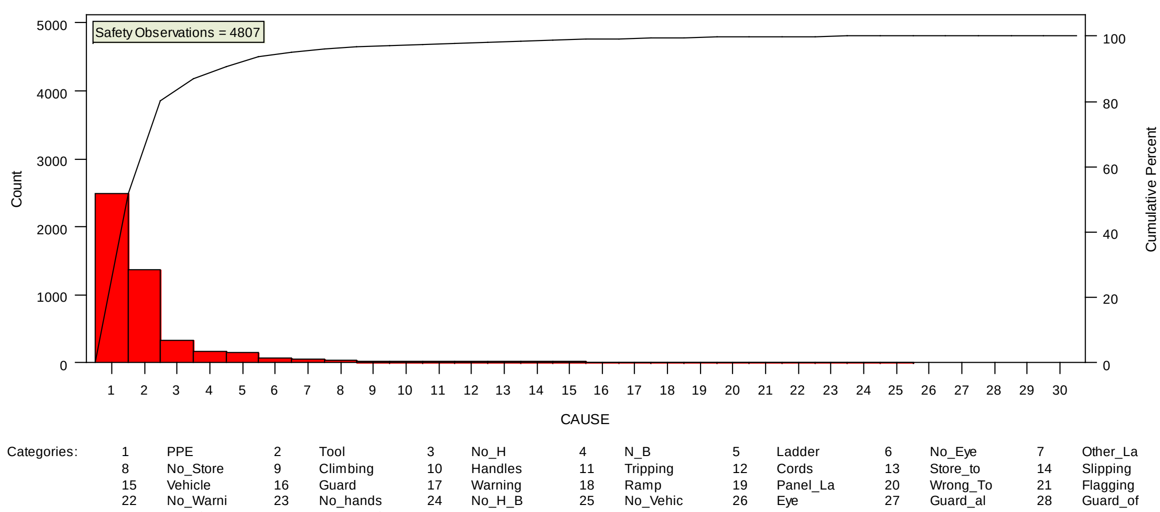


Figure 33 - Pareto for Safety

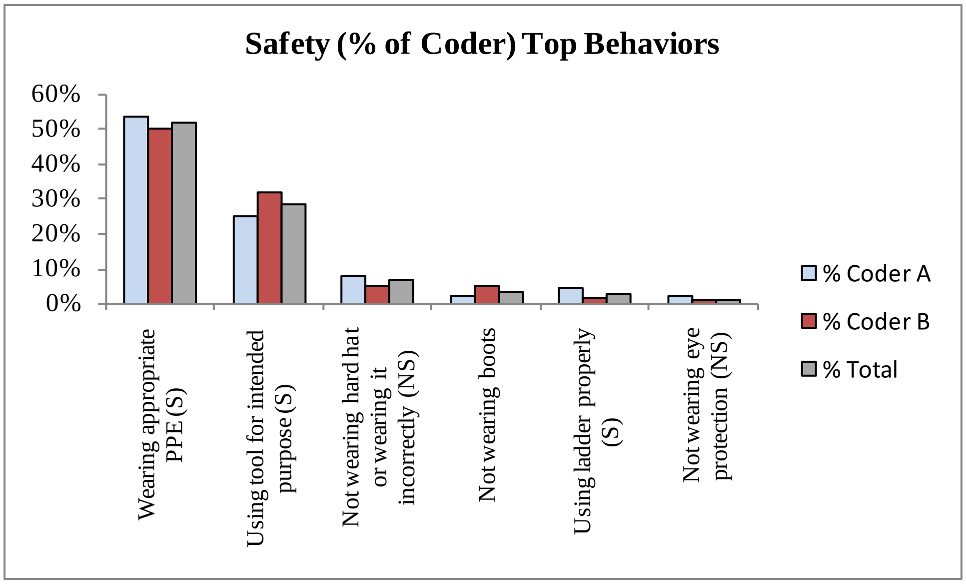


Figure 34 - Safety Behaviors (Top Cumulative >80% of total)

For waste, four behaviors contributed to the top 86% of the total (Figure 35). The behaviors included, 1) No waiting, idle, transportation or travelling waste (58%), 2) Transportation requires manual material handling by worker (12%), 3)Worker is idle (10%) and 4) Worker walking around aimlessly (8%) (Figure 36). All four behaviors were the top behaviors calculated for each coder.

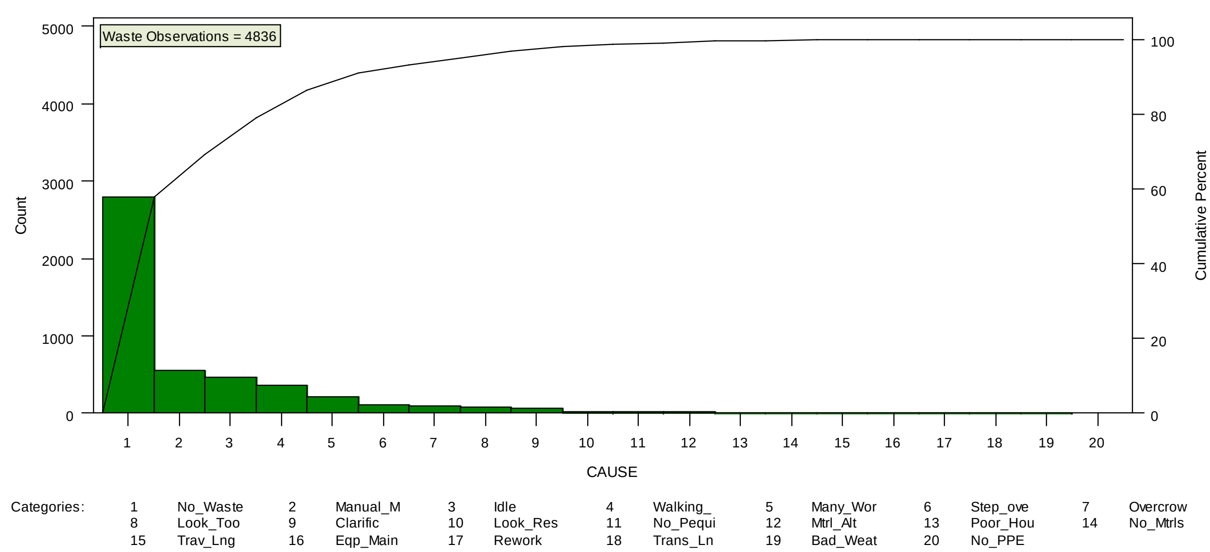


Figure 35 - Pareto for Presence of Waste

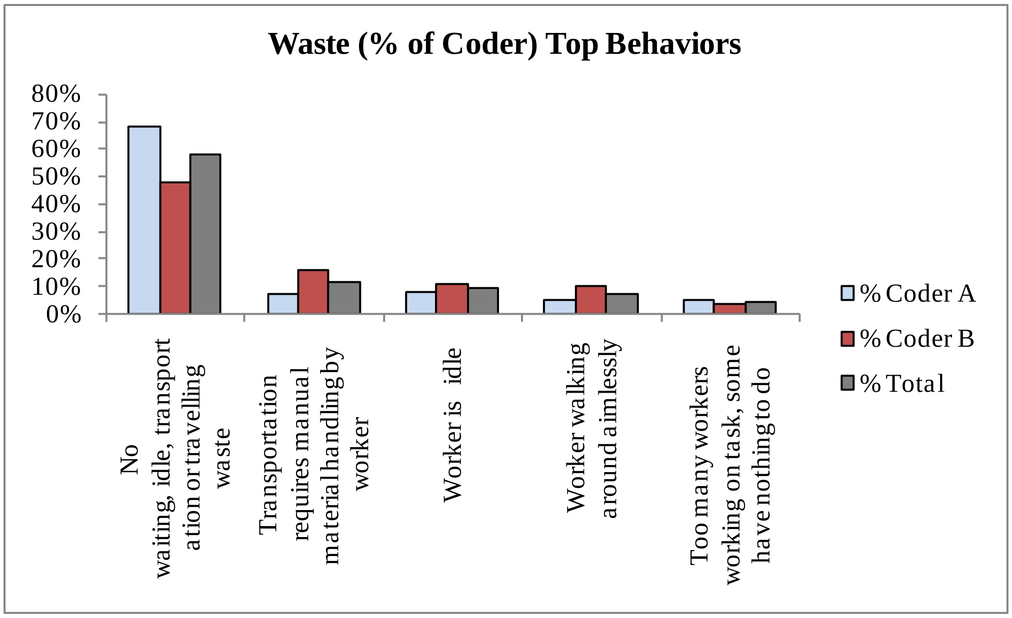


Figure 36 - Waste Behaviors (Top Cumulative >80% of total)

4.3.5.1 Discussion

All productivity field ratings resulted in scores greater than 60. For specialized crews, satisfactory performance is considered higher than 60% (Oglesby et al., 1989). The sample size of approximately 400 provides the result with reasonable certainty. Although all crews accounted for greater than 60% field ratings results, crews 47 and 48 received the lowest ratings of all from both coders. Crew 47 received 70%, 60% respectively from coder A and 79%, 61% respectively from coder B. The two top non-working behaviors contributing to this are “waiting for another to finish work” and “waking about empty handed”.

All safety ratings were above 79%. However, several non-safe behaviors were in the top total. Not wearing appropriate PPE or wearing incorrect PPE, including hard hats, boots and eye protective equipment accounted for 13% and 11% of coder A and coder B, respectively. Wearing appropriate personal protective equipment is the last step, step 6, for protection of the worker in the safety engineering process of control of hazards (Grimaldi, 1975).

The presence of waste ratings ranged from 26-42% for coder A and from 39-59% for coder B. The top behaviors that contributed to the presence of waste included manual material handling, 7% for coder A and 16% for coder B. Additionally worker walking, idle, overcrowded and too many workers for task accounted for 20% for coder A and 27% for coder B.

For overall categories, the waste data partially supported the results from Serpell (1997). In his study, Serpell (1997) found the top non-contributory time (as percent of total) to be, “transportation”, 14%, “waiting”, 9%, “idle time”, 7%, “traveling”, 6%. The results of this study found the top waste behaviors to be, “waiting”, 4%, “idle”, 14% and “traveling”, 12%.

The results of the waste ratings showed the presence of waste with results greater than 47% of time of the observations, for both coders. This finding is consistent with previous research. According to the Construction Industry Institute (2005), only 3-20 percent of tasks add value with their share in total cycle time. Vedder & Carey (2005) cited a field study of mechanical installation work that showed over 50% of total observed time in a construction site to be non value added. Additionally, Serpell (1997) found non-contributory (categorized as waste) worked to be 25% of a total of 17 observed construction of buildings.

Manual material handling accounted for 12% of the total work observations for both coders. Manual material handling has been shown to be related to accidents. A study of 355 reported occupational accidents showed that 32% of these accidents occurred during material handling (Perttula, Merjama, Kiurula, & Laitinen, 2003). Additionally, a risk assessment of panelized work in residential construction showed hazardous incidents involved with lifting, carrying, hoisting, holding and fixing activities with the use of panelization (Kim, Nussbaum, Hyang, Kim, & Smith-Jackson, 2006).

4.4 Perception and Behavior Analysis

4.4.1 Normality

Total video analysis counts for “working”, “safe” and “no waste” were averaged for the two coders, at the crew level. Normality tests were performed at the crew level to determine whether the data set was normally distributed. A Shapiro-Wilk test was applied to test for a normal distribution (α=0.05). Safety climate, (0.88, p = 0.27), risk behavior (0.91, p = 0.46), CQWaste (0.93, p = 0.62), CQLoss (0.86, p =0.20), own (0.98, p = 0.97), observed working (0.97, p = 0.92), observed safe (0.86, p = 0.17), and observed waste (0.70, p = 0.01). The normality assumptions were not violated; therefore, parametric tests were used.

4.4.2 Perception and Behavior Correlation

Relationships among safety climate, risk behavior, waste presence, waste loss, ownership, observed working, observed safe and observed waste were examined (Table 24). Pearson's correlation was used to test the relationship between the variables at $\alpha=0.05$ significance. Pearson's correlation resulted in $r = -0.82$ ($p < 0.05$), a strong negative relationship between safety climate and CQLoss. No other significant relationship was found. A relationship of interest resulted between risk behavior and safety climate $r = 0.79$ ($p < 0.065$), CQWaste and safety climate $r = -0.75$ ($p < 0.08$), CQWaste and risk behavior $r = -0.77$ ($p < 0.07$).

4.4.2.1 Discussion

It was hypothesized that a positive relationship would exist between safety climate and observed safe behavior (H_9). Results from this analysis did not support the hypothesis. The present results did not find a relationship between safety climate and behavioral observation measurement of safety (Glendon & Litherland, 2001). The results of this study does not support research by Zohar that resulted in a relationship between safety climate and performance (Zohar, 1980).

Table 24- Pearson's Correlation Results, n=6

	Safety Climate	Risk Behavior	CQWaste	CQLoss	Work Ownership	Obs Prod (Avg)	Obs Safety (Avg)	Obs Waste (Avg)
Safety Climate	1.0							
Risk Behavior	0.79 *p*=0.065 **	1.0						
CQWaste	-0.75 *p*=0.08**	-0.77 *p*=0.07**	1.0					
CQLoss	-0.82 *p*=0.05*	-0.49 *p*=0.32	0.52 *p*=0.29	1.0				
Work Ownership	-0.16 *p*=0.76	-0.23 *p*=0.66	-0.25 *p*=0.64	0.21 *p*=0.70	1.0			
Obs Prod (Avg)	0.38 *p*=0.46	0.56 *p*=0.26	-0.46 *p*=0.36	-0.45 *p*=0.37	-0.58 *p*=0.22	1.0		
Obs Safety (Avg)	0.50 *p*=0.31	0.26 *p*=0.62	0. 01 *p*=0.98	-0.16 *p*=0.76	-0.28 *p*=0.59	-0.29 *p*=0.57	1.0	
ObsWaste (Avg)	-0.34 *p*=0.50	-0.45 *p*=0.37	0.05 *p*=0.92	0.16 *p*=0.76	-0.04 *p*=0.94	0.35 *p*=0.49	0.52 *p*=0.30	1.0

*Significant *(p<0.05), ** Values of Interest*

Several studies, however, have found no significant relationship between safety climate and safety behavior. Glendon & Litherland (2001) evaluated five construction crews for safety climate and recorded a total of 331 observations. The results failed to find any relationship between safety climate and safety performance. Additionally, a study that evaluated thirty one construction projects, with 1,045 questionnarie responses observed no statistical significance between safety climate and safety performance (recordable incidence rate) (Maloney, 2010).

It was hypothesized that a positive relationship would exist between work ownership and observed productivity (H_{10}). Results from this analysis did not support the hypothesis. The relationship between ownership and productivity was not significant. There are several reasons that may have contributed to the absence of relationship between perceived and observed safety and perceived and observed productivity. The methods used in this study to were used to evaluate relationships between perception and behaviors. The methods should, perhaps, be seen as complementary rather than overlapping measures of safety (Glendon & Litherland, 2001).

The behavioral observation may not have been sensitive enough to differiante differences in safety performances between crews. All crews achrieved a relatively high percentage of safe behaviors. The measure was limited to behavior that could be observed, like wearing personal protective equipment, which accounted for over 50% of the top behaviors.

A further challenge of the behavior observation was the crew-based measure of the observations. Crew based observational results were compared with aggregated perception results. Although, an individual measure of safety performance is not recommended due to the nature of the work (Glendon & Litherland, 2001), a further level of agregation is recommended for the videos.

The questionnaires were agreegated by crew to obtain climate results. The observations were also agregrated but consistency of the worker label was not kept between observations, due to the difficulty in identifying workers between observations. A suggestion for consistency in worker rating for future studies include a method for inditifying the workers (i.e. colored shirts, marking on hard hat, etc.). This would allow the opportunity to aggregate crew observations of behaviors by workers.

4.4.3 Model

Multiple regression analysis was applied to evaluate whether safety climate, perceived productivity, perceived risk behavior, and safe behavior were predictors of observed productivity. Values were averaged for each crew. Six crews were evaluated. All values were added to the model simultaneously. The variables were evaluated with an α=0.05. The model was not significant $F_{4, 5}$=0.42, p=0.8034.

Multiple regression analysis was applied to evaluate whether safety climate, perceived productivity, perceived risk behavior, safe behavior and observed productivity were predictors of observed safety. Values were averaged for each crew. Six crews were evaluated. All values were added to the model simultaneously. The variables were evaluated with an α=0.05. The model was not significant $F_{4,5}$=0.91, p=0.65.

4.4.3.1 Discussion

It was hypothesized that no relationship would be found among safety climate, perceived productivity, perceived risk behavior, safe behavior and observed productivity (H_{11}). The results of the analysis supported the hypothesis. Models were tested for predictive capacity between perception and observed behaviors. The models did not predict observed safety or productivity. There are several reasons that may have contributed to the absence of predictability between perceived and observed productivity. The methods used in this study should, perhaps, be seen as complementary rather than overlapping measures of safety (Glendon & Litherland, 2001).

Additionally, it was hypothesized that no relationship would be found among safety climate, perceived productivity, perceived risk behavior, observed productivity and observed safe behavior (H_{12}). The results of the analysis supported the hypothesis.

For this research, Cooper's (2002) adaptation of Bandura's (1977) model was used to understand the relationship between safety and productivity in construction. The model has three elements: person, job and organization. This study, however, focused on the relationship between the internal psychological factors (attitudes and perception) and ongoing behaviors. The third prong, or organizational factors, was not included.

For this research, the methodology for the first two components of the model, climate and observation, were tested. Results included reliable questionnaire methods, as measured by Cronbach's alpha. The reliability for productivity coding indicated results of "Fair" for four crews and results of “Moderate” for two crews. Results for safety coding indicate values of “Moderate” for all crews. Results for waste coding indicate values of “Fair” for all crews.

Chapter 5. Conclusion

5.1 General Conclusions

The construction industry leads the private sector with the most fatalities of any industry in the United States. Construction worker health and safety continues to be at the forefront of concerns for the industry. Although the causes of injuries and illnesses in construction have long been tracked, reported and researched, the industry continues to lead in occupational related fatal and non-fatal injuries. Extensive analysis of health and safety and best practices exist in the construction research literature. Construction, however, is a temporary endeavor for which a new organization is created for every project, thereby creating unique challenges. Worksites are dynamic with various levels of awareness and training of personnel (Bertelsen, 2003).

The construction industry has historically functioned as independent parties that "pass down" the responsibilities of the project after their section has been completed. Perceptions of performance pressure can lead workers to believe that engaging in short cut behavior is expected or a required part of the job (Wright, 1986). Workers who perceive a high degree of performance pressure can focus their attention on completing work and less on the safety of their work procedures (Hofmann & Stetzer, 1996).

It has long been assumed that a relationship exists between productivity and safety. In the construction industry it is critical to understand if a tradeoff exists between safety and productivity to avoid shortcut behaviors. This is specifically important due to the number of contractors, subcontractors and laborers that participate in the different projects.

The overall objective of this research was to increase the understanding of the relationship between perceived and observed safety and productivity and to understand the variability in perception and behavior between crews working for the same general contractor in the homebuilding construction industry. Understanding this relationship can contribute to the design of safety interventions, and consequently, the reduction of injuries and fatalities.

For this study, questionnaires from Phase I and Phase II were combined for analysis (n=190, 45 crews), including a total of one hundred and fifty seven participants (39 crews) from Phase I and forty-one participants (6 crews) for Phase II. Observational studies for Phase II were conducted for forty-one participants (6 crews).

A total of 92% of the participants responded to their ethnicity as Latino. This is representative of the unique growth of the Latino community in the industry. Accordingly, 92% of the workers opted to complete all materials in Spanish. Participants (n=190) from Phase I and Phase II indicated that 36% speak English, 24% read English and 19% write English. These results are consistent with the aforementioned research.

A study that evaluated data from the U.S Bureau of Labor Statistic's Current Population Survey from 1998-2001, showed that among the Hispanic carpenters and construction laborers in the analysis, about 34% indicated that they could only communicate in Spanish (Goodrum, 2004). The results of Phase II for this study are consistent with this finding; framers indicated that 20% (n=41) spoke English.

CPWR (2008) reported that in 2005, one of four construction workers spoke a language other than English at home with 84% reporting they spoke Spanish. Among Latino construction workers, 42% reported they could speak English very well and 42% reported they couldn't speak English at all (CPWR, 2008). The results of this study are consistent with these findings with 36% (n=190) of the participants indicating they spoke English.

An important finding of this research includes the moderate positive relationship between safety climate and risk scores at the crew level and a moderate positive relationship between safety climate and risk scores at the worker level. These results indicate that higher safety climates compliment a low frequency of perceived risk taking, at both the crew and worker level.

Although the safety climate and risk behaviors were aggregated and analyzed at the crew level, certain questionnaire items were identified as points of interest. A total of 77% of the participants responded to "Agree" or "Strongly Agree" when asked if taking risks was part of their job (safety climate). A total of 48% of participants responded to "Agree" or "Strongly Agree" when responding to the likelihood of them being injured in the next twelve months. These findings highlight several common areas identified by a study of the safety climate in CityCenter and Cosmopolitan construction projects in Las Vegas conducted by The Center for Construction Research and Training (CPWR).

CPWR conducted a worksite assessment of the CityCenter and Cosmopolitan construction projects to understand, among other objectives, safety climate (Gittleman et al., 2009). Understanding the safety climate was important since earlier in the year, workers walked off the job site, demanding increased jobsite safety. The goal of understanding the safety climate was defined by CPWR to assess perceived attitudes, knowledge and beliefs about the safety practices on the job sites (Gittleman et al., 2009). Among the results of the safety climate questionnaire item frequency count, it was found that 25% of 2,802 workers agreed that sometimes they ignored a safety rules or policy in order to carry out an assignment or meet the schedule and 16% of 2,796 workers disagreed that they would not suffer a lost time injury on the job site (Gittleman, et al., 2009). Although these results are slightly lower than the results found in this dissertation research, they highlight areas of opportunities for improvement in risk taking behavior.

In accordance with the safety climate results, a total of 75% of all participants for this research responded to “Sometimes” and “Often” when asked if they took chances or risks to get a job done and 62% of participants responded to “Sometimes” and “Often” when asked about bending the rules to achieve a production target. A total 57% of all participants responded to “Sometimes” and “Often” when responding to job stress stopping them from working to the rules.

A model was developed for predicting risk scores that suggests that safety climate and ownership are predictors of risk behavior, or perceived frequency of risk behaviors. The model was found to explain about 25% of the variance in predicting new observations, compared to 41% of the variability in the original data explained by the least-squares fit. The result of this model provides a baseline to further explore the relationship between risk behavior, safety climate and work ownership. This relationship is important to understand since employee attitudes, safety commitment and organizational factors (including ownership) may affect acceptability of rule violations and the status of safety rules and instructions (Rundmo, 2000).

The differences among crews were evaluated at two levels, individual crews and critical path groups to understand significance. All tests were significant for differences among crews. To further understand these differences, crews were grouped in accordance with the critical path of a homebuilding schedule. A significant difference existed for risk behavior, loss and ownership. The framing group had a higher perception of loss due to waste and a lower risk score (higher frequency of risk behavior) when compared to the mechanical systems group. Framing group had a higher perception of loss due to waste and a higher ownership value when compared to the painting and wall covering group. Finally, insulation/plaster/drywall group had a higher ownership value when compared to painting/wall covering group.

Behavioral observation was used to evaluate crew performance for Phase II. The reliability for productivity coding indicated results of “Fair” for four crews and results of “Moderate” for two crews. Results for safety coding indicated values of “Moderate” for all crews. Results for waste coding indicated values of “Fair” for all crews.

Although relationships between perception and performance were not significant, several important findings should be highlighted. All productivity field ratings resulted in scores greater than 60. For specialized crews, satisfactory performance is considered higher than 60% (Oglesby et al., 1989). All safety ratings were above 79%. It is imperative to continue to work to reduce fatalities, injuries and illnesses in the construction industry. It is very important, however, to create a culture where workers are encouraged to report unsafe jobsites. David Michaels, the administrator of the Occupational Safety and Health Administration commented that if “zero-tolerance” results in the firing of a worker who reports injuries, workers may not likely come forward (Tuchman & Ichniowski, 2010).

Among the top “non-safe” behaviors, Not wearing appropriate PPE or wearing it incorrectly, including hard hats, boots and eye protective equipment accounted for 13% and 11% of coder A and coder B, respectively. Wearing appropriate personal protective equipment is the last step, step 6, for protection of the worker in the safety engineering process of control of hazards (Grimaldi, 1975).

For overall categories, the waste data partially supported the results from Serpell (1997). For the study, Serpell (1997) found the top non-contributory time (as percent of total) to be, “waiting”, 9%, “idle time”, 7%, and “traveling”, 6%. The results of this research found the top waste behaviors to be “transportation”, 12%, “waiting”, 4%, “idle”, 14% and “traveling”, 12%.

The results of the waste ratings show the presence of waste with results greater than 47% of time of the observations, for both coders. This finding is consistent with previous research. According to CII (2005), only 3-20 percent of tasks add value with their share in total cycle time. Vedder & Carey (2005) cited a field study of mechanical installation work that showed over 50% of total observed time in a construction site to be non value added. Additionally, Serpell (1997) found non-contributory (categorized as waste) worked to be 25% of a total of 17 observed construction of buildings. Manual material handling accounted for 12% of the total work observations for both coders. Manual material handling has been shown to be related to accidents. A study of 355 reported occupational accidents showed that 32% of these accidents occurred during the material handling (Perttula et al., 2003).

Some work that does not directly add value but is essential to finishing the construction unit, such as material handling at the work station, is required in all jobs (Oglesby et al., 1989). Therefore acceptable values of it will vary based on the type of work or the trade. Productivity studies, if used, improperly can threaten job morale and attempts to used productivity ratings as a basis for criticism, discipline or discharge are bound to defeat their main purpose (Oglesby et al., 1989).

Overall, learning from this research provides insight into the relationships between safety climate, risk behavior, productivity and work ownership. Additionally, a process for observational studies was created and tested. The study provides a contribution to the research of construction safety in the field, through the evaluation of safety climate, risk behavior, labor productivity, and observed productivity and safety behaviors.

5.2 Review of Study Objectives

As discussed in Chapter One, the research objectives of this study are listed, including a brief discussion of their relationship to the study.

1. Evaluate the dimensions of perceived safety climate, risk behavior and productivity.

A total of three survey instruments, five open ended questions, and a demographics questionnaire, were used to create the Safety and Productivity Perception (SPP) tool. A factor analysis was run to evaluate the dimensions of the Safety and Productivity Perception Tool. Eleven factors were retained and explained a cumulative variance of 71.6%. The overall factors were consistent with the dimensions of the questionnaires including, safety climate, risk behavior, productivity including materials, tools, production equipment, rework, language translation, material delivery, material handling, risk acceptance, information and work ownership.

2. Evaluate the relationship between workers' perception of safety climate, productivity, risk behavior, and work ownership.

The relationship between workers' perception of safety climate, productivity, risk behavior, and work ownership was evaluated through the use of questionnaire analysis.

Spearman's correlation resulted in a moderate positive relationship between safety climate and risk behavior at the crew level and a moderate positive relationship between safety climate and risk behavior at the worker level. These results indicate that higher safety climates compliment a low frequency of perceived risk taking, at both the crew and worker level. A moderate correlation was found between CQLoss and Work ownership at the crew level and a weak correlation between Work ownership and CQLoss at the worker level. Spearman's correlation did not result in significant relationships between safety climate and perceived productivity (waste or loss) at the worker or crew level.

Multiple regression analysis was applied to evaluate whether safety climate, waste, loss and work ownership were predictors of risk behavior. A model was found for predicting risk behavior that partially supported the hypothesis. Two independent variables were significant, safety climate and work ownership. The model from this research suggests that safety climate and work ownership are predictors of risk behavior, or perceived frequency of risk behaviors.

3. Evaluate if perceptions of safety climate, risk behavior, and productivity differ among crews working for the same general contractor.

The differences among crews were evaluated at two levels, individual crews and critical path groups. All tests were significant for differences among crews. A significant difference existed for risk behavior, loss and work ownership between critical path groups. Overall, the framing group had a higher perception of loss due to waste and a lower risk score (higher frequency of risk behavior) when compared to the mechanical systems group. The framing group had a higher perception of loss due to waste and a higher work ownership value when compared to painting and wall covering group. Finally, insulation/plaster/drywall group had a higher work ownership value when compared to painting/wall covering group. A possible factor in the perception of loss of framers can be the work ownership of materials scheduling. The General Contractor manages the schedule of material delivery. Further research is recommended, controlling for critical path groups, to explore these behavior.

4. Evaluate the relationship between workers' perception of safety climate and observed safe behavior, workers' perception of risk behavior and observed safe behavior, and workers' perception of productivity and observed labor productivity.

The results of this study did not show significant a relationship between safety climate and observed safety or between risk behavior and observed safe behavior. Additionally the results of the study did not find a relationship between perception of productivity and observed labor productivity. The behavioral observations may not have been sensitive enough to differiante differences in performances between crews. Additionally, the measure was limited to behavior that could be observed, like wearing personal protective equipment, which accounted for over 50% of the top behaviors. A further challenge of the behavior observation was the crew-based measure of the observations. The questionnaires were agreegated by crew to obtain climate results. The observations were also agregrated but consistency of the worker label was not kept between observations, due to the difficulty in identifying workers between observations.

5. Evaluate the relationship between workers' perception of productivity, safety climate, observed labor productivity and observed safe behavior.

Multiple regression analysis was applied to evaluate whether safety climate, perceived productivity, perceived risk behavior, and safe behavior were predictors of observed productivity. The model was not significant and no relationship was found between worker's perception of productivity, safety climate, observed labor productivity and observed safe behavior. Additionally, multiple regression analysis was used to evaluate whether safety climate, perceived productivity, perceived risk behavior, safe behavior and observed productivity were predictors of observed safety. The model was not significant.

The reported relationships between safety climate and safety behavior in the literature have been mostly inferred from structural equation models based on self-report instruments (Cooper & Phillips, 2004). Glendon and Litherland (2001) measured safety climate and actual safety behaviors in road construction and found no significant relationship between the two. In accordance with this research, the present study failed to find a significant relationship between perception and behavior. Although Cooper and Phillips (2004) found an empirical link between a limited set of safety climate perceptions and actual behavior, the relationship was very complex where changes in climate perceptions did not necessarily reflect changes in behavioral safety. The degree of complexity of the relationship between safety performance and safety climate requires much more research. Cooper and Phillips (2004) suggest future research based on a variety of safety performance outcomes rather than self-reported instruments. The results for this research support the need to further understand safety and productivity behavior.

5.3 Limitations

5.3.1 Phase I

Field studies, in general, are challenging since the researcher does not control the situation, which allows for unpredictable events. Construction sites are dynamic and the continuous influx of subcontractors creates temporary organizations which are complex to observe and analyze. The process of collecting and analyzing field data can be costly and time consuming. Field data collection was used for both Phase I and Phase II. Although this may have contributed to the overall external validity of the study, there are several limitations that should be discussed.

Convenience sampling was used (Patton, 1990) based on the availability of new single family home construction. Participants were recruited from contractors that had been hired by a general contractor to complete construction work. Since the study used convenience sampling, self-selection bias of the participants may have existed. In an effort to mitigate self-selection, the participants were not aware of the study prior to the data collection. The participants did not receive any compensation and the General Contractor was not aware of the crews which participated.

The participants were all recruited from a large General Contractor in Southwest Virginia. Therefore, the results may not generalize to other General Contractors or other geographical areas. Limitations related to the use of questionnaires may also apply. The ability of the worker to read and comprehend the survey may have resulted in a biased response. An attempt to mitigate this limitation included the presence of the bilingual researcher to read the questions to the participants, if reading level was concern. The terms “supervisor” and “managers” were used in the questionnaires. Different perceptions of “supervisor” and “managers” may have existed among the participants. The terms should have been explained to the participants before the beginning of the study.

Participants may have been selective on their responses due to social desirability. Participants may not have wanted to disclose their true opinions for fear of losing their jobs. This is particularly important for Latinos. Research has shown Latinos tend to score higher on psychometric indicators of socially desirable responding (Hopwood, Flato, Ambwani, Garland, & Morey, 2009; Marin & Marin, 1991). The researcher communicated the confidentiality of the study verbally and by providing a copy of the informed consent to each worker to attempt to mitigate worker concerns of their responses being shared with their employer.

This research did not address the various types of wastes suggested by lean theory and practice. Only four types of waste were included in the research as part of non-contributory work. The four types were selected based on previous findings by Serpell (1997). Therefore, the representation of waste in the system is not complete does not generalize to "lean theory" wastes.

5.3.2 Phase II

Video instrumentation may have been a limitation to the data collection process. Two different brand cameras and tripods were used to record the tasks. This may have affected the quality of the video image. Additionally, due to construction site constraints, the cameras had to be moved to allow for material delivery, worker travel, material handling, etc. This was not controllable between crews and may have contributed to the potential loss of the larger environmental context outside the view of the camera lens (Kopenhaver Haidet et al., 2009).

Limitations related to the coders may have existed. The coders were from different academic backgrounds and did not have residential construction experience. Convenience sampling was used for coder selection based on geographical location. It was difficult to find coders with compatible expertise in productivity, safety and lean production systems in homebuilding construction.

The coders were novices to using the Noldus Observer® XT 8.0 software. Both coders used their personal computer. The laptops used were different and may have influenced the fidelity of the videos. This was mitigated by having the coders use the exact external drive and video files.

Limitations existed from using video recordings. Video recording provides a window of what happens in real time and may lack important contextual data (Latvala, Vuokila-Oikkonen, & Janhonen, 2000). This may be true even with multiple strategically placed cameras.

Maintenance of coder training was a limitation. The coders did not receive continuous training throughout the coding timeline. They received three training sessions, one before the productivity, safety and waste coding, respectively. It is recommended that coding errors be continuously reviewed (Castorr et al., 1990) and retraining be completed accordingly. The researcher provided a source of consistency by training both coders. To mitigate researcher bias, the coding analysis was done when both researchers had completed the observations. Errors were not identified "real time" and feedback was only provided to the coders during the training sessions. This may have contributed to coding errors.

An additional factor that could potentially threaten the validity of these findings was the modest sample size of Phase II. The sample size included only one sample per crew since each crew was videotaped framing only one house. Furthermore, the observational measures used, which emphasize frequency of behaviors, may not have captured the impact of infrequent behaviors that have major impact on productivity, safety and waste. Behaviors were limited to observable ones and did not include a complete range of safety performance.

The aim of the study was not designed to include 100% Latinos. Therefore, the results of 100% Latinos in the sample of study may be a limitation to generalizability to other populations. This may, however, provide an opportunity for further learning on the influx of the Latino population in the construction industry.

5.4 Recommendations for Future Research

The results of this study showed a significant difference between groups in different stages of the critical path of the home building process. Due to new home construction availability, not all critical path stages were included. The Critical Path of Construction for a single family home was used to reduce the analysis crews for evaluation. Future research is recommended to build on these results. It is recommended that a future study be completed controlling for trades in the critical path process. The questionnaires used in this study, the Safety and Productivity Perception (SPP), resulted in high reliability values measured by Cronbach's Alpha. The SPP should be used to evaluate differences between groups in the critical path. This will allow for a further understanding of safety and productivity throughout the schedule of homebuilding. Further understanding of safety throughout the production schedule can provide insight into development of safety interventions, training processes, contracting systems, formal/informal metrics and accident causation (measured by safety metrics) understanding. Identifying concern areas throughout the process provides a starting point for understanding root causes and establishing proactive, preventative health and safety measures. Unsafe acts can lead to minor injuries and, over time to major injuries. According to Heinrich's theory of accident causation, it is proposed that for every 300 unsafe acts there are 29 minor injuries and one major injury (Heinrich, 1959).

Safety climate, productivity and work ownership were evaluated for predicting risk behavior. Two independent variables were significant, safety climate and work ownership. Productivity scores were not significant in the model. The model from this research suggests that safety climate and work ownership are predictors of risk behavior, or perceived frequency of risk behaviors. Further research is recommended, increasing the sample size to include multiple general contractors. Additionally, it is recommended that the same scale be used to measure all three variables. The safety climate scale measured agreement and the risk and work ownership scale measured frequency. The result of this model provides a baseline to further explore the relationship between risk behavior, safety climate and work ownership. This relationship is important to understand since employee attitudes, safety commitment and organizational factors (including work ownership) may affect acceptability of rule violations and the status of safety rules and instructions (Rundmo, 2000).

For this research, Cooper's (2002) adaptation of Bandura's (1977) model was used to understand the relationship between safety and productivity in construction. The model has three elements: person, job and organization. This study focused only on the relationship between the internal psychological factors (attitudes and perception) and ongoing behaviors. A two-phased data collection approach was used to include an evaluation of the relationship between perceived safety climate, risk behaviors, productivity, work ownership and variability among construction crews working for the same general contractor and an evaluation of the relationship between perceived safety climate, perceived productivity and observed safety behavior and labor productivity measures among framers working for the same general contractor. The third prong, or organizational factors, was not included.

Results showed no significant relationship between perception and behavior. This study, however, provides a platform for future research. The methodology for the first two components of the model, climate and observation, have been tested. Questionnaire results were high in reliability. It is recommended that the third factor, organizational factors, be added to future studies. This can include measures of subcontractor's formal safety programs, including safety inspection results, measures of near misses, etc. This may provide further information on the relationships between perception and observation of safety and productivity. Additionally, a study is recommended that measures influence of higher or lower safety climate scores on formal construction project safety metrics.

A methodology for exploring productivity, safety and waste at the perception and behavior level was created for this study. Future studies are recommended to re-test the reliability of the observational studies. An increase in sample size is recommended to further explore this relationship. Additionally, a more extensive methodology is recommended for determining the extent to which the coder training was maintained throughout the study. Periodic recalibration of coder training can be achieved by having the coders score the same type of hypothetical materials used in training. This allows the researcher to examine if any coder drift is occurring and reduce it through retraining (Kendall & Butcher, 1982). An ongoing assessment of coder accuracy (against a baseline) can help the researcher understand the extent to which the principles conveyed in the training are maintained throughout the course of the study (Castorr et al., 1990).

An additional recommendation for a future research includes the use of coders with construction experience. An evaluation of the differences in reliability between coders with construction experience and coders with no construction experience (current study) can help understand the robustness of the coding process and predetermined behaviors.

The overall objective of this research was to increase the understanding of the relationship between perceived and observed safety and productivity and to understand the variability in perception and behavior between crews working for the same general contractor in the homebuilding construction industry. The findings of this research contribute to the body of knowledge of construction health and safety. Learnings from this research provide further understanding of the relationship between safety climate, risk behavior, productivity and work ownership. A model for the prediction of risk behavior provides motivation for continued research in work climates in the field of construction. Further, the process for observational studies provides a platform for research to understand the contributing behaviors to productivity, safety and the presence of waste among crews in construction.

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Appendix A - List of Special Interest Organizations Focusing on Construction Safety and Health

Organization	Description
The Center for Construction Research and Training(CPWR) *www.cpwr.com/indexstart.html*	A non-profit organization created by the Building and Construction Trades Department, AFL-CIO in 1979. In 1990, CPWR began working with NIOSH (competitive grants). CPWR uses a three-pronged approach: research, training and service to focus on construction safety and health.
Center for Innovation in Construction Safety and Health Research (Virginia Tech) *csc.eng.vt.edu*	The Center was formed in 2004 to help reduce the number and severity of construction incidents in the United States through applied research and outreach. The formation of the Center was made possible by a grant from NIOSH.
Construction Safety Alliance (Purdue University) *www.engineering.purdue.edu/CSA/about_us/csa*	The mission of the Construction Safety Alliance (CSA) is to develop, implement and evaluate a National Research Program in construction safety and health by bringing together the elements in the construction industry together with infrastructures of established research and education programs in engineering, public health, and construction management. Partially funded by Purdue University and NIOSH.
National Safety Council *http://www.nsc.org/Pages/Home.aspx*	A nonprofit, nongovernmental, international public service organization dedicated to protecting life and promoting health. The NSC is a membership organization, founded in 1913 and chartered by the U.S. Congress in 1953. Members include businesses, labor organizations, schools, public agencies, private groups and individuals.
International Code Council *www.iccsafe.org/*	The International Code Council is a membership association dedicated to building safety and fire prevention. It develops the codes used to construct residential and commercial buildings, including homes and schools. Most U.S. cities, counties and states that adopt codes choose the International Codes developed by the International Code Council. Membership ranges from $25-$200 based on category
The Construction Specification Institute *www.csinet.org*	Professional association promoting the interests of the nonresidential building design and construction industry. Membership ranges from $95 to $210 based on professional category.
Construction Industry Institute (CII), The University of Texas at Austin *www.construction-institute.org/scriptcontent/Index.cfm*	A consortium of owners, engineering and construction contractors, and suppliers who have a mission to improve the cost effectiveness of the capital facility project life cycle, from pre-project planning through completion and commissioning.

Appendix B - Informal Interview with Builder

1) What is a typical critical path for a single family home?

Typical critical path for a large single family home includes:

Step	**Week**	**Action**
1	Prior to start to week 1	Stake-out
2	1	Excavation
3	1	Footing
4	2 & 3	Foundation
5	4 & 5	Framing
6	6 & 7	Mechanicals
7	7	Insulation
8	7 & 8	Drywall
9	9	Trim
10	9	Paint
11	10	Ceramic/Resilient
12	11	Final Trades
13	12	Carpet/Wood
14	13	Pre-Settlement Demonstration

2) Process for production planning?
Production planning begins upon signing of sale contract. Quality is carried out through field inspections (checklists). CAD drawings are generated (based on model type, not individual sales contract; one set of plans for every model type) and hard copies are sent to the field.

3) What is included in framing?
Framing consists of the joists, studding, sheathing, trusses, and setting of windows, doors and stairs of the home.

4) Type of framing used by builder?
Builder uses panelization. Panelization is a framing system, which refers to the construction of components including walls, trusses, stairs, doors, etc. in a controlled environment (manufacturing site).

5) What is the panel delivery schedule?
Panels are delivered as needed but there is a certain amount of batching from manufacturing facility for production and transportation efficiency (not field task efficiency). Panels can be sorted several times upon arrival based on batching, stacking space availability, delivery time, etc.

6) What is the truss delivery schedule?
Trusses can be sorted several times upon arrival based on batching, stacking space availability, delivery time, etc. Crane is required for truss positioning. Additionally, some framers use forklifts or on single story homes they hand deliver the trusses.

7) Is framing process similar among contractors?
There are differences between contractors. Work is contracted out and the contractor determines the timing and resources needed.

8) Is material handling in the framing process the same for all contractors?
No, material handling varies by contractor. Can vary in carrying aides and/or number of workers. Some contractors use forklifts while others handle manually.

9) Does the builder have durations for the framing process components?
Yes, high-level durations are available based on home type.

10) What percent of the work is contracted out?
About 99% of the work is contracted out.

11) What kind of training system does the builder have?
Production training in classes and internal safety training (based on OSHA 10 hr training). Safety training is completed for production managers, project manager and supervisors. Additional training, office or in the field, will be developed for other topics or products issues that the company feels are needed.

12) Does builder train contractors in safety?
No. However, it is expected that all contractors are trained in safety before contract is awarded.

13) Are safety systems manual/automated or both?
Safety software is in process for implementation. Expected implementation of PDAs or Laptops for safety self checks. Monthly safety newsletter is sent, which highlights safety topics. Safety committee works on safety improvement projects. Safety requirements are incorporated specifications.

14) How often are safety audits conducted
Safety audits are done on every community, every three months. Additionally, safety liaisons have been identified for all divisions.

15) What are the most frequent production delays?
On-time delivery from component manufacturer, possibly due to their production schedule, weather and local inspection processes.

16) What are the most frequent occurring safety violations?
Based on production staff observations, absence of or incorrect wearing of PPE (i.e. hard hats). The audit program will generate additional safety knowledge.

17) Are there corporate improvement teams?
Corporate improvement teams working to improve Phases (i.e. framing team in progress) and standardization across processes.

18) How are field operations tracked?
"On schedule" software for production and for safety, there are two systems currently in process of implementation.

Appendix C - Questionnaires (English)

Safety Climate Questionnaire - Adapted from (Dedobbeleer & Béland, 1991)

*Please respond to the following statements by marking a √ or an **X** in the square that most represents your opinion about your experience in your current job site. Only select one answer per question.*

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1. I think worker's safety practices are important to my managers.					
2. Supervisors and other top managers seem to care about my safety.					
3. My foreman emphasizes safety practices on the job.					
4. I was given instructions on the safety policy and safety requirements of the company when I was hired by my direct employer.					
5. There are regular job safety meetings at my present job site.					
6. There is proper equipment for our tasks available at this job site.					
7. I feel I have control over what happens to my safety on the job.					
8. Taking risks is part of the job.					
9. I think I am likely to be injured on the job in the next 12-month period.					

Perceived Risk Behaviors' Questionnaire - Adapted from (Rundmo, 2000)

		Often	Sometimes	Never
10.	I take chances to get a job done.			
11.	I bend the rules to achieve a production target.			
12.	I take risks to get the job done.			
13.	Job stress at the workplace stops me from working to the rules.			
14.	I break safety rules due to management pressure.			
15.	I ignore when safety rules are broken.			

Craftsmen's Questionnaire - Adapted from (Oglesby et al., 1989)

Please respond to the following statements by marking a √ or an ***X*** *in the square that most represents your opinion about your experience in your current job site. Only select one answer per question.*

16. I have to stop work and wait or move to another task because I don't have the materials needed to do the job.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

17. How many hours per week do you think you spend waiting for materials, getting materials from somewhere else or moving to a different area because materials are not available?
☐Less than 1 ☐1-2 ☐2-3 ☐3-4 ☐4-5 ☐more than 5

18. I have to stop work and wait or move to another task because I don't have the tools needed to complete the job.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

19. How many hours per week do you think you spend waiting for suitable tools, getting tools, or moving to a different area because the appropriate tools are not available?
☐Less than 1 ☐1-2 ☐2-3 ☐3-4 ☐4-5 ☐more than 5

20. I have to stop work and wait or move to another task because I don't have the production equipment needed to complete the job.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

21. How many hours per week do you think you spend waiting for production equipment, getting production equipment, or moving to a different area because the production equipment is not available?

☐Less than 1 ☐1-2 ☐2-3 ☐3-4 ☐4-5 ☐more than 5

22. I have to stop work and wait or move to another task because I don't have the safety equipment needed to complete the job.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

23. How many hours per do you think you spend waiting for safety equipment, getting safety equipment, or moving to a different area because the safety equipment is not available?
☐Less than 1 ☐1-2 ☐2-3 ☐3-4 ☐4-5 ☐more than 5

24. In your opinion, please list the safety equipment that is often short in supply.
____.

25. I spend time doing completed work over again (rework).
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

26. How many hours per week do you think you spend doing completed work again (rework)?
☐Less than 1 ☐1-2 ☐2-3 ☐3-4 ☐4-5 ☐more than 5

27. Please list causes of rework.
____

28. I often spend time waiting for someone to give me the information that I need to do my job.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

29. How many hours per week do you think you lose because you are waiting for information you need to do your job?
☐ Less than 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ 4-5 ☐ more than 5

30. I often spend time waiting for someone to translate (language) the information that I need to do my job.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

31. How many hours per week do you think you lose because you are waiting for translations (language) that you need to do your job?
☐ Less than 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ 4-5 ☐ more than 5

32. Materials often have to be moved to a different location than where they were delivered.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

33. How many hours per week do you think you spend moving materials to a different location than where they were delivered?
☐ Less than 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ 4-5 ☐ more than 5

34. I have to stop work and wait or move to another task because I don't have the equipment to move materials.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

35. How many hours per week do you think you spend looking for the equipment to move materials?
☐ Less than 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ 4-5 ☐ more than 5

36. If I can't find the equipment, I will move the materials manually.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

37. How many hours per week do you think you spend moving materials manually?
☐ Less than 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ 4-5 ☐ more than 5

38. I receive clear daily task priorities.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

39. I receive clear job completion dates.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

40. I feel a high degree of personal ownership for this job.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

41. I feel a high degree of personal ownership for meeting daily task goals.
☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always

Demographics Questionnaire

Please respond to the following statements by marking a √ or an ***X*** *in the square that most represents your opinion about your experience in your current job site. Only select one answer per question.*

42. Age ______________		
43. Racial/Ethnic Group.	☐ African American	☐ Hispanic/Latino
	☐ American Indian	☐ European
	☐ Asian	☐ Nonresident Alien
	☐ Caucasian/White	☐ Other ________________.
44. How long have you worked for this employer?	☐ Less than 1 month	☐ 1-5 years
	☐ Less than 3 months	☐ 5-10 years
	☐ 3-6 months	☐ 10-20 years
	☐ 6-12 months	☐ Over 20 years
45. How long have you worked in residential construction?	☐ Less than 1 month	☐ 1-5 years
	☐ Less than 3 months	☐ 5-10 years
	☐ 3-6 months	☐ 10-20 years
	☐ 6-12 months	☐ Over 20 years
46. Do you speak English?	☐ Yes	☐ No
47. Do you read in English?	☐ Yes	☐ No
48. Do you write in English?	☐ Yes	☐ No

49. Did you have job safety training by your employer?

☐ Yes ☐ No

50. If yes to #49, Please describe the type of training you had.

____

____

51. Have you ever had an accident at work?

☐ Yes ☐ No

52. If yes to #51, Please describe the kind of accident you had.

____

____

53. In what area do you work?

☐ Brick masonry	☐ Material Moving
☐ Carpentry	☐ Miscellaneous
☐ Concrete/ Foundation	☐ Painting & wall covering
☐ Construction Management	☐ Plasterer
☐ Crane operator	☐ Plumbing, heating & A/C
☐ Design	☐ Project manager
☐ Drywall and Insulation	☐ Roofing
☐ Electrical	☐ Site Preparation
☐ Engineering	☐ Supervisor
☐ Foreman	☐ Truck Driver
☐ Framing	☐ Welder
☐ Laborer	☐ Other ________________

Appendix D - Questionnaires (Spanish)

Cuestionario acerca del clima de seguridad - Adaptado de (Dedobbeleer & Béland, 1991)

Por favor responda a las siguientes declaraciones marcando una √ o una ***X*** *en el cuadro que mas representa su opinión acerca de su trabajo presente. Solamente haga una marca por pregunta.*

	Fuertemente en desacuerdo	En Desacuerdo	Ni de acuerdo o en desacuerdo	De Acuerdo	Fuertemente en acuerdo
1. Pienso que las prácticas de seguridad del trabajador es importante para mis encargados.					
2. Los supervisores y otros encargados superiores parecen preocuparse sobre mi seguridad.					
3. Mi capataz acentúa prácticas de seguridad en el trabajo.					
4. Me dieron instrucciones en los procedimientos de seguridad y los requisitos de seguridad de la compañía cuando mi patrón me contrato.					
5. Hay reuniones regulares de seguridad del trabajo en mi actual sitio del trabajo.					
6. Hay equipo apropiado disponible para nuestras tareas en este sitio del trabajo.					
7. Yo siento que tengo control sobre mi seguridad en el trabajo.					
8. Tomar riesgos es parte del trabajo.					
9. Pienso que soy probable en ser lastimado en el trabajo en el próximo período de 12 meses.					

Comportamientos Percibidos del Riesgo - Adaptado de (Rundmo, 2000)

	A Menudo	A veces	Nunca
10. Yo corro riesgos para completar el trabajo.			
11. Doblo las reglas para alcanzar una meta producción			
12. Yo me arriesgo para completar el trabajo.			
13. La tensión en el trabajo me impide seguir las reglas.			
14. Rompo las reglas de seguridad debido a la presión de la gerencia			
15. Ignoro cuando las reglas de seguridad son rotas.			

Cuestionario de Craftsman - Adaptado de (Oglesby et al., 1989)

*Por favor responda a las siguientes declaraciones marcando una √ o una **X** en el cuadro que mas representa su opinión acerca de su trabajo presente. Solamente haga una marca por pregunta.*

16. Tengo que parar de trabajar y esperar o trasladarme a otra tarea porque no tengo los materiales necesarios para hacer el trabajo.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

17. ¿Cuántas horas por semana usted piensa que pasa esperando por los materiales, consiguiendo los materiales de alguna parte o trasladándose a otra área porque los materiales no están disponibles?
☐Menos de 1 ☐1-2 ☐2-3 ☐3-4 ☐4-5 ☐mas de 5

18. Tengo que parar el trabajo y esperar o trasladarme a otra tarea porque no tengo las herramientas necesarias para terminar el trabajo.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

19. ¿Cuántas horas por semana usted piensa que pasa esperando por las herramientas apropiadas, consiguiendo las herramientas, o trasladándose a otra área porque las herramientas apropiadas no están disponibles?
☐Menos de 1 ☐1-2 ☐2-3 ☐3-4 ☐4-5 ☐mas de 5

20. Tengo que parar el trabajo y esperar o trasladarme a otra tarea porque no tengo el equipo de producción necesario para terminar el trabajo.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

21. ¿Cuántas horas por semana usted piensa que pasa esperando por el equipo de producción, consiguiendo el equipo de producción, o trasladándose a una otra área porque el equipo de producción no está disponible?

☐Menos de 1 ☐1-2 ☐2-3 ☐3-4 ☐4-5 ☐mas de 5

22. Tengo que parar el trabajo y esperar o trasladarme a otra tarea porque no tengo el equipo de seguridad necesario para terminar el trabajo.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

23. ¿Cuántas horas por semana usted piensa que pasa esperando por el equipo de seguridad, consiguiendo el equipo de seguridad, o trasladándose a otra área porque el equipo de seguridad no esta disponible?
☐Menos de 1 ☐1-2 ☐2-3 ☐3-4 ☐4-5 ☐mas de 5

24. En su opinión, enumere el equipo de seguridad que a menudo esta corto de abastecimiento.
____.

25. Yo paso tiempo haciendo trabajo terminado otra vez (rehacer).
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

26. ¿Cuántas horas por semana usted piensa que pasa haciendo trabajo terminado otra vez (rehacer)?
☐Menos de 1 ☐1-2 ☐2-3 ☐3-4 ☐4-5 ☐mas de 5

27. Por favor liste las causas por las cuales tiene que hacer un trabajo terminado otra vez:
____

28. A menudo paso tiempo esperando por alguien que provea la información que necesito para hacer mi trabajo.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

29. ¿Cuantas horas por semana usted piensa que pierde porque está esperando la información que necesita para hacer su trabajo?
☐ Menos de 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ 4-5 ☐ mas de 5

30. A menudo paso tiempo esperando por alguien que traduzca (lenguaje) la información que necesito para hacer mi trabajo.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

31. ¿Cuántas horas por semana usted piensa que pierde porque está esperando las traducciones (lenguaje) que necesita para hacer su trabajo?
☐ Menos de 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ 4-5 ☐ mas de 5

32. Los materiales tienen que ser movidos a menudo a una localización diferente de donde fueron entregados.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

33. ¿Cuántas horas por semana usted piensa que pasa moviendo materiales a una localización diferente de donde fueron entregados?
☐ Menos de 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ 4-5 ☐ mas de 5

34. Tengo que parar de trabajar y esperar o trasladarme a otra tarea porque no tengo el equipo para mover los materiales.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

35. ¿Cuántas horas por semana usted piensa que pasa buscando equipo para mover los materiales?
☐ Menos de 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ 4-5 ☐ mas de 5

36. Si no puedo encontrar el equipo, yo mismo muevo los materiales manualmente.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

37. ¿Cuántas horas por semana usted piensa que pasa moviendo materiales manualmente?
☐ Menos de 1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ 4-5 ☐ mas de 5

38. Yo recibo claramente prioridades diarias de la tarea.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

39. Yo recibo fechas claras de la finalización del trabajo.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

40. Siento un alto grado de propiedad personal por este trabajo.
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

41. Siento un alto grado de propiedad personal para alcanzar metas diarias de la tarea..
☐ Nunca ☐ Raramente ☐ De vez en cuando ☐ A menudo ☐ Siempre

Cuestionario Demográfico

*Por favor responda a las siguientes declaraciones marcando una √ o una **X** en el cuadro que mas representa su opinión acerca de su trabajo presente. Solamente haga una marca por pregunta.*

42. Edad ______________________________		
43. Grupo Étnico/Racial	☐ Afro Americano	☐ Hispano/Latino
	☐ Indio Americano	☐ Europeo
	☐ Asiático	☐ Extranjero no residente
	☐ Blanco	☐ Otro _______________.
44. ¿Cuanto tiempo usted lleva trabajando para esta compańia?	☐ Menos de 1 mes	☐ 1-5 años
	☐ Menos de 3 meses	☐ 5-10 años
	☐ 3-6 meses	☐ 10-20 años
	☐ 6-12 meses	☐ Sobre 20 años
45. ¿Cuanto tiempo usted ha trabajado en construcción residencial?	☐ Menos de 1 mes	☐ 1-5 años
	☐ Menos de 3 meses	☐ 5-10 años
	☐ 3-6 meses	☐ 10-20 años
	☐ 6-12 meses	☐ Sobre 20 años
46. ¿Usted habla Ingles?	☐ Sí	☐ No
47. ¿Usted lee en Ingles?	☐ Sí	☐ No
48. ¿Usted escribe en Ingles?	☐ Sí	☐ No

49. ¿Tuvo usted un adiestramiento de seguridad en el trabajo administrado por su patrono?

☐ Sí ☐ No

50. Si contesto sí a la pregunta #49, Por favor describa que tipo de adiestramiento tuvo.

____

____

51. ¿Ha tenido usted un accidente en el trabajo?

☐ Sí ☐ No

52. Si contesto sí a la pregunta #51, Por favor describa que tipo de accidente tuvo.

____

____

53. ¿En que posición trabaja usted?

☐ Albañilería ladrillos	☐ Moviendo materiales
☐ Carpintería.	☐ Misceláneo
☐ Fundación/Concreto	☐ Pintura / Paredes
☐ Manejo de construcción	☐ Plasterer (Trabador de yeso)
☐ Operador de grúa	☐ Plomería, calefacción & A/C
☐ Diseño	☐ Manejo de Proyecto
☐ Placa de yeso y Aislamiento	☐ Techado/ Techos
☐ Electricidad	☐ Preparación de obra
☐ Ingeniería	☐ Supervisor
☐ Capataz	☐ Conductor de camión
☐ Armazón	☐ Soldador
☐ Laborados	☐ Otro ________________

Appendix E - Script for Recruiting Workers

Recruitment Script for Participation

Script for Job Foreman

Questionnaire administrator: May I please speak to the job foreman?

Potential Participant: Identifies the foreman.

Questionnaire administrator: My name is [co-PIs] and I am a *doctoral student* in the department of Industrial and Systems Engineering at Virginia Tech. I am currently conducting research on safety and productivity perceptions and behaviors in construction work.

I would like to invite your workers to participate in this research. I am happy to briefly explain the study to you.

Potential Participant: Please go ahead.
OR
Potential Participant: I am sorry. My workers are not available to participate in your study.

Questionnaire administrator: Thank you.[Go through the informed consent information]. If you are fine with the study, can I approach the workers to invite them to participate?
OR
Questionnaire administrator: Thank you.

Potential Participant: Yes.
OR
Potential Participant: No.

Questionnaire administrator: Thank you

Script for Workers

Questionnaire administrator: My name is [co-PIs] and I am a *doctoral student* in the department of Industrial and Systems Engineering at Virginia Tech. I am currently conducting research on safety and productivity perceptions and behaviors in construction work.

I would like to invite you to participate in this research. I am happy to briefly explain the study to you.

Potential Participant: Please go ahead.
OR
Potential Participant: I do not wish to participate in the study.

Questionnaire administrator: Thank you.[Go through the informed consent information].
OR
Questionnaire administrator: Thank you.

Appendix F - Informed Consents Phase I and Phase II (English)

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants in Research Projects Involving Human Subjects

Title of Project:

An Evaluation of Perceived and Observed Safety and Productivity in Homebuilding Construction (Phase I)

Principal Investigators:

Brian M. Kleiner, PhD
Elizabet Haro, Industrial and Systems Engineering Graduate Student

PURPOSE OF PROJECT

The purpose of this research is to evaluate the relationship between perceived safety climate, perceived risk behavior and perceived productivity in residential homebuilding crews.

PROCEDURES

You will be asked to read and sign the informed consent form for this study. Once the informed consent form is completed, the researcher will provide you with a questionnaire that will ask information about your perception of safety, risk, and productivity related to your current workplace. Additionally some general question regarding your experience will be included. It is expected that completion of the questionnaire will take approximately 30 minutes.

RISKS

Participation in this project does not put you at more than daily risk.

BENEFITS

Your participation in this study is voluntary. It will help gain an understanding of the relationship between perceived safety, risk and productivity. It is expected that understanding this relationship will help reduce the number of accidents and injuries in the construction industry.

CONFIDENTIALITY

The results of this research will be kept strictly confidential. The questionnaires will be anonymous including only a code to identify the work group. Data will be stored securely and will be made available only in the context of research publications and discussion. No reference will be made in oral or written reports, which could link you to the data, nor will you ever be identified as a participant in this project.

FREEDOM TO WITHDRAW

You are free to withdraw from this study at any time without penalty.

APPROVAL OF THE RESEARCH

This research has been approved by the Institution Review Board for research projects involving human participants at Virginia Polytechnic Institute and State University. A copy of this form will be provided to you.

PARTICIPANTS' RESPONSIBILITIES

It is important that you keep the activities and information discussed confidential, since others will be participating in the research.

PARTICIPANT'S PERMISSION

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

____ ______________

Subject signature Date

____

Printed Name

CONTACT

If you have questions at any time about the project or the procedures, you may contact:

Principal Investigator:	Elizabet Haro Graduate Student, Grado Department of Industrial and Systems Engineering Email: eharo@vt.edu Phone: (540) 230-4575
Faculty Advisor:	Dr. Brian M. Kleiner Professor, Grado Department of Industrial and Systems Engineering

	Email: bkleiner@vt.edu Phone: (540) 231-4926

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant have been violated during the course of this project, you may contact Dr. David Moore, Chair of the Institutional Review Board Research Division at 540-231-4991.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants in Research Projects Involving Human Subjects

Title of Project:

An Evaluation of Perceived and Observed Safety and Productivity in Homebuilding Construction (Phase II)

Principal Investigators:

Brian M. Kleiner, PhD
Elizabet Haro, Industrial and Systems Engineering Graduate Student

PURPOSE OF PROJECT

The objective of phase two is to use questionnaires, video data collection techniques and field observations to understand the difference between your perception and behavior regarding safety and productivity at work. This work is part of a dissertation project. Although the results will be published in journals, no reference will be made which could link you to the data.

PROCEDURES

You will be asked to read and sign the informed consent form for this study. Once the informed consent form is completed, the researcher will provide you with a questionnaire that will ask information about your perception of safety, risk, and productivity related to your current workplace. Additionally some general questions regarding your experience will be included. It is expected that completion of the questionnaire will take approximately 30 minutes.

The researcher will videotape your crew for eight hours. Two stationary cameras will be positioned on the right and left side of the job site. Additionally, a data collector will complete “general observation” logs. The data collector will wear a camera mounted on his/her hardhat. This will allow for additional footage, specifically in locations that are hard to reach by the stationary cameras. You are asked to carry out your daily activities.

RISKS

Participation in this project does not put you (the participant) at more than daily risk.

There may be minimal risks for the observer introduced by wearing a video-taping & recording system. 1) The strength of a hard hat was not tested by adding a camera onto it.
2) The cable which connects the camera to the digital video recorder in the vest may affect his/her dexterity.

BENEFITS

Your participation in this study is voluntary. It will help gain an understanding of the relationship between perceived and observed safety, risk and productivity. It is expected that understanding this relationship will help reduce the number of accidents and injuries in the construction industry.

CONFIDENTIALITY

The results of this research will be kept strictly confidential. The questionnaires will be anonymous, including only a code to identify the work group. The videos will be confidential and will not be shared with the employer.

Data will be stored securely and will be made available only in the context of research publications and discussion. No reference will be made in oral or written reports, which could link you to the data, nor will you ever be identified as a participant in this project.

FREEDOM TO WITHDRAW

You are free to withdraw from this study at any time without penalty.

APPROVAL OF THE RESEARCH

The Institution Review Board for research projects involving human participants at Virginia Polytechnic Institute and State University has approved this research. A copy of this form will be provided to you.

PARTICIPANTS' RESPONSIBILITIES

It is important that you keep the activities and information discussed confidential, since others will be participating in the research.

PARTICIPANT'S PERMISSION

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

____ __________________

Subject signature Date

____

Printed Name

CONTACT

If you have questions at any time about the project or the procedures, you may contact:

Principal Investigator:	Elizabet Haro Graduate Student, Grado Department of Industrial and Systems Engineering Email: eharo@vt.edu Phone: (540) 230-4575
Faculty Advisor:	Dr. Brian M. Kleiner Professor, Grado Department of Industrial and Systems Engineering Email: bkleiner@vt.edu Phone: (540) 231-4926

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant have been violated during the course of this project, you may contact Dr. David Moore, Chair of the Institutional Review Board Research Division at 540-231-4991.

Appendix G - Informed Consents Phase I and Phase II (Spanish)

INSTITUTO POLITÉCNICO Y UNIVERSIDAD ESTATAL DE VIRGINIA
Formulario de Consentimiento Informado Para Participantes en Proyectos de Investigaciones que Incluyen Sujetos Humanos

Titulo del Proyecto:

Una evaluación de la percepción y observación de la seguridad y productividad en el trabajo en construcción residencial (Parte I).

Investigadores Principales:

Brian M. Kleiner, PhD
Elizabet Haro, Estudiante Graduada, Departamento Grado de Ingeniería Industrial y Sistemas

PROPOSITO DEL PROJECTO

El propósito de esta investigación es evaluar la relación entre el clima de seguridad percibido, el comportamiento arriesgado percibido y la productividad percibida en equipos de trabajo en la construcción residencial de casas.

PROCEDIMIENTO

A usted se le pedirá que lea y firme el Formulario de Consentimiento Informado para este estudio. Después que el Formulario de Consentimiento Informado haya sido completado, la investigadora le proveerá con un cuestionario que preguntara información acerca de su percepción de la seguridad en el trabajo, riesgos y productividad relacionados con su presente empleo. Adicionalmente, preguntas generales acerca de su experiencias en el trabajo serán incluidas. Se espera que completar este cuestionario demorara aproximadamente 30 minutos.

RIESGOS

Su participación en este proyecto no lo pondrá en mas riesgo de lo normal.

BENEFICIOS

Su participación en este estudio es voluntaria. Esta ayudara a el entendimiento de la relación entre la seguridad, el riesgo y la productividad percibida. Se espera que entender esta relación ayude a reducir el numero de accidentes y lesiones en la industria de construcción.

CONFIDENCIALIDAD

Los resultados de esta investigación serás mantenidos estrictamente confidencial. Los cuestionarios serán anónimos; solamente un código será incluido para identificar su grupo de trabajo. La data será guardada seguramente y estará disponible únicamente en el contexto de publicaciones y discusiones de la investigación. Ninguna referencia será hecha en reportes orales o escritos que puedan identificarlo a usted con la data. Usted nunca será identificado como un participante en este proyecto

LIBERTAD EN RETIRARSE

Usted estará libre de retirarse de este estudio en cualquier momento sin ningún tipo de penalización.

APRUEVO DE LAS INVESTIGACION

Esta investigación ha sido aprobada por el Grupo Institucional de Investigaciones para Proyectos de Investigaciones Científicas que incluyen sujetos humanos en El Instituto Politécnico y Universidad Estatal de Virginia. Una copia de este formulario se le proveerá a usted.

REPONSABILIDAD DEL PARTICIPANTE

Es importante que usted mantenga en confidencialidad las actividades e información discutidas en este proyecto, debido a que otros empleados estarán participando también en la misma investigación científica.

PERMISO DEL PARTICIPANTE

Yo he leído y entiendo el Formulario de Consentimiento Informado y las condiciones de este proyecto. Todas mis preguntas han sido contestadas. Yo, reconozco la información incluida y doy mi consentimiento voluntario para la participación en este proyecto.

____ ____________
Firma del Participante Fecha

____
Nombre en Letra de Molde

CONTACTO

Si usted tiene preguntas sobre el proyecto o los procedimientos, usted puede contactar:

Investigadora Principal:	Elizabet Haro Estudiante Graduada, Departamento Grado de Ingeniería Industrial y Sistemas Correo electrónico: eharo@vt.edu

	Teléfono: (540) 230-4575
Consejero de facultad:	Dr. Brian M. Kleiner Profesor, Departamento Grado de Ingeniería Industrial y Sistemas Correo electrónico: bkleiner@vt.edu Teléfono: (540) 231-4926

Si usted siente que no se le a tratado de acuerdo con la descripción de este formulario, o piensa que sus derechos como participante han sido violados durante este proyecto, por favor comuníquese con el Dr. David Moore, Gerente de la División de Repasos Institucionales de Investigación al 540-231-4991.

INSTITUTO POLITÉCNICO Y UNIVERSIDAD ESTATAL DE VIRGINIA
Formulario de Consentimiento Informado Para Participantes en Proyectos de Investigaciones que Incluyen Sujetos Humanos

Titulo del Proyecto:

Una evaluación de la percepción y observación de la seguridad y productividad en el trabajo en construcción residencial (Parte II).

Investigadores Principales:

Brian M. Kleiner, PhD
Elizabet Haro, Estudiante Graduada, Departamento Grado de Ingeniería Industrial y Sistemas

PROPOSITO DEL PROJECTO

El propósito de esta investigación es usar cuestionarios, técnicas de recolección de datos de vídeo, y observaciones para entender la diferencia entre la percepción y el comportamiento de seguridad y productividad en el trabajo. Este trabajo es parte de un proyecto de tesis. Aunque los resultados serán publicados en revistas, ninguna referencia será hecha que lo pueda identificar a usted con la data.

PROCEDIMIENTO

A usted se le pedirá que lea y firme el Formulario de Consentimiento Informado para este estudio. Después que el Formulario de Consentimiento Informado haya sido completado, la investigadora le proveerá con un cuestionario que preguntara información acerca de su percepción de la seguridad en el trabajo, riesgos y productividad relacionados con su presente empleo. Adicionalmente, preguntas generales acerca de su experiencias en el trabajo serán incluidas. Este cuestionario demorara aproximadamente 30 minutos en completar.

La investigadora grabara a su equipo de trabajo por ocho oras. Dos cámaras estacionarias serán puestas en la derecha y izquierda de la obra. Adicionalmente, la investigadora completara observaciones generales. La investigadora usara una cámara montada en el casco. Esto ayudara a coleccionar videos adicionales en lugares que son difícil de alcanzar con la cámara estacionarias. Se le pedirá que siga sus actividades diarias.

RIESGOS

Su participación en este proyecto no lo pondrá (al participante) en mas riesgo de lo normal.

Puede haber riesgos mínimos para la observadora por usar el sistema de video:
1) La fuerza del casco no fue probada con la cámara añadida, 2) El cable que conecta la cámara al a grabadora de video en el chaleco puede afectar la destreza.

BENEFICIOS

Su participación en este estudio es voluntaria. Esta ayudara a el entendimiento de la relación entre la seguridad, el riesgo y la productividad percibida. Se espera que entender esta relación ayude a reducir el numero de accidentes y lesiones en la industria de construcción.

CONFIDENCIALIDAD

Los resultados de esta investigación serás mantenidos estrictamente confidencial. Los cuestionarios serán anónimos; solamente un código será incluido para identificar su grupo de trabajo. Los videos serán confidenciales y NO serán compartidos con el empleador.

La data será guardada seguramente y estará disponible únicamente en el contexto de publicaciones y discusiones de la investigación. Ninguna referencia será hecha en reportes orales o escritos que puedan identificarlo a usted con la data. Usted nunca será identificado como un participante en este proyecto

LIBERTAD EN RETIRARSE

Usted estará libre de retirarse de este estudio en cualquier momento sin ningún tipo de penalización.

APRUEVO DE LAS INVESTIGACION

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____ ____________
Firma del Participante Fecha

Nombre en Letra de Molde

CONTACTO

Si usted tiene preguntas sobre el proyecto o los procedimientos, usted puede contactar:

Investigadora Principal:	Elizabet Haro Estudiante Graduada, Departamento Grado de Ingeniería Industrial y Sistemas Correo electrónico: eharo@vt.edu Teléfono: (540) 230-4575
Consejero de facultad:	Dr. Brian M. Kleiner Profesor, Departamento Grado de Ingeniería Industrial y Sistemas Correo electrónico: bkleiner@vt.edu Teléfono: (540) 231-4926

Si usted siente que no se le a tratado de acuerdo con la descripción de este formulario, o piensa que sus derechos como participante han sido violados durante este proyecto, por favor comuníquese con el Dr. David Moore, Gerente de la División de Repasos Institucionales de Investigación al 540-231-4991.

Appendix H - Camera Video Times

25-Mar

	C1 On	C1 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	C2 On	C2 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	Offset (s)
Tape1	8:02 AM	9:25 AM	1:23	5100		1:25:03	8:03 AM	9:26 AM	1:23	4920		1:22:00	78
Tape2	9:28 AM	11:00 AM	1:32	5520	10620	1:32:22	9:29 AM	11:02 AM	1:33	5520	10440	1:32:46	10
Tape3	11:02 AM	12:34 PM	1:32	5520	16140	1:32:00	11:03 AM	12:36 PM	1:33	5280	15720	1:28:34	34
Tape4	12:35 PM	2:07 PM	1:32	5460	21600	1:31:58	12:37 PM	2:09 PM	1:32	5460	21180	1:31:54	10
Tape5	2:08 PM	3:35 PM	1:27	5220	26820	1:27:16	2:09 PM	3:36 PM	1:27	5100	26280	1:25:22	77
Tape6	3:38 PM	4:45 PM	1:07	3960	30780	1:06:59	3:39 PM	4:46 PM	1:07	3840	30120	1:04:33	11

9-Apr

	C1 On	C1 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	C2 On	C2 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	Offset
Tape1	8:02 AM	9:35 AM	1:33	5520		1:32:44	8:04 AM	9:37 AM	1:33	5520		1:32:54	65
Tape2	9:42 AM	11:12 AM	1:30	5400	10920	1:30:00	9:44 AM	11:15 AM	1:31	4680	10200	1:18:00	559
Tape3	11:15 AM	12:41 PM	1:26	5100	16020	1:25:40	11:16 AM	12:42 PM	1:26	5100	15300	1:25:40	155
Tape4	12:42 PM	2:14 PM	1:32	5460	21480	1:31:54	12:43 PM	2:16 PM	1:33	5400	20700	1:30:37	120
Tape5	2:15 PM	3:40 PM	1:25	5040	26520	1:24:31	2:17 PM	3:42 PM	1:25	4920	25620	1:22:54	911
Tape6	3:42 PM	4:30 PM	0:48	2880	29400	0:48:00	3:43 PM	4:30 PM	0:47	2820	28440	0:47:41	145
Batt	3:26 PM	3:27 PM											
Lunch	12:05 PM	12:41 PM											

	5-May												
	C1 On	C1 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	C2 On	C2 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	Offset
Tape1	8:34 AM	9:35 AM	1:01	3660		1:00:46	8:35 AM	9:38 AM	1:03	3900		1:04:29	60
Tape2	9:36 AM	11:09 AM	1:33	5580	9240	1:32:00	9:39 AM	11:11 AM	1:32	5520	9420	1:32:39	120
Tape3	11:10 AM	1:44 PM	2:34	5640	14880	1:32:10	11:13 AM	1:47 PM	2:34	5640	15060	1:30:01	112
Tape4	1:46 PM	3:18 PM	1:32	5520	20400	1:31:54	1:48 PM	3:20 PM	1:32	5520	20580	1:32:26	132
Tape5	3:20 PM	4:40 PM	1:20	4800	25200	0:59:26	3:21 PM	4:40 PM	1:19	4740	25320	0:58:17	100
Lunch	12:30 PM	1:30 PM											

	13-Jul	14-Jul											
	C1 On	C1 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	C2 On	C2 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	Offset
Tape1	8:31 AM	10:02 AM	1:31	5460		1:16:17	8:32 AM	10:06 AM	1:34	5640		1:26:20	93
Tape2	10:06 AM	11:38 AM	1:32	5520	10980	1:23:00	10:07 AM	11:41 AM	1:34	5640	11280	1:33:14	54
Tape3	11:41 AM	1:07 PM	1:26	5160	16140	1:21:38	11:43 AM	1:07 PM	1:24	5040	16320	1:19:12	99
Tape4	7:07 AM	8:40 AM	1:33	5580	21720	1:32:54	7:08 AM	8:43 AM	1:35	5700	22020	1:13:07	72
Tape5	8:43 AM	10:14 AM	1:31	5460	27180	1:32:00	8:44 AM	10:15 AM	1:31	5460	27480	1:32:02	120
Tape6	10:15 AM	11:06 AM	0:51	3060	30240	0:53:08	10:17 AM	11:10 AM	0:53	3180	30660	0:53:00	84
Lunch	12:07	12:52											

21-Jul

	C1 On	C1 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	C2 On	C2 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	Offset
Tape 1 - Part1	7:41 AM	9:13 AM	0:26	1560		1:32:00	7:42 AM	9:15 AM	0:26	1560			0
Tape 1- Part2			1:06	3960	5520				0:49	2940	4500		1586
Tape 2	9:14 AM	10:47 AM	1:33	5580	11100	1:31:59	9:16 AM	10:49 AM	1:33	5580	10080	1:33:16	82
Tape 3	10:48 AM	12:20 PM	1:32	5520	16620	1:31:52	10:50 AM	12:22 PM	1:32	5520	15600	1:32:16	102
Tape 4	12:21 PM	1:54 PM	1:33	5580	22200	1:33:15	12:23 PM	1:57 PM	1:34	5640	21240	1:32:52	177
Tape 5	1:56 PM	3:17 PM	1:21	4860	27060	1:21:01	1:58 PM	3:22 PM	1:24	5040	26280	1:23:48	126
Tape 6	3:21 PM	3:50 PM	0:29	1740	28800	0:28:40	3:23 PM	3:50 PM	0:27	1620	27900	0:27:52	72
Lunch	1:09 PM	2:16 PM											

20-Aug

	C1 On	C1 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	C2 On	C2 Off	Diff (hr:m)	Diff (s)	Total (s)	Actual On	Offset
Tape 1	8:20 AM	9:50 AM	1:30	5400		1:30:00	8:21 AM	9:53 AM	1:32	5520		1:32:00	78
Tape 2	9:52 AM	11:24 AM	1:32	5520	10920	1:31:05	9:54 AM	11:27 AM	1:33	5580	11100	1:33:15	54
Tape 3	11:26 AM	12:58 PM	1:32	5520	19140	1:30:36	11:29 AM	12:59 PM	1:30	5400	19200	1:31:29	98
Tape 4	1:45 PM	3:13 PM	1:28	5280	24420	1:29:56	1:45 PM	3:15 PM	1:30	5400	24600	1:13:33	65
Tape 5	3:14 PM	4:14 PM	1:00	3600	28020	1:09:26	3:16 PM	4:15 PM	0:59	3540	28140	0:54:45	120
Lunch	1:00 PM	1:44 PM											

Appendix I - Coding Manual

Objectives:

1. Evaluate field ratings.
2. Evaluate safety ratings.
3. Evaluate waste ratings.

Process for Field Ratings:

Activity sampling will be used to evaluate 1) Labor productivity, 2) Safe Behaviors and 3) Presence of waste. Sampling, involves observing and classifying a percentage of some whole of obtain a representation via a statistically valid sample. Field observations will be recorded and analyzed to understand the activity level of framing operations.

Field Ratings (Behaviors in Noldus):

Working	Not Working
- Carrying material or holding or supporting material - Participating in active physical work - Measuring - Laying out - Reading blueprints - Filling in time cards - Writing orders - Giving instructions - Holding a tag line - Supporting a ladder - Operating a machine - Operating equipment	- Waiting for another to finish work - Talking while not actively working - Attending self-operating machines - Walking about empty handed - Riding

Guidelines:

- Equipment is the set of articles of physical resources serving to equip yourself (i.e. the tools on their tool belts: hammers, markers, screwdriver, pencils and/or safety equipment).
- Machines include electrical components (i.e. electric drills, electric saws, electric nail guns).
- Waiting for another – worker is awaiting tools, measuring, cutting, lumber, etc.

Recommendations for appropriate field rating techniques include (Oglesby et al., 1989):

- At least 75% of the personnel must be in the sample (5 workers).
- The rating should be taken at the first instant of observation. The observer should not bias the result y speculating about whether or not the subject was or will be active a moment before or after the observation.
- Counts should not begin until at least ½ hour after the worker start or return to work or closer than ½ hour until quitting time (lunch or end of day).
- No counts should be discarded.

Process for Safety Behavior Ratings:

Safe	Not Safe
- Appropriate personal protective equipment used (PPE) - Eye protection is used in any situation where damage to the eye as a result of flying particles may occur (including nail guns) - Tools are used for their intended purposes - Tools are stored away when not being used - Ladders are used properly - Both hands must be used when climbing extension ladders - Power saws have blade guards - Saws turned off before leaving them unattended - Tools are raised and lowered by their handles - Worker stays clear of backing and turning vehicle - Backup warning systems are functioning properly - Flaggers are used when the operator is unable to see	- No hard hat worn while on the jobsite - No boots worn - No eye protection worn where damage to the eye as a result of flying particles may occur (including nail guns) - No boots or hard hats worn - Tools used for alternative purposes (other than their intended function) - Tools are not stored away after use - Ladders used for other than their intended function - Both hands are not used when climbing extension ladders - Power saws do not have blade guards - Saws kept running while unattended - Tools are raised and lowered by their cords - Workers slips (trash, debris, materials) - Worker trips (trash, debris, materials) - Ramps don't have cleats - Lifting panels while climbing ladder - Worker does not stay clear of backing and turning vehicles - Backup warning systems are not functioning properly - Flaggers are not used when the operator is unable to see

Guidelines

- For multiple behaviors, the unsafe behavior should be coded
- For multiple safe behaviors, select one
- For multiple unsafe behaviors, select one

Recommendations for appropriate field rating techniques include :

- At least 75% of the personnel must be in the sample (5 workers).
- The rating should be taken at the first instant of observation. The observer should not bias the result y speculating about whether or not the subject was or will be active a moment before or after the observation.
- Counts should not begin until at least ½ hour after the worker start or return to work or closer than ½ hour until quitting time (lunch or end of day).
- No counts should be discarded.

Both hands must be placed on extension ladders (NAHB-OSHA, 2007):	
Saw blade must be guarded (NAHB-OSHA, 2007):	
Hard hats must be worn correctly at all times. Eye protection should used in any situation where damage to the eye as a result of flying particles may occur (including nail guns) (NAHB-OSHA, 2007):	

Process for non-contributory work (Waste)

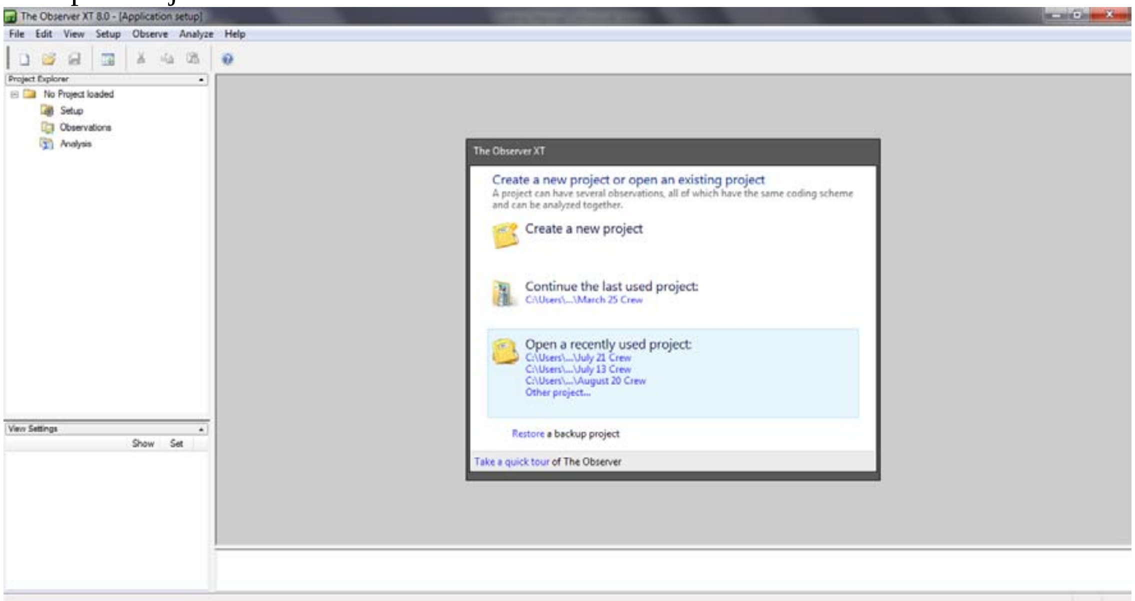
Non-contributory (Waste) work – work that is not necessary or adds no value to complete the work. This can include work inactivity or ineffective work.

		Guidelines
Waiting	Operations delayed by (not enough/missing) materials or parts	
	Material alteration – material does not comply with specifications	- Altering constructed material (ie. Panels) - Damaged or broken plywood
	Worker has to perform equipment maintenance	
	Shortage of PPE	- Workers sharing personal protection equipment.
	Shortage of production equipment	- Workers sharing equipment - Worker needs to wait for others to finish with equipment
	Work area is overcrowded	- Movement is altered to accommodate other workers
	Bad weather delays progress	- Weather conditions that stop the work
	Need for rework	The unnecessary effort of redoing a process or activity that was incorrectly implemented the first time - Errors - Damage to material - De-installing
	Need for clarification of drawing	- More than one worker reviewing drawing
Idle Time	Worker is idle	- Worker not doing any work
	Too many workers working on task, worker has nothing to do	- Allocated to worker no performing a task
Traveling Time	Worker has to look for tools	
	Worker has to locate resources (power, extension cord)	
	Worker has to take longer route due to site conditions	- Shorter path exists but contains materials, debris

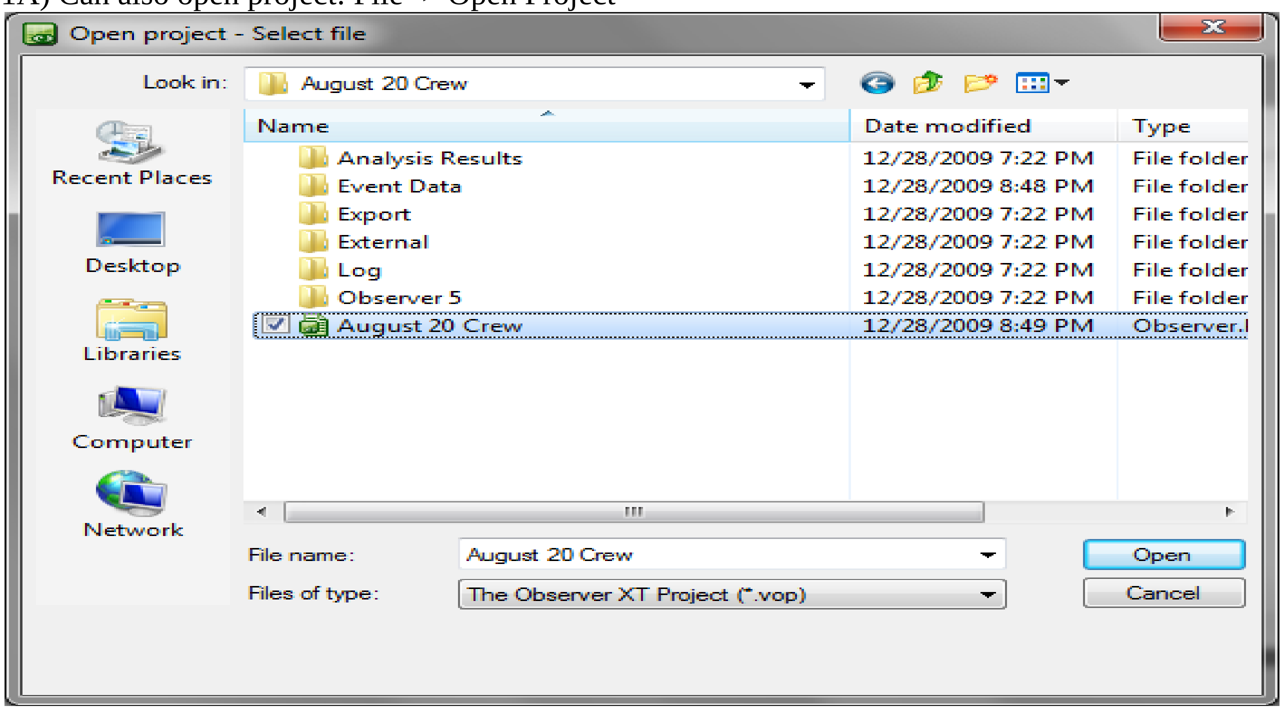
	Worker has to step over materials/debris – poor housekeeping	- Worker is not carrying materials
	Worker walking around aimlessly	
Transportation	Transportation requires manual material handling by worker	- Materials are moved manually; all workers involved should be coded
	Worker has to step over material/debris – poor housekeeping	- Worker is transporting material
	Worker has to take longer route due to site conditions	- Shorter path exists but contains materials, debris
No Waste	No waiting, idle, traveling or transportation waste	

Noldus Instructions:

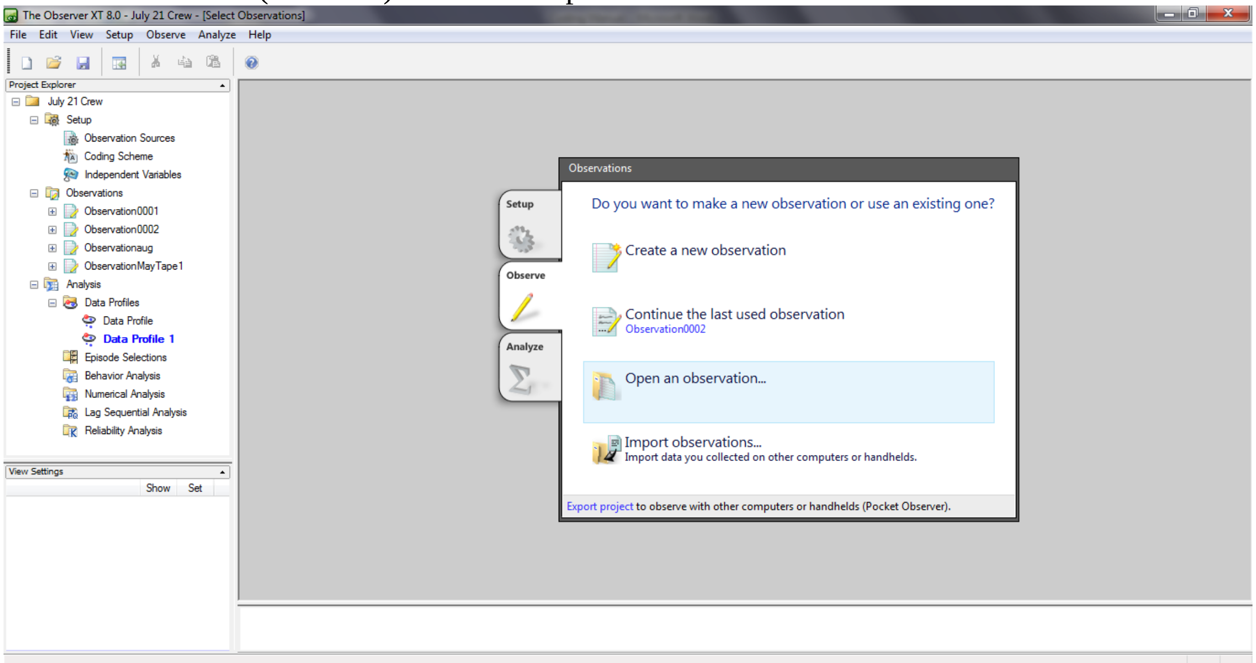
1. Open Project



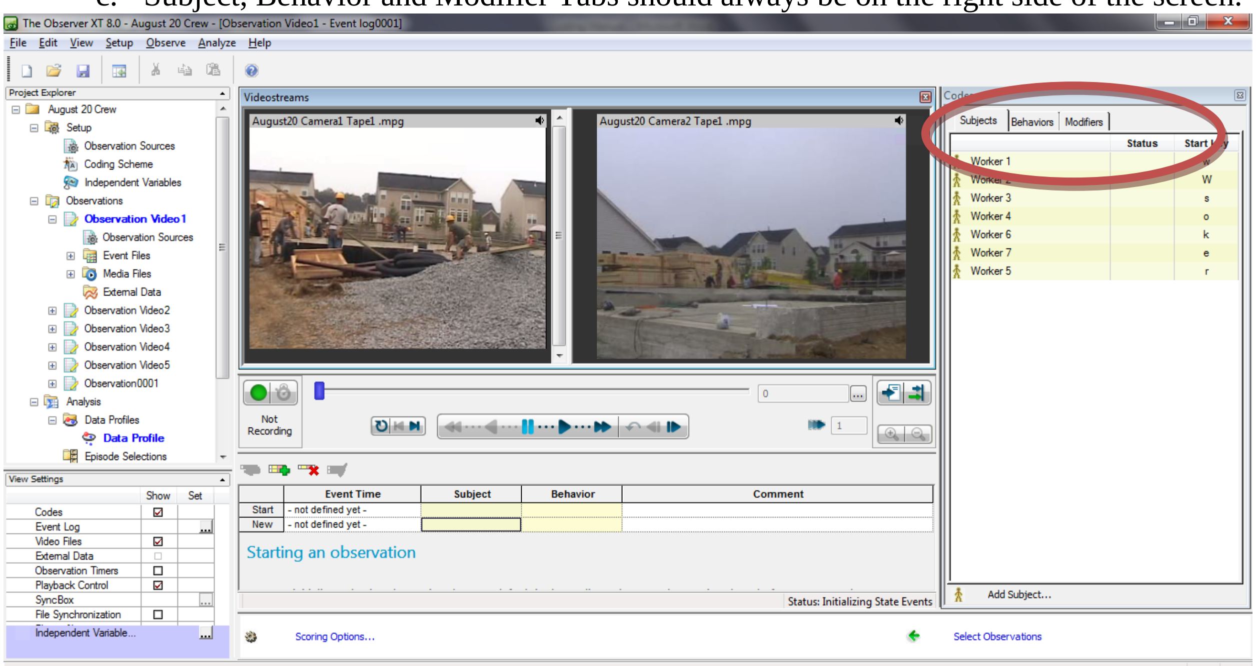
1A) Can also open project: File -> Open Project



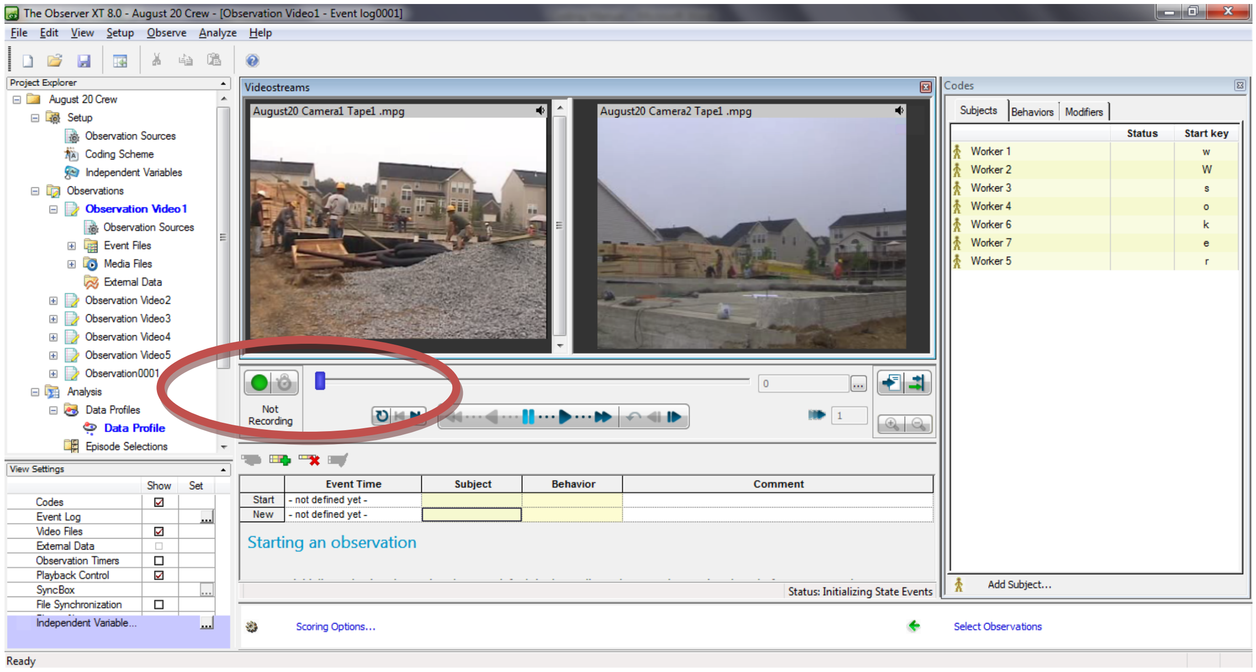
2. Select Observe Tab (Side Tab) and Select Open an Observation



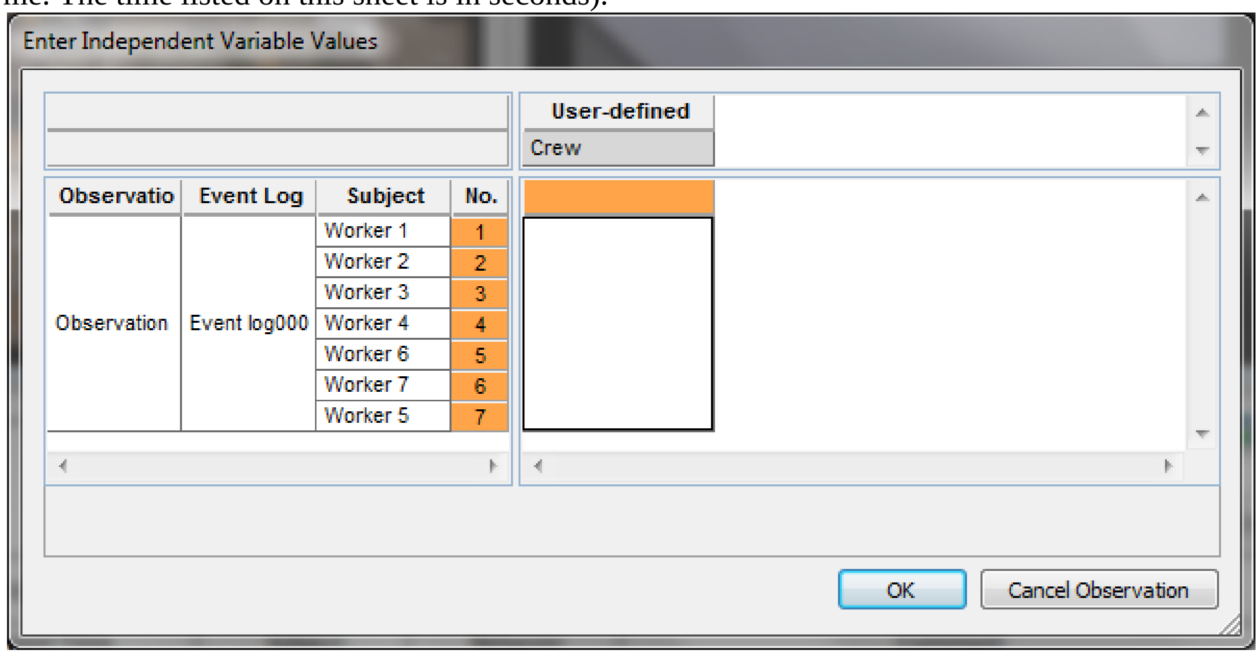
3. Review Observation Set up prior to beginning
   a. Two videos should appear in a split screen (adjust screen to fit both videos if necessary).
   b. Camera1 video should always be on the left side. If camera1 video is on the right side, click the video for swapping.
   c. Subject, Behavior and Modifier Tabs should always be on the right side of the screen.



4. Select Green light to start the observation

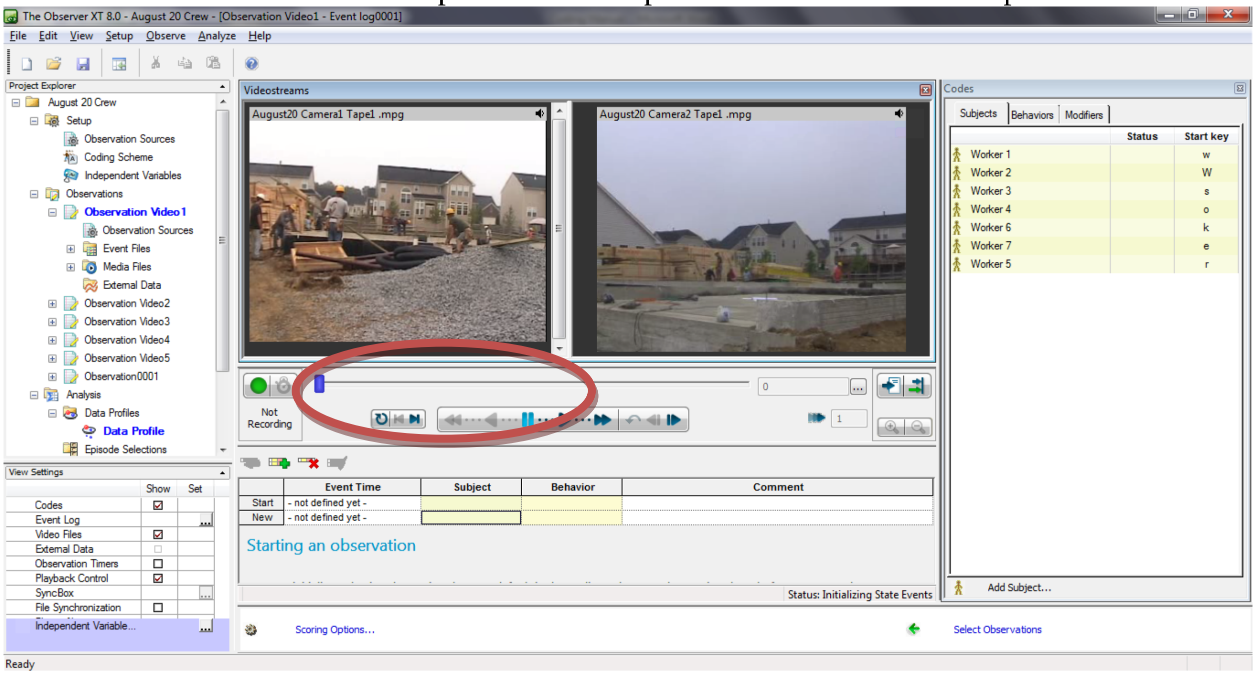


5. Refer to random time sheet for observation times. (This sheet is a separate hand out provided by me. The time listed on this sheet is in seconds).

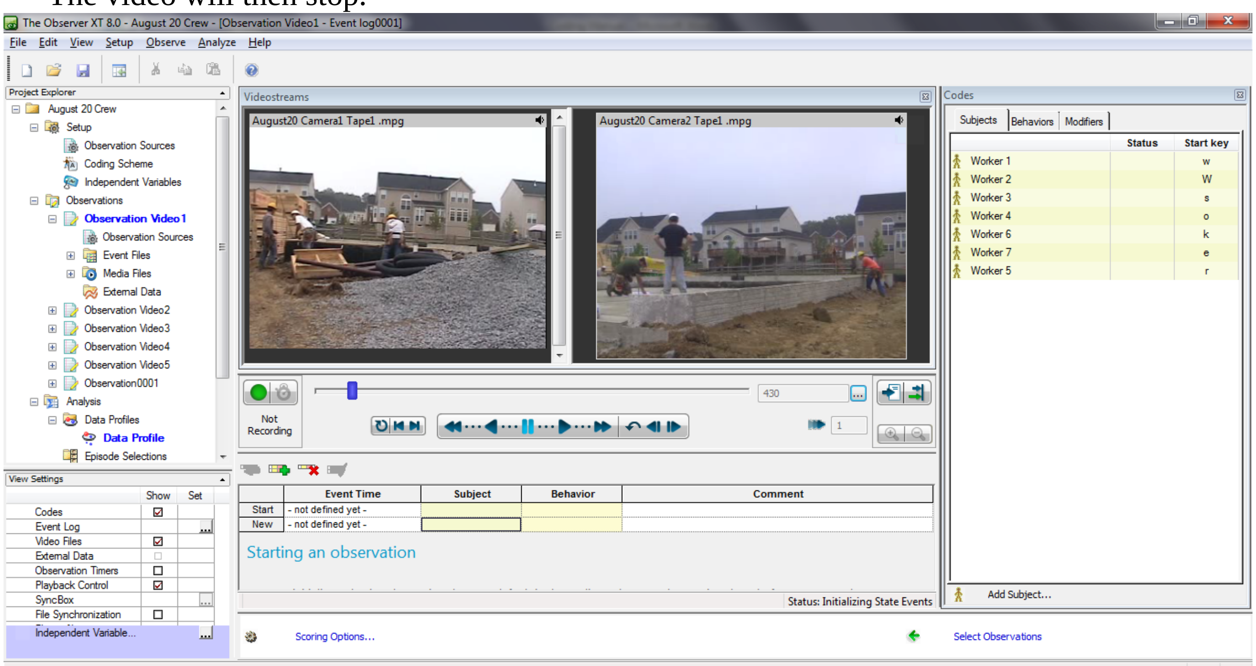


6. Select ok.

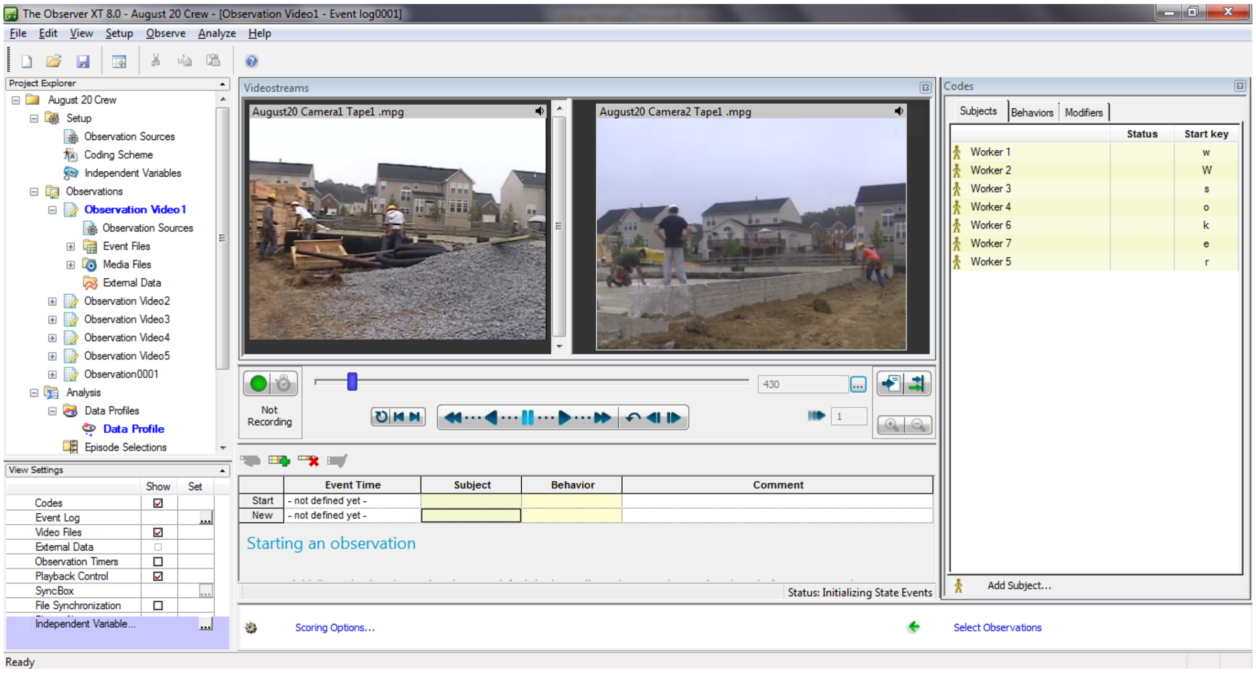
7. Move slide bar to random sample time. Select pause from the scroll bar to pause the video.



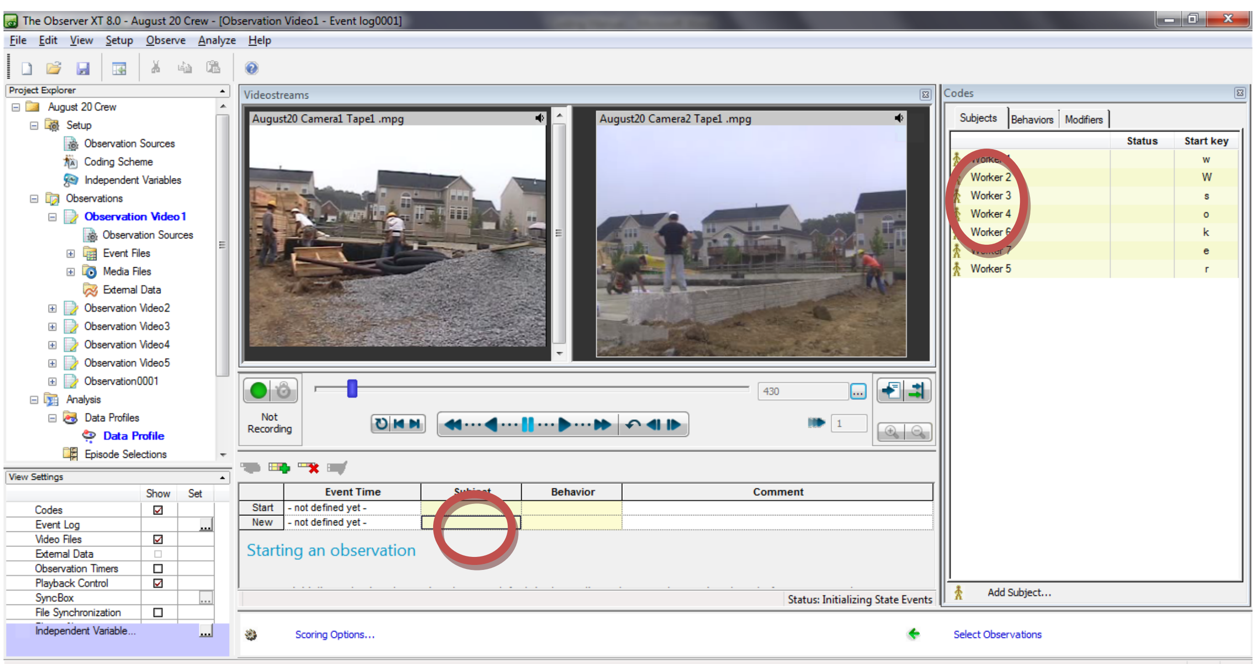
8. Select the Quick Review Button. This will rewind and play the video (at half speed) for 6 seconds. The video will then stop.

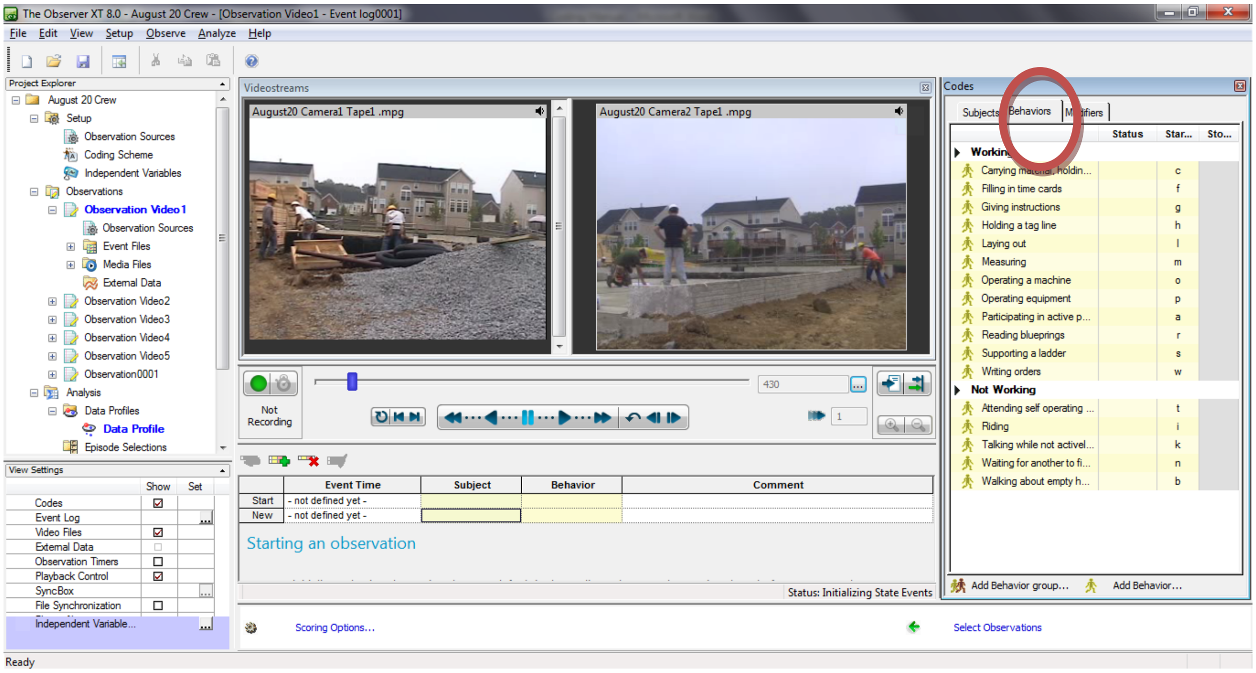


9. Each worker should be identified with a subject number. The subject number will stay constant throughout that current observation (to not double count between the two videos). Can add a note about specific characteristics of the worker to help identify them (i.e. Worker 1 - yellow hard hat, Worker 2 – Red Sweatshirt) in the comment section.



10. Start observations from left to right. Observe the worker. Place cursor on *Subject* field and select *Worker number*. Next select *Behavior*. Behaviors can be selected by clicking on the *Behavior Tab*. The *Event Time* should show the time you had previously selected.





11. Continue to do this until you have completed 400 observations. Videos are in ~1.5 hours so you will have to open up to 6 observations per project to satisfy the 384 total. When a new observation in the same project needs to be opened, document the total number of observations in provided in the random time sheet to help you keep track.

12. If an observation does not include at least 5 workers (can't see their actions or not in the video), circle in random observation sheet.

Appendix J - Video Coding Random Sample Times

Table 25 - Random Coding Times

25-Mar					
2220	Tape1	120	Tape3	5460	
2460		240		120	Tape5
2640		300		180	
2940		600		480	
3360		720		600	
3600		780		660	
3720		1560		1320	
3780		1620		1500	
3900		1800		1680	
4140		2100		1740	
4260		2340		2400	
4500		2400		2640	
4620		2520		2880	
4980		2580		3000	
5100		2640		3240	
300	Tape2	3540		3420	
420		3720		3540	
600		3840		4560	
960		4200		4800	
1260		4260		4920	
1380		4560		4980	
1500		4680		5040	
2160		4920		180	Tape6
2400		5040		300	
3600		60	Tape4	420	
3840		120		540	
4380		480		600	
4500		660		660	
4680		1140		720	
5160		1860			
5520		2040			
		2580			
		2700			
		2820			
		2940			
		3480			
		3720			
		4140			
		4680			
		5280			

Offset	Seconds
Tape 1	78
Tape 2	10
Tape 3	34
Tape 4	10
Tape 5	77
Tape 6	11

9-Apr

1860	Tape1	2100	Tape4	660	Tape6
1980		2220		780	
2340		2280		900	
2700		2340		960	
2880		2400		1080	
3000		2460			
3120		2700			
3300		2820			
3900		2940			
4140		3000			
4320		3180			
4560		3300			
4680		3600			
4740		3780			
4860		4260			
4980		4500			
5040		4620			
5100		4680			
5340		4800			
5460		4980			
780	Tape2	5040			
900		5160			
1080		5220			
1260		960	Tape5		
1320		1140			
1380		1920			
1800		2160			
1860		2280			
2220		2520			
2340		2880			
2400		2940			
2580		3000			
2760		3420			
3000		3540			
3480		3660			
3600		3720			
3720		3840			
4320		3900			
240	Tape3	3960			
1080		4020			
1200		4260			
1260		4500			
		4560			
		4860			
		5400			

Offset	Seconds
Tape 1	65
Tape 2	559
Tape 3	155
Tape 4	120
Tape 5	911
Tape 6	145

5-May

2040	Tape 1	960		720	Tape5
2160		1320		900	
2220		1380		1080	
2580		1740		1140	
2700		2100		1320	
2820		2160		1380	
2880		2460		1560	
3000		2580		1680	
3060		2640		1860	
3120		3060		2100	
3180		3120		2220	
3240		3240		2340	
3360		180	Tape4	2460	
3480		360		2580	
3600		420		2640	
3660		540		2760	
3780		600		2820	
480	Tape2	900		3000	
540		1200		3240	
840		1440		3360	
900		1560		3540	
1020		1620		3780	
1140		2100		4020	
1500		2160		4080	
1860		2520		4200	
1980		2880			
2100		3060			
2580		3120			
2640		3180			
2820		3360			
3120		3720			
3420		3960			
3840		4260		Offset	Seconds
3900		4440		Tape 1	60
4260		4500		Tape 2	120
4680		4680		Tape 3	112
5520		4740		Tape 4	132
180	Tape3	5040		Tape 5	100
240		5160			
360		5220			
480		5280			
600					
660					

13-Jul

1920	Tape1	1140	Tape4	120	Tape 6
2340		1320		360	
2400		1560		540	
2520		1620		960	
3060		2040		1020	
3240		2280		1320	
3300		2820		1440	
3420		3060		1620	
3780		3420			
3840		3840			
4620		4080			
4740		4200			
5220		4320			
5280		4380			
120	Tape2	4680			
180		4980			
360		5100			
1140		5160			
1260		5280			
1380		5400			
1440		780	Tape5		
1620		840			
1800		900			
2160		960			
2220		1140			
2280		1380			
2400		1440			
2520		1500			
2700		1620			
3180		2220			
3600		2280			
3780		2340			
3900		2400			
3960		2820			
4080		3120			
4140		3360			
4260		4200			
4380		4320			
4680		4380			
4980		4500			
5040		4980			
5100					
5160					

Offset	Seconds
Tape 1	93
Tape 2	54
Tape 3	99
Tape 4	72
Tape 5	120
Tape 6	84

21-Jul

2940	Tape1 Part 2	1500	Tape3	3800	Tape5
3240		1860		3860	
3480		2520		4040	
3540		2640		4100	
3720		2760		4160	
3900		2940		4340	
3960		3000		4400	
4140		3120		4580	
4200		3300		4640	
4380		3480		4700	
4440		3660		4760	
4500		3840		4820	
4560		3900		5000	
2040	Tape2	3960			
2160		4020			
2280		4440			
2340		4560			
2520		4680			
2640		4740			
3300		5040			
3360		240	Tape4		
3420		480			
3600		660			
4260		780			
4560		960			
4680		1020			
4800		1260			
4920		1380			
4980		1500			
5160		1620			
5220		1920			
5460		2040			
5520		2280			
5640		2460			
		2520			
		2580			
		2760			
		2820			
		2880			
		2940			
		3000			

Offset	Seconds
Tape 1 Part2	1586
Tape 2	82
Tape 3	102
Tape 4	177
Tape 5	126
Tape 6	72

20-Aug

1980	Tape1	120	Tape3	240	Tape5
2220		180		300	
2580		360		360	
2820		600		420	
3060		720		540	
3300		780		780	
3540		840		900	
3780		900		1020	
3900		1020		1140	
3960		1080		1200	
4260		1320		1260	
4380		1440		1380	
4620		1620		1500	
4740		1800		1560	
4920		1860		1620	
4980		1920		1740	
5100		2100			
5280		2340			
5340		2400			
5400		2460			
420	Tape2	2640			
720		2700			
840		2760			
900		3000			
1020		3420			
1080		3600			
1260		3900			
1440		2100	Tape4		
1620		2280			
1800		2400			
1920		2640			
2160		3300			
2340		3360			
2760		3420			
3300		3540			
3660		3960			
4560		4380			
4620		4560			
5160					
5280					
5340					

Offset	Seconds
Tape 1	78
Tape 2	54
Tape 3	98
Tape 4	65
Tape 5	120

5-May Additional

2520	Tape 1	2340	Tape 1
2940		3540	
3720		660	Tape 2
2400	Tape 2	1380	
2520		900	Tape 3
3060		1020	
3300		2400	Tape 4
4140		2700	
4440		3600	
4860		1920	Tape 5
5040		2400	
780	Tape 3		
1080			
1260			
1500			
1560			
1980			
2040			
2940	Tape 5		
3120			
3300			
3420			

Offset	Seconds
Tape 1	60
Tape 2	120
Tape 3	112
Tape 4	132
Tape 5	100

13-Jul - Additional

2580	Tape1	2460	Tape4
2760		2640	
2820		3300	
3180		3720	
3540		3780	
3600		4260	
3660		1740	Tape5
3960		1860	
4200		1920	
4260		2580	
1980	Tape2	2640	
2100		3180	
2580		3240	
2880		720	Tape6
3000		780	
3060		1260	
3420			
3720			
4620			

Offset	Seconds
Tape 1	93
Tape 2	54
Tape 3	99
Tape 4	72
Tape 5	120
Tape 6	84

21-Jul Additional

3000	Tape1 Part2	1320	Tape 4
3180		1800	
3780		1860	
2400	Tape 2	2100	
2760		2220	
2820		3920	Tape 5
3000		4220	
3540		4280	
4440		4940	
4500			
5280			
2100	Tape 3		
2340			
3180			
3540			
4860			

Offset	Seconds
Tape 1 Part2	1586
Tape 2	82
Tape 3	102
Tape 4	177
Tape 5	126
Tape 6	72

20-Aug Additional

2100	Tape1	4500		2520	Tape1
2160		4920		2700	
2340		5100		2880	
2940		300	Tape 3	4440	
3000		480		1560	Tape 2
3360		1680		2100	
3420		2040		2700	
3720		2160		5220	
4680		2520		420	Tape 3
5460		2580		2280	
600	Tape 2	2880		3540	
1140		2940		3780	Tape 4
1200		3180		3840	
1380		3240		2160	
1860		3720		4140	
2040		480	Tape 5	4200	
2400		360		4320	
2580		660		1440	Tape 5
3180		720			
3420					
3480					
3600					
3840					
4200					
4320					
4440					

Offset	Seconds
Tape 1	78
Tape 2	54
Tape 3	98
Tape 4	65
Tape 5	120

Appendix K - Normality Tests

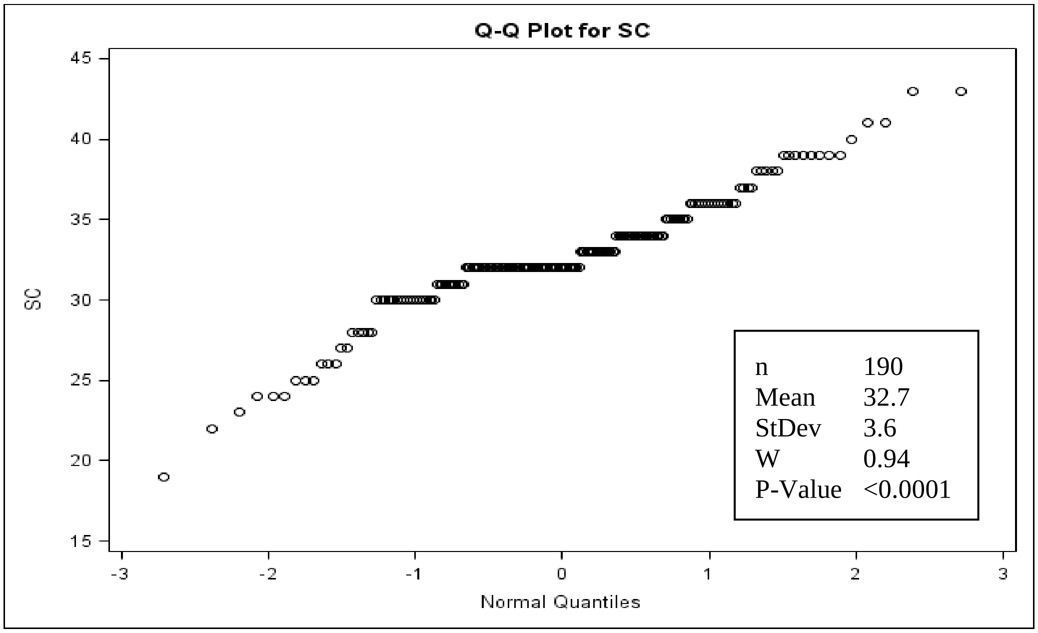


Figure 37 - Normality Test at Individual Level for Safety Climate

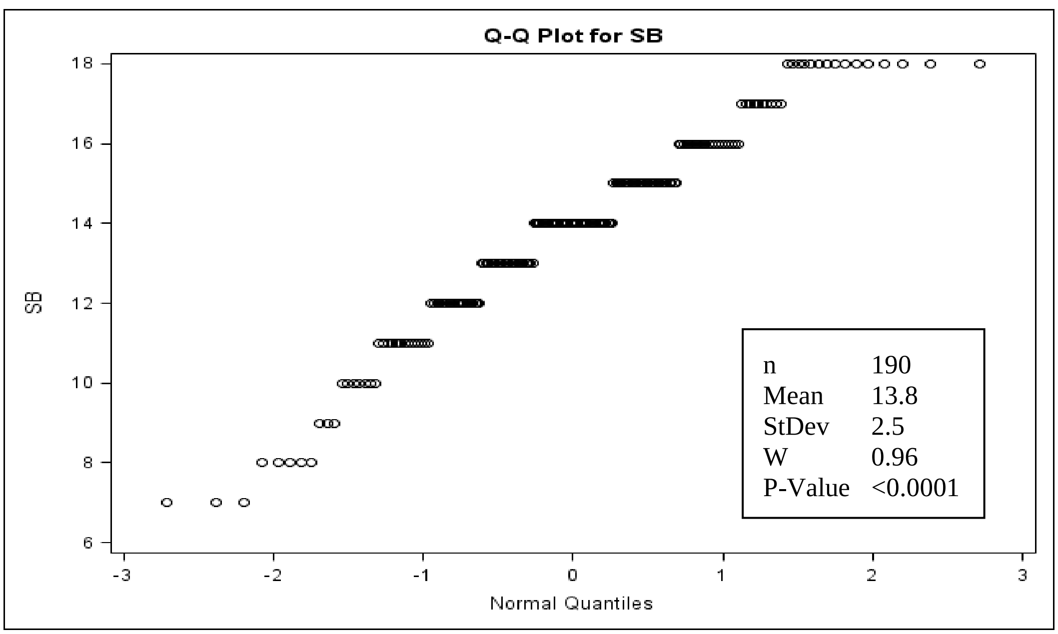


Figure 38 - Normality Test at Individual Level for Risk Behavior

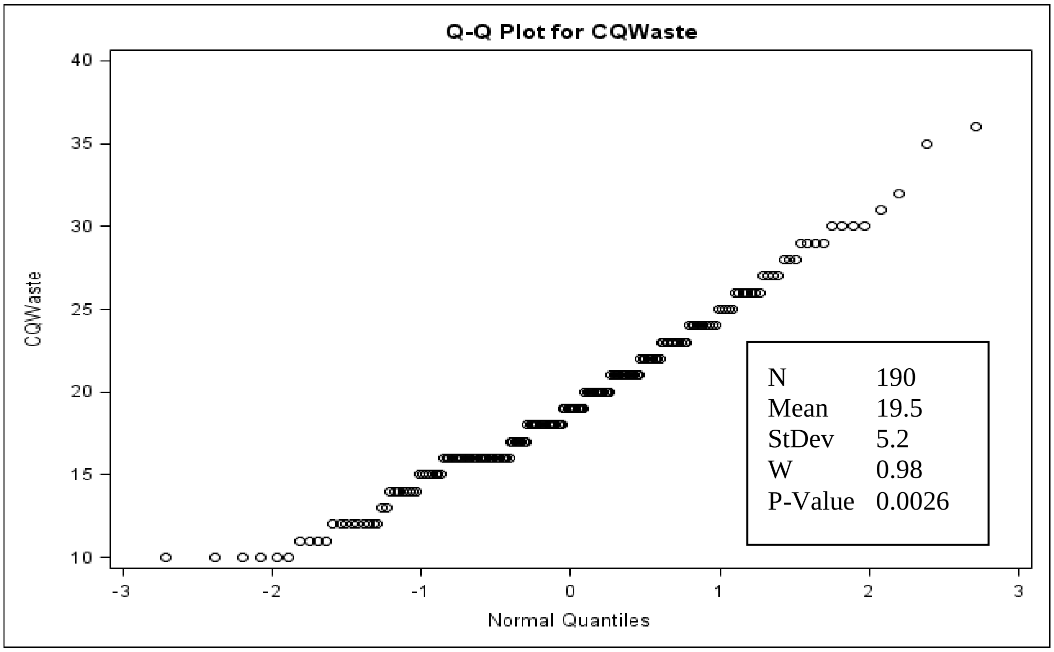


Figure 39 - Normality Test at Individual Level for Craftsman Questionnaire Waste

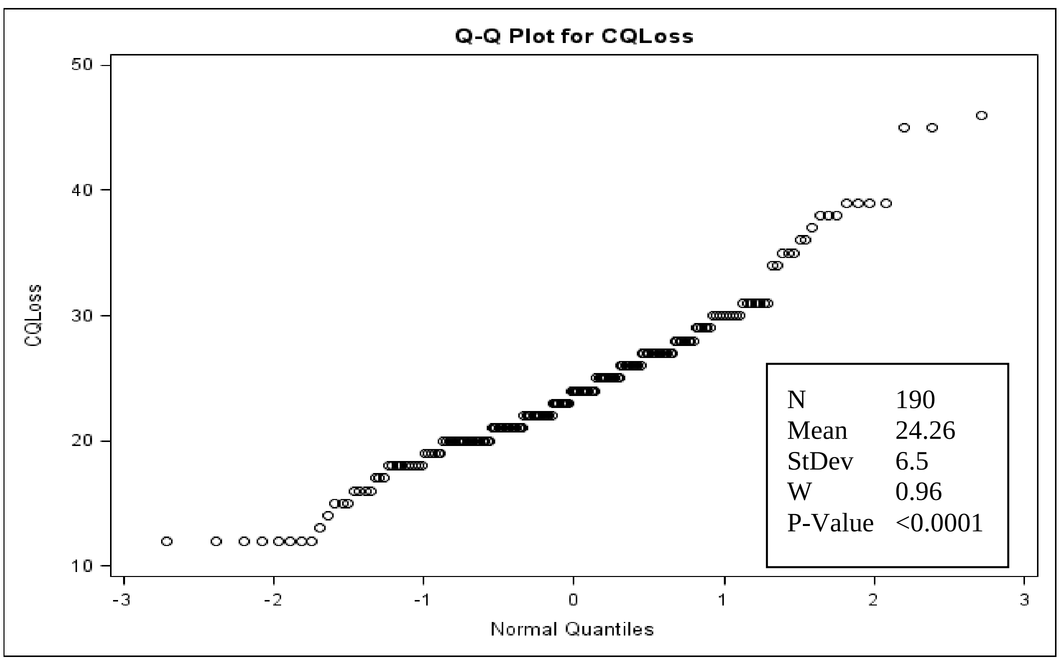


Figure 40 - Normality Test at Individual Level for Craftsman Questionnaire Loss

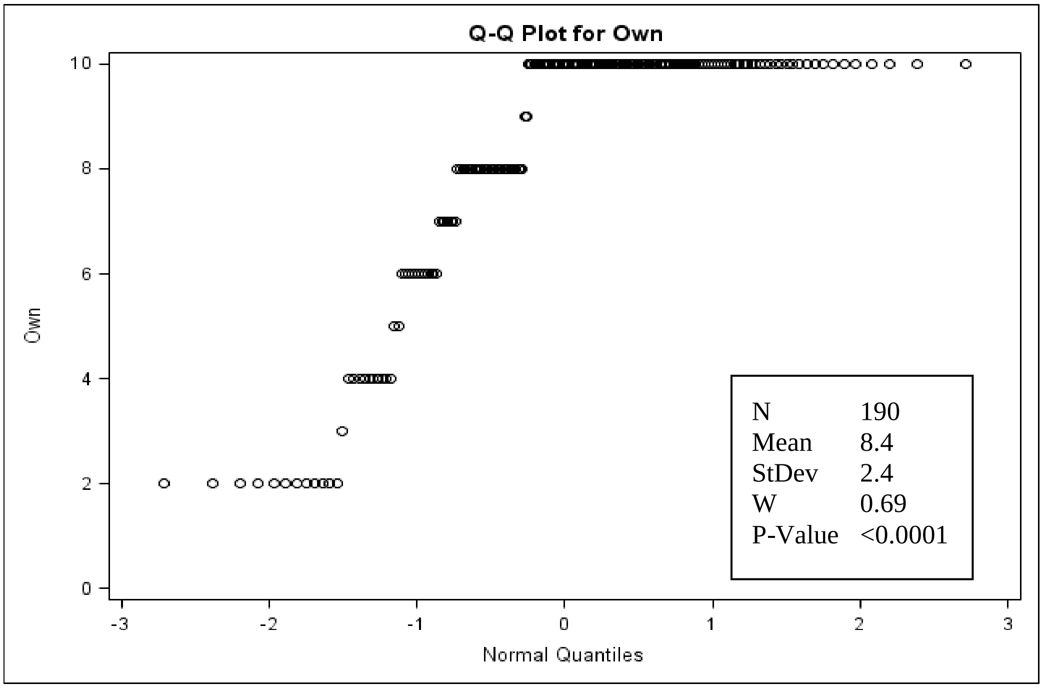


Figure 41 - Normality Test at Individual Level for Work Ownership

Appendix L - Mean Values for Questionnaires

Table 26 - Mean Crew Values

Crew	Safety Climate	Risk Behavior	Perceived Waste	Perceived Loss	Own	Age	Area
1	30.0	13.8	19.5	24.3	5.0	40.8	Electrical
2	32.0	14.0	14.0	12.0	2.0	40.7	Electrical
3	32.7	17.7	20.7	27.0	7.0	27.0	Carpentry
4	34.9	14.6	18.4	18.6	5.1	28.8	Painting and Wall Covering
5	29.3	13.7	25.3	26.7	7.0	35.7	Insulation
6	36.3	16.0	12.5	17.8	7.3	26.0	Gutters
7	31.7	14.3	19.3	20.0	4.3	31.0	Painting and Wall Covering
8	29.0	15.5	17.0	18.5	3.5	31.0	Electrical
9	35.0	16.0	29.5	29.0	10.0	37.5	Plumbing, Heating and A/C
10	34.5	11.5	32.0	28.5	10.0	27.5	Concrete/Foundation
11	31.7	15.3	17.0	16.7	8.0	31.7	Plumbing, Heating and A/C
12	40.5	16.5	23.0	24.0	10.0	60.5	Laborer
13	34.3	15.0	25.8	26.3	8.5	26.5	Painting and Wall Covering
14	40.3	18.0	11.3	16.7	8.7	28.0	Painting and Wall Covering
15	33.0	12.7	27.7	25.3	8.0	37.0	Concrete/Foundation
16	33.8	13.5	25.5	26.5	10.0	31.0	Plaster
17	33.5	13.2	26.7	28.7	7.5	31.5	Landscape
18	35.5	15.0	22.5	22.0	8.0	23.5	Tiling
20	32.0	14.7	15.7	20.1	10.0	30.7	Carpentry
21	30.0	11.4	15.0	18.0	6.4	29.4	Cleaning
22	31.6	12.6	17.4	20.0	9.2	28.2	Roofing
23	33.8	15.0	23.0	22.3	6.3	30.5	Piping
24	28.0	7.0	25.7	27.0	10.0	35.3	Plaster
25	33.8	14.3	17.7	23.2	10.0	24.0	Brick Masonry
26	32.8	14.0	16.0	25.3	10.0	34.8	Concrete/Foundation
27	32.0	14.5	12.0	21.0	5.0	58.5	Painting and Wall Covering
29	34.0	13.0	18.0	30.8	10.0	35.3	Landscape
30	33.0	13.0	13.0	21.5	10.0	33.0	Drywall/Insulation
31	31.7	12.0	21.0	37.7	10.0	35.0	Framing
32	35.2	15.2	14.8	21.3	10.0	29.8	Electrical
33	31.0	12.0	19.3	19.0	10.0	31.3	Concrete/Foundation
34	32.4	15.0	16.1	30.9	10.0	27.9	Framing
35	32.0	16.5	18.3	22.0	10.0	40.8	Plaster
36	33.0	11.0	18.0	17.5	10.0	25.5	Cabinets
37	33.3	13.0	18.3	24.0	10.0	22.7	Plaster
39	34.7	13.3	19.7	27.3	9.0	36.3	Siding
40	30.0	12.0	18.0	23.5	10.0	47.5	Painting and Wall Covering
41	36.0	12.5	20.0	27.5	10.0	32.0	Carpentry
42	30.8	14.5	18.5	23.8	10.0	38.0	Painting and Wall Covering
43	30.6	13.0	21.3	25.3	8.3	31.1	Framing
44	32.3	14.5	18.2	28.2	8.0	30.5	Framing
45	33.3	12.9	21.3	25.4	7.3	23.6	Framing

46	34.6	13.4	17.3	24.1	9.7	27.0	Framing
47	26.4	11.5	22.6	33.0	9.3	29.9	Framing
48	34.8	14.5	19.2	26.7	8.7	26.2	Framing

Table 27 - Descriptive Statistics for Workers

	Safety Climate	**Risk Behavior**	**Perceived Waste**	**Perceived Loss**	**Own**
Mean	32.90	13.80	19.70	23.80	8.38
Median	33.00	14.00	18.50	24.00	9.20
Standard Dev	2.67	1.92	4.64	4.90	2.06
Skewness	0.45	-0.68	0.53	0.23	-1.34
Kurtosis	1.70	2.66	0.14	0.51	1.21
Max Value	40.50	18.00	32.00	37.70	10.00
Min Value	26.40	7.00	11.30	12.00	2.00

Table 28 - Average Critical Path Crew Summary Statistics

	SC Score	**Risk Score**	**Perceived Waste**	**Perceived Loss**	**Own**	**Age**	**Group**	**Area**
Mean	33.6	14.0	20.8	22.55	8.2	31.2		
Stdev	3.96	2.5	6.84	4.77	2.8	6.7		
Min	22.0	8.0	11.0	12.0	2.0	19		
Max	43.0	18.0	35.0	30.0	10.0	45		
n	22	22	22	22	22	22	100	Foundation/Concrete, Piping, Gutters
Mean	32.2	13.6	19.1	27.0	9.05	29.05		
Stdev	3.29	2.1	3.01	6.13	1.62	7.87		
Min	24.0	8.0	14.0	15.0	2.0	19		
Max	41.0	18.0	27.0	45.0	10.0	52		
n	79	79	79	79	79	76	200	Framing, Carpentry, Roofing, Brick Masonry, Siding
Mean	32.3	14.9	18.6	19.45	6.7	35.6		
Stdev	4.1	2.11	7.3	5.5	3.54	8.2		
Min	19.0	8.0	10.0	12.0	2.0	23		
Max	38.0	18.0	30.0	29.0	10.0	52		
n	22	22	22	22	22	21	300	Plumbing, Heating and A/C, Electrical
Mean	31.8	13.0	20.7	24.4	9.6	33.3		
Stdev	3.3	3.1	5.99	6.6	1.36	9.2		
Min	25.0	7.0	12.0	12.0	4.0	10		
Max	36.0	18.0	36.0	46.0	10.0	50		
n	21	21	21	21	21	21	400	Insulation, Plaster, Drywall/Insulation
Mean	33.8	14.8	18.3	21.2	7.2	35.0		
Stdev	4.26	2.63	6.37	4.74	3.0	12.44		
Min	23.0	9.0	10.0	12.0	2.0	18		
Max	43.0	18.0	30.0	30.0	10.0	61		
n	25	25	25	25	25	21	500	Painting and Wall Covering
Mean	33.6	13.0	20.7	24.4	8.2	33.1		
Stdev	3.2	2.9	5.12	7.6	1.8	11.8		
Min	30.0	8.0	15.0	17.0	6.0	19		
Max	41.0	18.0	31.0	45.0	10.0	61		
n	21	21	21	21	21	21	600	Cabinets, Tiling, Landscaping, Laborers, Cleaning

Appendix M - Item Specific Responses to Questionnaires

Table 29 - Safety Climate Item Specific Responses

		Strongly Disagree	Disagree	Neither Agree /Disagree	Agree	Strongly Agree
		1	2	3	4	5
1	I think worker's safety practices are important to my managers.	0	1	0	159	30
2	Supervisors and other top managers seem to care about my safety.	1	2	0	160	27
3	My foreman emphasizes safety practices on the job.	1	3	0	162	24
4	I was given instructions on the safety policy and safety requirements of the company when I was hired by my direct employer.	3	21	0	137	29
5	There are regular job safety meetings at my present job site.	3	59	8	104	16
6	There is proper equipment for our tasks available at this job site.	2	19	7	146	16
7	I feel I have control over what happens to my safety on the job.	0	9	1	156	24
8	Taking risks is part of the job.	1	34	9	140	6
9	I think I am likely to be injured on the job in the next 12 month period.	7	55	36	90	2

Table 30 - Risk Behavior Item Specific Responses

		Often	Sometimes	Never
		1	2	3
10	I take chances to get work done.	31	111	48
11	I bend the rules to achieve a production target.	16	101	73
12	I take risks to get the job done.	31	111	48
13	Job stress at the workplace stops me from working to the rules.	17	91	82
14	I break rules due to management pressure.	5	69	116
15	I ignore when safety rules are broken.	37	40	113

Table 31 - Craftman's Questionnaire Item Specific Responses (CQWaste)

		Strongly Disagree	Disagree	Neither Agree /Disagree	Agree	Strongly Agree
		1	2	3	4	5
16	I have to stop work and wait or move to another task because I don't have the materials needed to do the job	33	39	101	13	4
18	I have to stop work and wait or move to another task because I don't have the tools needed to complete the job.	125	42	20	2	1
20	I have to stop work and wait or move to another task because I don't have the production equipment needed to complete the job.	121	44	23	1	1
22	I have to stop work and wait or move to another task because I don't have the safety equipment needed to complete the job.	128	39	20	0	3
25	I spend time doing completed work over again (rework).	54	55	75	2	4
28	I often spend time waiting for someone to give me the information that I need to do my job.	97	36	25	0	4
30	I often spend time waiting for someone to translate (language) the information that I need to do my job.	118	40	25	5	2
32	Materials often have to be moved to a different location than where they were delivered.	72	36	65	13	4
34	I have to stop work and wait or move to another task because I don't have the equipment to move materials.	112	47	26	3	2
36	If I can't find the appropriate equipment, I will move the materials manually	58	11	34	33	54

Table 32 - Craftman's Questionnaire Item Specific Responses (CQLoss)

		< 1	1-2 hrs	2-3 hrs	3-4 hrs	4-5 hrs	> 5
		1	2	3	4	5	6
17	How many hours per week would you estimate you spend waiting for materials, getting materials from somewhere else or moving to a different area because materials are not available?	76	58	14	9	13	20
19	How many hours per week would you estimate you spend waiting for suitable tools, getting tools, or moving to a different area because the appropriate tools are not available?	165	19	1	2	2	1

21	How many hours per week would you estimate you spend waiting for production equipment, getting production equipment, or moving to a different area because the production equipment is not available?	159	19	7	0	2	3
23	How many hours per week would you estimate you spend waiting for safety equipment, getting safety equipment, or moving to a different area because the safety equipment is not available?	167	18	3	0	1	1
26	How many hours per week would you estimate you spend doing completed work again (rework)?	105	44	19	6	8	8
29	How many hours per week would you estimate you lose because you are waiting to get information you need to do your job?	146	36	5	3	0	0
31	How many hours per week would you estimate you lose because you are waiting for translations (language) that you need to do your job?	170	16	2	0	1	1
33	How many hours per week would you estimate you spend moving materials to a different location than where they were delivered.	111	41	21	5	9	3
35	How many hours per week would you estimate spend looking for the appropriate equipment to move materials.	152	23	7	1	0	7
37	How many hours per week do you think you spend moving materials manually?	82	33	13	16	21	25

Table 33 - Priority and Work Ownership Item Specific Responses

		Never	Rarely	Occasionally	Often	Always
		1	2	3	4	5
38	I receive clear daily task priorities.	11	12	20	47	100
39	I receive clear job completion dates.	20	16	23	39	92
40	I feel a high degree of personal ownership for this job.	14	12	16	32	116
41	I feel a high degree of personal ownership for meeting daily task goals.	13	8	20	32	117

Appendix N - Multiple Regression Data

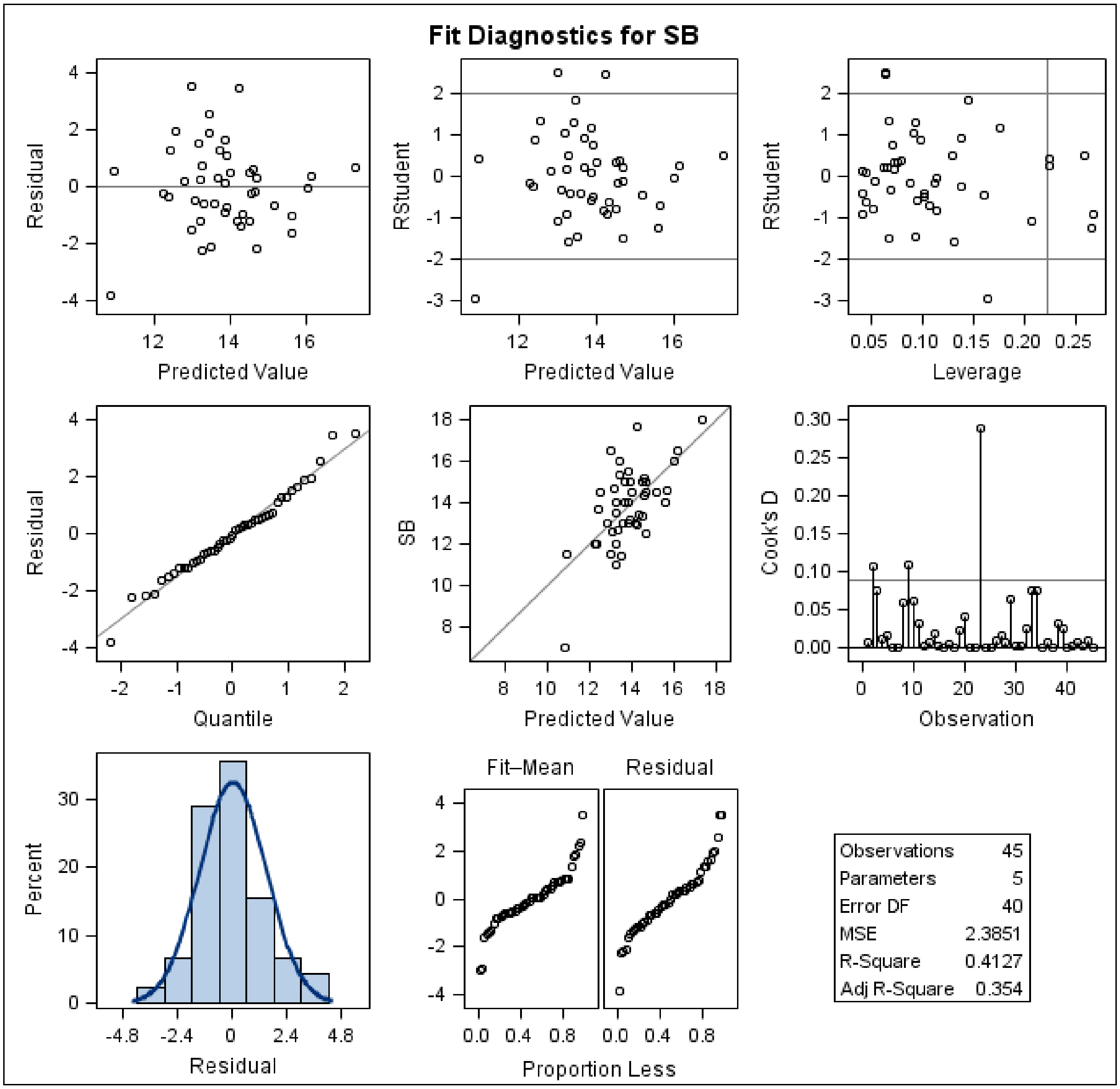


Figure 42 - Fit Diagnostics for Risk Behavior Regression Model

Table 34 - Multiple Regression Residuals

Crew	Resid	Presstat	Press^2
1	0.738272	0.847761	0.718698
2	-1.60993	-2.19349	4.811394
3	3.470776	3.711966	13.77869
4	-1.04637	-1.17132	1.371987
5	1.297294	1.438567	2.069475
6	-0.03102	-0.03503	0.001227
7	-0.25174	-0.28371	0.08049
8	1.64935	2.000842	4.003367
9	2.546858	2.980943	8.88602
10	-1.49071	-1.88	3.534391
11	1.872578	2.064293	4.261305
12	0.352527	0.455053	0.207074
13	1.105462	1.190949	1.418361
14	0.698682	0.942222	0.887783
15	-0.6005	-0.66869	0.447147
16	0.267173	0.28792	0.082898
17	-0.70023	-0.77944	0.607526
18	0.304216	0.325882	0.106199
20	1.545089	1.70047	2.891597
21	-2.0854	-2.29872	5.284135
22	-0.4867	-0.52278	0.273301
23	0.48844	0.526632	0.277342
24	-3.82857	-4.58197	20.99442
25	0.146624	0.153598	0.023592
26	0.335442	0.357579	0.127863
27	-0.67385	-0.80318	0.645102
29	-1.192	-1.34689	1.814102
30	-0.87919	-0.97237	0.945508
31	-1.22938	-1.67868	2.81795
32	0.585793	0.636016	0.404517
33	-0.35783	-0.41491	0.172148
34	1.300647	1.508541	2.275697
35	3.514449	3.753714	14.09037
36	-2.25011	-2.59243	6.720699
37	-0.60394	-0.62996	0.396846
39	-1.21059	-1.27805	1.633409
40	-0.24384	-0.26746	0.071535
41	-2.18256	-2.34307	5.489997
42	1.959559	2.101515	4.416364
43	0.19061	0.198819	0.039529
44	0.480841	0.520786	0.271218
45	-1.36005	-1.42032	2.017301
46	-0.93922	-0.98393	0.968127
47	0.576478	0.743131	0.552244
48	-0.17343	-0.18316	0.033549

Appendix O - Video Coding Summary Times

Table 35 - Coder Productivity

Relative Time (s)	25-Mar	Working	Not Working	Total Obs
2220	Video1	7	0	7
2460		5	2	7
2640		4	3	7
3360		7	0	7
3600		3	2	5
3720		4	1	5
3780		5	0	5
3900		3	2	5
4140		5	0	5
4260		3	2	5
4500		6	0	6
4620		6	0	6
4980		3	3	6
300	Video2	7	0	7
600		6	0	6
1260		4	2	6
1380		6	0	6
1500		4	1	5
2160		6	0	6
2400		5	0	5
3600		7	0	7
3840		5	0	5
4500		2	3	5
4680		4	2	6
5160		6	0	6
240	Video3	5	0	5
300		6	0	6
600		5	0	5
720		7	0	7
780		6	1	7
1560		5	0	5
1620		5	0	5
1800		6	0	6
2100		5	0	5
2340		5	0	5
2400		4	1	5
2520		4	3	7
2580		6	0	6
2640		5	0	5
3540		3	2	5
3720		6	0	6
3840		5	0	5
4200		5	0	5
4260		5	0	5
4561		5	0	5
4680		5	0	5
4920		4	1	5
5040		5	0	5
60	Video4	7	0	7
120		6	0	6
480		5	0	5
660		5	0	5
1140		5	0	5
2940		1	4	5
3480		5	0	5
4680		5	0	5
5280		4	1	5
120	Video5	4	1	5
180		4	1	5
480		5	1	6
600		7	0	7
660		7	0	7
1320		5	0	5
1500		4	1	5
1740		5	0	5
2880		4	1	5
3240		5	0	5
3540		5	0	5
4920		5	0	5
4980		4	1	5
300	Video6	5	0	5
420		5	0	5
540		5	0	5
660		6	0	6
Total		368	42	410
Field Rating		90%	10%	

Relative Time (s)	9-Apr	Working	Not Working	Total Obs
1860	Video1	5	0	5
1980		5	0	5
2340		5	0	5
2700		4	0	4
2880		5	0	5
3000		3	2	5
3120		5	0	5
3900		5	0	5
4140		5	0	5
4320		4	1	5
4560		2	3	5
4680		5	0	5
4740		4	1	5
4980		5	0	5
5040		5	0	5
5100		4	1	5
5340		3	2	5
5460		4	1	5
780	Video2	6	0	6
900		5	0	5
1080		4	2	6
1260		5	0	5
1320		5	1	6
1380		3	2	5
1800		5	0	5
1860		5	0	5
2340		5	0	5
2400		6	0	6
2580		5	0	5
2760		5	0	5
3000		5	0	5
3480		5	0	5
3600		5	0	5
3720		5	0	5
4320		5	0	5
240	Video3	4	1	5
1080		4	2	6
1200		4	1	5
1260		4	1	5
2100	Video4	6	0	6
2200		7	0	7
2280		4	2	6
2340		6	1	7
2400		6	0	6
2460		7	0	7
2700		5	0	5
2820		4	1	5
2940		5	0	5
3000		5	0	5
3180		4	1	5
3300		5	0	5
3780		4	1	5
4260		5	0	5
4500		7	0	7
4620		6	0	6
4680		5	0	5
4800		4	1	5
4980		5	0	5
5040		5	0	5
5160		6	0	6
5220		4	1	5
960	Video5	4	1	5
1140		6	0	6
2160		5	0	5
2520		5	0	5
2880		4	2	6
2940		5	0	5
3000		5	0	5
3420		6	1	7
3540		6	0	6
3660		4	1	5
3720		7	0	7
3840		5	0	5
3960		4	1	5
4020		3	2	5
4260		5	0	5
Total		367	37	404
Field Rating		91%	9%	

Relative Time (s)	5-May	Working	Not Working	Total Obs
2040	Video1	5	0	5
2160		5	0	5
2220		4	1	5
2580		4	1	5
2700		3	2	5
3000		6	1	7
3120		5	0	5
3180		5	0	5
3240		4	1	5
3360		4	1	5
3480		3	2	5
3540		6	0	6
3600		5	0	5
480	Video2	5	1	6
540		5	0	5
660		6	0	6
840		5	0	5
900		5	0	5
1020		4	1	5
2400		6	0	6
2580		5	0	5
2640		4	1	5
2820		4	1	5
3420		4	1	5
3900		4	1	5
4400		5	0	5
5040		6	0	6
180	Video3	5	0	5
240		5	0	5
360		7	0	7
960		5	0	5
1560		6	0	6
1740		5	0	5
1980		6	0	6
2040		7	0	7
2100		5	0	5
2460		4	1	5
2640		5	0	5
3060		5	0	5
3120		5	0	5
3240		4	2	6
360	Video4	4	1	5
540		5	1	6
600		4	1	5
1200		5	0	5
1560		5	0	5
1620		4	1	5
2520		4	1	5
2880		4	1	5
3120		5	0	5
3180		5	0	5
3720		5	0	5
3960		5	0	5
4680		5	1	6
4740		5	0	5
5040		5	0	5
5160		4	1	5
5220		5	0	5
5280		5	0	5
1320	Video5	5	0	5
1380		4	1	5
1680		5	0	5
1860		5	0	5
2100		5	0	5
2220		5	0	5
2340		5	0	5
2460		4	1	5
2580		4	1	5
2640		5	0	5
2760		5	0	5
2820		5	0	5
2940		5	0	5
3000		5	0	5
3240		5	0	5
3300		6	0	6
3360		6	0	6
3420		5	0	5
Total		374	29	403
Field Rating		93%	7%	

Relative Time (s)	13-Jul	Working	Not Working	Total Obs
1920	Video1	5	1	6
2340		4	1	5
2520		5	0	5
2760		3	2	5
3060		5	0	5
3180		4	2	6
3300		3	2	5
3420		5	2	7
3660		4	1	5
3780		4	1	5
3840		3	2	5
3960		3	2	5
4200		5	0	5
4260		3	3	6
120	Video2	5	0	5
180		4	1	5
360		6	0	6
1260		5	0	5
1380		5	0	5
1440		5	0	5
1620		5	0	5
1800		6	0	6
1980		5	0	5
2100		5	0	5
2160		3	2	5
2220		5	0	5
2280		5	0	5
2400		5	0	5
2520		5	0	5
2580		4	1	5
2880		6	0	6
3000		5	0	5
3900		4	1	5
3960		5	1	6
4080		5	0	5
4140		6	1	7
4260		5	0	5
4380		6	1	7
4680		6	1	7
4980		7	0	7
5040		6	0	6
1560	Video4	7	0	7
2040		7	0	7
2280		7	0	7
3060		5	1	6
3840		5	0	5
4200		6	0	6
4320		3	2	5
4380		6	0	6
4980		3	2	5
5100		6	0	6
5160		4	1	5
5280		5	1	6
780	Video5	5	0	5
900		4	2	6
960		5	0	5
1380		5	0	5
1440		5	0	5
2220		5	0	5
2280		5	0	5
2340		5	0	5
2820		5	0	5
3120		5	0	5
3360		5	0	5
4200		5	0	5
4320		5	0	5
4380		5	0	5
4980		4	1	5
120	Video6	3	2	5
360		4	1	5
540		5	0	5
960		5	0	5
1320		3	2	5
1620		3	2	5
Total		355	45	400
Field Rating		89%	11%	

Relative Time (s)	21-Jul	Working	Not Working	Total Obs
2940	Video1 P2	5	0	5
3540		4	1	5
3720		4	3	7
3900		6	0	6
3960		7	0	7
4140		6	0	6
4200		4	3	7
4380		5	0	5
4440		6	0	6
4500		3	3	6
4560		4	1	5
2040	Video2	4	1	5
2160		6	0	6
2340		3	2	5
2520		5	0	5
2640		5	0	5
3300		6	0	6
3360		6	0	6
3420		5	0	5
3600		5	0	5
4260		4	1	5
4560		6	1	7
4680		4	1	5
4800		4	1	5
4920		5	0	5
4980		5	0	5
5160		7	0	7
5220		4	1	5
5460		5	0	5
5520		4	2	6
1500	Video3	4	1	5
1860		5	2	7
2520		7	0	7
2640		5	1	6
2760		6	1	7
2940		5	2	7
3000		5	0	5
3120		4	2	6
3300		6	1	7
3480		4	2	6
3900		6	0	6
3960		6	0	6
4020		5	2	7
4440		5	1	6
4560		4	3	7
4680		7	0	7
4740		3	3	6
5040		4	2	6
240	Video4	4	2	6
480		1	4	5
780		2	3	5
960		2	3	5
1020		3	2	5
1260		5	0	5
1500		3	2	5
1620		5	0	5
1920		5	0	5
2040		6	0	6
2520		7	0	7
2580		4	2	6
2760		0	6	6
4040	Video5	3	3	6
4100		5	0	5
4160		5	0	5
4340		2	4	6
4400		5	1	6
4580		0	5	5
4760		5	0	5
5000		2	3	5
Total		312	84	396
Field Rating		79%	21%	

Relative Time (s)	20-Aug	Working	Not Working	Total Obs
2160	Video1	4	1	5
2220		4	1	5
2520		6	0	6
2700		5	0	5
2820		4	1	5
2880		5	1	6
3060		3	2	5
3300		2	3	5
3360		6	0	6
3420		4	2	6
3540		5	0	5
3720		4	2	6
3780		3	3	6
3900		4	1	5
3960		4	1	5
4260		6	0	6
4440		5	1	6
4680		4	2	6
4740		2	4	6
4920		4	1	5
5280		4	2	6
5460		3	2	5
420	Video2	4	2	6
1380		6	0	6
1560		3	2	5
1620		4	1	5
1860		4	2	6
1920		5	0	5
3420		2	3	5
3480		3	2	5
3600		4	1	5
3660		5	0	5
3840		1	4	5
480	Video3	4	1	5
600		5	0	5
720		5	0	5
780		5	0	5
900		5	0	5
1020		5	0	5
1620		3	3	6
1680		1	4	5
1800		4	1	5
1860		3	2	5
1920		4	1	5
2280		6	0	6
2340		4	1	5
2400		3	2	5
2460		5	0	5
2520		7	0	7
2580		4	2	6
2640		3	2	5
2700		3	2	5
2880		4	2	6
2940		5	0	5
3000		5	0	5
3180		5	1	6
3240		4	3	7
3420		5	0	5
3600		4	1	5
3720		6	0	6
3900		6	0	6
4860		4	1	5
4980		4	1	5
5040		4	1	5
5100		5	0	5
5160		5	0	5
5400		5	0	5
2100	Video4	5	0	5
2400		5	0	5
2640		5	0	5
3420		4	1	5
3840		5	0	5
3960		4	1	5
4380		4	1	5
360	Video5	2	4	6
420		4	1	5
480		4	1	5
1140		5	0	5
1200		4	1	5
1380		5	0	5
1620		4	1	5
Total		342	89	431
Field Rating		79%	21%	

Table 36 - Coder A Safety

Relative Time (s)	25-Mar	Safe	Not Sate	Total Obs
2200	Video 1	4	2	6
2460		4	2	6
2640		4	2	6
2940		4	2	6
3360		4	2	6
3720		4	1	5
3780		5	1	6
3900		4	1	5
4140		5	0	5
4500		3	2	5
4620		5	0	5
4980		5	1	6
5100		5	0	5
300	Video 2	4	2	6
420		3	2	5
600		3	2	5
1260		4	1	5
1380		4	2	6
2160		4	1	5
2400		3	2	5
3600		5	2	7
3840		5	0	5
4500		4	1	5
4680		4	1	5
5160		4	1	5
5520		4	1	5
120	Video 3	4	1	5
240		3	2	5
300		4	1	5
600		3	2	5
720		6	1	7
780		6	1	7
1560		4	1	5
1620		4	2	6
1800		5	2	7
2100		6	1	7
2340		5	2	7
2400		6	1	7
2520		5	2	7
2580		5	2	7
2640		5	1	6
3540		4	1	5
3840		4	1	5
4260		4	3	7
4560		5	1	6
4680		4	1	5
4920		4	2	6
5040		4	1	5
60	Video 4	6	1	7
120		4	3	7
480		5	0	5
660		4	1	5
1140		5	0	5
3720		5	0	5
4680		6	1	7
5280		5	0	5
5460		4	1	5
120	Video 5	4	1	5
180		3	2	5
480		2	4	6
600		3	2	5
660		5	2	7
1320		4	2	6
1500		5	2	7
1740		3	2	5
2400		4	2	6
2640		2	3	5
2880		4	2	6
3540		3	2	5
4800		4	1	5
4980		4	1	5
Total		301	101	402
Safety Rating		75%	25%	

Relative Time (s)	9-Apr	Safe	Not Sate	Total Obs
1860	Video 1	5	0	5
1980		5	1	6
2340		4	1	5
2700		5	0	5
2880		5	0	5
3000		5	0	5
3120		5	0	5
3300		4	1	5
3900		4	1	5
4140		4	1	5
4320		4	1	5
4560		4	1	5
4680		4	1	5
4740		4	1	5
4860		4	1	5
4980		4	1	5
5040		4	1	5
5100		4	1	5
5340		5	1	6
5460		4	1	5
780	Video 2	4	1	5
900		5	1	6
1080		5	1	6
1260		4	1	5
1800		2	4	6
1860		4	1	5
2220		5	1	6
2340		6	1	7
2400		6	1	7
2760		4	1	5
3000		4	1	5
3600		4	3	7
3720		3	2	5
4320		3	3	6
1080	Video 3	5	1	6
1200		4	1	5
1260		5	0	5
2100	Video 4	5	1	6
2220		6	1	7
2280		4	3	7
2340		5	2	7
2400		6	1	7
2460		5	1	6
2700		4	1	5
2820		4	1	5
2940		4	1	5
3180		4	1	5
3300		4	1	5
3600		3	2	5
3780		3	2	5
4260		5	1	6
4500		3	3	6
4620		4	2	6
4680		4	2	6
4800		4	1	5
4980		4	1	5
5040		4	1	5
5160		4	2	6
5220		6	1	7
960	Video 5	6	0	6
1140		4	1	5
1920		5	1	6
2160		6	0	6
2280		5	1	6
2520		5	1	6
2880		5	1	6
2940		6	1	7
3000		5	1	6
3420		6	1	7
3540		5	1	6
3660		6	0	6
3720		6	0	6
Total		325	80	405
Safety Rating		80%	20%	

Relative Time (s)	5-May	Safe	Not Sate	Total Obs
1860	Video 1	5	0	5
2700		5	0	5
3000		4	1	5
3120		5	0	5
3180		4	1	5
3240		1	4	5
3360		4	1	5
3480		5	0	5
3540		6	0	6
3600		5	0	5
480	Video 2	4	1	5
660		6	0	6
840		5	0	5
1020		5	0	5
1140		5	0	5
2520		5	0	5
2580		5	0	5
2640		5	0	5
3060		5	0	5
3900		5	0	5
4260		5	0	5
4440		5	0	5
4680		5	0	5
180	Video 3	5	0	5
240		5	0	5
360		6	0	6
900		4	1	5
960		5	0	5
1380		5	0	5
1560		4	1	5
1980		6	0	6
2040		6	1	7
2100		5	0	5
2460		4	1	5
2640		5	0	5
3060		6	0	6
3120		5	0	5
3240		6	0	6
360	Video 4	5	0	5
540		6	0	6
600		5	0	5
1200		5	0	5
1560		4	1	5
1620		4	1	5
2520		4	1	5
2880		5	0	5
3960		6	0	6
4680		5	1	6
4740		5	0	5
5040		5	0	5
5160		6	0	6
5220		5	0	5
5280		5	0	5
720	Video 5	4	1	5
1320		5	0	5
1380		5	0	5
1680		5	1	6
1860		4	1	5
2100		6	0	6
2220		4	1	5
2340		5	1	6
2460		7	0	7
2580		7	0	7
2640		7	0	7
2760		6	1	7
2820		7	0	7
2940		5	0	5
3000		5	0	5
3240		6	0	6
3300		5	1	6
3360		6	0	6
3420		3	2	5
Total		363	25	388
Safety Rating		94%	6%	

Relative Time (s)	13-Jul	Safe	Not Sate	Total Obs
1920	Video 1	6	1	7
2340		6	1	7
2400		4	1	5
2521		4	1	5
2580		4	1	5
2760		3	3	6
2820		4	1	5
3060		3	2	5
3180		5	2	7
3420		6	1	7
3540		4	1	5
3780		5	0	5
3960		5	0	5
4200		4	1	5
120	Video 2	6	0	6
180		5	1	6
360		5	2	7
1260		4	1	5
1380		5	1	6
1440		4	1	5
1620		4	1	5
1800		6	1	7
2160		3	2	5
2220		6	0	6
2280		5	0	5
2400		4	1	5
2520		4	2	6
2700		3	2	5
3180		5	0	5
3900		3	2	5
3960		3	3	6
4080		4	2	6
4141		3	3	6
4260		3	2	5
4380		5	2	7
4680		6	1	7
4981		5	2	7
5040		4	2	6
5160		4	1	5
1560	Video 4	7	0	7
1620		6	1	7
2040		6	1	7
2280		6	0	6
3060		6	0	6
3840		5	0	5
4200		6	0	6
4320		6	0	6
4380		4	2	6
4980		5	0	5
5100		7	0	7
5160		5	0	5
5280		6	0	6
840	Video 5	5	1	6
900		6	0	6
1380		5	0	5
2220		5	0	5
2340		5	0	5
2820		5	0	5
3120		6	0	6
3360		5	0	5
4200		5	0	5
4320		6	0	6
4380		4	1	5
4980		5	0	5
120	Video 6	5	1	6
360		6	0	6
540		5	0	5
960		5	0	5
1320		5	0	5
1440		5	0	5
1620		5	0	5
Total		345	58	403
Safety Rating		86%	14%	

Relative Time (s)	21-Jul	Safe	Not Sate	Total Obs
2940	Video 1 P2	5	0	5
3240		5	0	5
3540		5	0	5
3720		7	0	7
3900		7	0	7
3960		7	0	7
4140		6	0	6
4200		7	0	7
4380		4	1	5
4440		6	1	7
4500		6	0	6
4560		5	0	5
2040	Video 2	6	1	7
2160		5	2	7
2340		6	1	7
2640		3	2	5
3300		5	1	6
3360		5	0	5
3420		5	1	6
3600		5	2	7
4260		5	1	6
4560		5	2	7
4680		3	2	5
4800		5	1	6
4920		6	1	7
4980		6	1	7
5160		4	3	7
5220		4	3	7
5460		5	2	7
5520		4	2	6
1500	Video 3	5	2	7
1860		6	1	7
2520		6	1	7
2640		6	1	7
2760		4	3	7
2940		4	3	7
3000		5	2	7
3120		5	2	7
3300		4	2	6
3480		4	1	5
3660		4	3	7
3840		4	3	7
3900		5	1	6
3960		5	1	6
4020		5	1	6
4440		5	2	7
4560		4	3	7
4680		5	2	7
4740		5	2	7
5040		6	0	6
660	Video 4	4	1	5
780		5	0	5
960		6	0	6
1020		4	1	5
1380		4	1	5
1500		5	0	5
1620		5	0	5
2040		4	1	5
2280		4	1	5
2760		6	1	7
2820		6	1	7
2880		3	3	6
3800	Video 5	5	0	5
3860		7	0	7
4040		5	1	6
Total		327	77	404
Safety Rating		81%	19%	

Relative Time (s)	20-Aug	Safe	Not Sate	Total Obs
1980	Video 1	5	0	5
2100		5	0	5
2160		5	0	5
2220		6	0	6
2520		6	0	6
2820		6	0	6
3000		5	0	5
3060		4	1	5
3300		5	0	5
3360		6	0	6
3420		5	1	6
3540		7	0	7
3720		5	1	6
3780		6	0	6
3900		6	0	6
3960		5	0	5
4260		6	0	6
4620		5	0	5
4680		7	0	7
4740		5	0	5
4920		5	0	5
5280		6	0	6
420	Video 2	6	0	6
840		5	0	5
1140		5	0	5
1380		6	0	6
1620		5	0	5
1860		6	0	6
1920		6	0	6
3420		5	0	5
3480		5	0	5
3600		5	0	5
3660		5	0	5
3840		5	0	5
180	Video 3	6	0	6
300		6	0	6
480		5	0	5
780		5	0	5
840		5	0	5
900		4	1	5
1320		4	1	5
1680		4	1	5
1800		5	0	5
1860		5	0	5
1920		5	0	5
2040		3	2	5
2400		4	1	5
2460		4	1	5
2520		6	0	6
2580		4	2	6
2640		6	0	6
2940		3	2	5
3000		5	0	5
3180		7	0	7
3240		3	2	5
3420		5	0	5
3600		5	0	5
3720		5	1	6
3900		4	1	5
2100	Video 4	5	0	5
2280		5	0	5
2640		5	0	5
3300		5	0	5
3360		5	0	5
3420		5	0	5
3540		5	0	5
3960		5	0	5
4380		4	1	5
240	Video 5	5	0	5
300		5	0	5
420		5	0	5
720		5	0	5
1260		5	0	5
1500		5	0	5
1740		5	0	5
Total		382	19	401
Safety Rating		95%	5%	

Table 37 - Coder A Presence of Waste

Relative Time (s)	25-Mar	Waste	No Waste	Total Obs
2220		5	1	6
2460		3	3	6
2640		3	3	6
2940		4	2	6
3360		7	0	7
3720		5	1	6
3780		2	3	5
3900		2	3	5
4140		5	0	5
4260		5	1	6
4500		3	4	7
4980		3	4	7
300	Video 2	0	6	6
420		1	4	5
600		6	0	6
1260		5	1	6
1380		5	1	6
1500		3	3	6
2160		6	1	7
2400		2	3	5
3600		7	0	7
3840		3	2	5
4500		1	4	5
4680		3	3	6
5160		4	3	7
240	Video 3	4	1	5
300		4	1	5
600		4	3	7
720		5	2	7
780		4	3	7
1560		4	1	5
1620		3	3	6
1800		6	1	7
2100		6	1	7
2340		6	0	6
2400		4	3	7
2520		3	4	7
2580		3	3	6
2640		1	6	7
3540		5	1	6
3840		4	1	5
4200		2	3	5
4260		5	0	5
4560		5	1	6
4680		3	2	5
4920		4	2	6
5040		4	1	5
60	Video 4	6	1	7
120		6	1	7
480		5	0	5
660		6	0	6
4679		7	0	7
5280		2	3	5
5460		2	3	5
120	Video 5	5	0	5
180		3	2	5
480		5	1	6
600		4	1	5
660		2	5	7
1320		3	3	6
1500		5	2	7
1740		5	0	5
2400		4	2	6
2640		3	2	5
2880		4	1	5
3000		5	0	5
3540		4	1	5
4560		3	2	5
Total		271	129	400
Waste Rating		68%	32%	

Relative Time (s)	9-Apr	Waste	No Waste	Total Obs
1860	Video 1	5	0	5
1980		4	2	6
2340		4	1	5
2700		4	1	5
2880		4	1	5
3000		4	1	5
3120		4	1	5
3300		5	1	6
3900		5	1	6
4140		4	2	6
4320		6	1	7
4560		3	3	6
4680		4	2	6
4740		3	2	5
4860		5	0	5
4980		5	0	5
5040		3	2	5
5100		4	2	6
5340		3	2	5
5460		2	3	5
780	Video 2	5	0	5
900		2	5	7
1080		4	3	7
1260		5	0	5
1800		4	2	6
1860		5	1	6
2220		2	4	6
2340		3	4	7
2400		2	5	7
3000		6	1	7
3480		4	1	5
3600		6	0	6
3720		5	0	5
4320		6	0	6
240	Video 3	5	0	5
1080		4	3	7
1200		4	2	6
1260		6	0	6
2100	Video 4	3	3	6
2220		6	1	7
2280		6	1	7
2340		7	0	7
2400		4	3	7
2460		5	2	7
2700		3	2	5
2820		4	1	5
2940		3	2	5
3180		3	2	5
3301		2	3	5
3600		2	3	5
3780		4	1	5
4260		5	1	6
4500		4	2	6
4620		5	1	6
4680		4	1	5
4800		4	1	5
4980		1	4	5
5040		3	2	5
5160		3	3	6
960	Video 5	4	2	6
1140		5	1	6
1920		5	1	6
2160		4	2	6
2280		4	2	6
2520		1	4	5
2880		4	1	5
2940		5	1	6
3000		5	1	6
3420		5	2	7
3540		4	2	6
Total		286	117	403
Waste Rating		71%	29%	

Relative Time (s)	5-May	Waste	No Waste	Total Obs
2580	Video 1	5	0	5
2880		4	1	5
3000		5	1	6
3180		4	1	5
3240		4	1	5
3360		4	1	5
3480		3	2	5
3540		6	0	6
3600		5	0	5
480	Video 2	4	1	5
660		6	0	6
840		3	2	5
1020		0	5	5
1140		3	2	5
2520		6	0	6
2580		5	0	5
2640		2	3	5
3060		4	2	6
3300		3	2	5
3840		4	1	5
3900		1	4	5
4260		3	2	5
4440		4	1	5
4680		2	4	6
240	Video 3	0	5	5
360		1	5	6
901		4	1	5
960		5	0	5
1380		5	0	5
1560		4	1	5
1740		4	1	5
1980		4	2	6
2040		7	0	7
2100		5	0	5
2460		5	0	5
2640		3	2	5
3060		2	3	5
3120		4	2	6
3240		5	1	6
540	Video 4	3	2	5
600		5	0	5
1200		5	0	5
1560		5	0	5
1620		3	2	5
2400		3	2	5
2520		3	2	5
2880		3	2	5
3120		4	1	5
3600		4	1	5
3720		5	0	5
3960		5	1	6
4680		5	1	6
4740		2	3	5
5040		5	1	6
5160		4	1	5
5220		4	1	5
5280		4	1	5
1320	Video 5	4	1	5
1380		4	1	5
1680		6	0	6
1860		4	1	5
1920		5	1	6
2100		5	1	6
2340		5	1	6
2400		5	1	6
2460		5	0	5
2580		3	2	5
2640		1	4	5
2760		5	0	5
2820		4	1	5
2940		5	1	6
3000		5	0	5
3240		5	1	6
3300		3	3	6
3360		4	3	7
3420		3	2	5
Total		301	104	405
Field Rating		74%	26%	

Relative Time (s)	13-Jul	Waste	No Waste	Total Obs
1920	Video 1	7	0	7
2340		6	1	7
2400		3	2	5
2520		3	2	5
2580		5	0	5
2760		5	1	6
2820		4	2	6
3060		5	0	5
3180		4	3	7
3420		3	4	7
3540		1	4	5
3780		3	3	6
3960		1	4	5
120	Video 2	4	3	7
180		6	1	7
360		7	0	7
1260		5	0	5
1380		5	1	6
1440		7	0	7
1620		5	0	5
1800		5	2	7
2160		4	1	5
2220		7	0	7
2280		6	0	6
2400		5	0	5
2520		5	0	5
3180		2	3	5
3900		3	2	5
3960		2	5	7
4080		2	4	6
4140		6	1	7
4260		2	3	5
4380		6	1	7
4680		5	2	7
4980		6	1	7
5040		6	0	6
5160		3	2	5
1320	Video 4	5	0	5
1560		5	2	7
1620		4	3	7
2040		7	0	7
2280		1	5	6
3840		4	1	5
4201		3	3	6
4320		3	2	5
4380		4	3	7
4980		3	3	6
5100		5	2	7
5160		5	1	6
5400		4	1	5
840	Video 5	5	1	6
900		6	1	7
960		3	2	5
1140		5	0	5
1380		2	3	5
2220		5	0	5
2280		2	3	5
2820		4	1	5
3120		4	2	6
3360		5	0	5
4200		7	0	7
4320		5	0	5
4380		5	0	5
4980		4	1	5
120	Video 6	4	1	5
360		4	2	6
540		4	1	5
1320		3	2	5
1620		3	2	5
Total		297	106	403
Field Rating		74%	26%	

Relative Time (s)	21-Jul	Waste	No Waste	Total Obs
2940	Video 1 P2	3	2	5
3240		3	2	5
3480		4	1	5
3540		5	2	7
3720		5	2	7
3900		5	1	6
3960		7	0	7
4140		3	4	7
4200		1	6	7
4380		3	4	7
4440		4	3	7
4500		0	7	7
4560		3	4	7
2040	Video 2	6	1	7
2160		5	2	7
2520		3	3	6
2640		7	0	7
3300		5	2	7
3360		4	2	6
3420		2	5	7
3600		3	2	5
4260		2	4	6
4560		5	2	7
4680		4	3	7
4800		3	3	6
4920		6	0	6
4980		3	4	7
5160		6	1	7
5220		4	3	7
5460		2	5	7
5520		3	4	7
1500	Video 3	1	6	7
1860		3	4	7
2520		5	2	7
2640		4	3	7
2760		4	3	7
2940		4	3	7
3000		2	5	7
3120		6	1	7
3300		5	1	6
3480		3	2	5
3660		2	5	7
3840		5	2	7
3900		3	3	6
3960		1	4	5
4020		5	1	6
4440		7	0	7
4560		7	0	7
4680		6	1	7
4740		6	1	7
5040		2	4	6
660	Video 4	1	6	7
780		4	2	6
960		3	3	6
1020		3	3	6
1500		4	2	6
2040		4	2	6
2280		5	0	5
2760		4	3	7
2820		2	5	7
2880		2	4	6
3860	Video 5	2	5	7
Total		234	170	404
Waste Rating		58%	42%	

Relative Time (s)	20-Aug	Waste	No Waste	Total Obs
1980	Video 1	3	2	5
2160		2	3	5
2220		3	3	6
2520		2	4	6
2700		3	4	7
2820		2	3	5
2880		4	2	6
3300		2	3	5
3360		5	1	6
3420		5	1	6
3540		4	2	6
3720		3	2	5
3780		4	3	7
3900		4	3	7
3960		2	4	6
4260		4	2	6
4440		5	0	5
4620		3	4	7
4680		3	4	7
4740		2	3	5
4920		1	4	5
5280		3	4	7
420	Video 2	3	3	6
1380		4	2	6
1560		1	4	5
1800		4	1	5
1860		6	0	6
1920		4	1	5
3420		3	2	5
3480		3	2	5
3600		1	4	5
3660		1	4	5
3840		0	5	5
180	Video 3	6	0	6
300		4	2	6
420		3	2	5
480		5	0	5
780		5	0	5
840		4	1	5
900		5	0	5
1320		3	2	5
1680		3	2	5
1800		3	2	5
1920		4	1	5
2040		4	1	5
2280		3	2	5
2400		5	1	6
2460		6	0	6
2520		4	2	6
2580		3	3	6
2640		3	3	6
2940		3	2	5
3000		3	2	5
3180		4	3	7
3240		4	1	5
3600		4	1	5
3720		5	1	6
3900		5	1	6
2100	Video 4	4	2	6
2280		5	0	5
2400		5	0	5
2640		4	1	5
3300		5	0	5
3360		5	0	5
3420		3	2	5
3540		4	1	5
3960		3	2	5
240	Video 5	2	3	5
540		3	2	5
1260		1	4	5
1380		1	4	5
1500		3	2	5
1740		3	2	5
Total		251	149	400
Waste Rating		63%	37%	

Table 38 - Coder B Productivity

Relative Time (s)	25-Mar	Working	Not Working	Total Obs
2220	Video1	6	0	6
2472		5	1	6
2640		4	3	7
3360		6	1	7
3720		4	1	5
3780		3	3	6
3900		5	2	7
4140		4	2	6
4260		4	1	5
4500		6	0	6
4620		3	2	5
4980		2	3	5
300	Video2	6	0	6
420		3	2	5
600		5	0	5
1260		3	2	5
1380		3	3	6
1500		4	1	5
3600		4	1	5
3840		3	3	6
4680		1	5	6
5160		4	3	7
5520		4	1	5
120	Video3	5	0	5
240		5	0	5
300		4	1	5
600		2	3	5
720		4	2	6
780		4	1	5
1560		3	2	5
1620		4	2	6
1800		4	3	7
2100		6	1	7
2340		4	1	5
2400		4	2	6
2520		4	3	7
2580		4	3	7
2640		3	3	6
3540		5	1	6
3720		4	1	5
3840		4	2	6
4200		4	2	6
4260		6	0	6
4560		6	1	7
4680		4	2	6
4920		4	3	7
5040		4	2	6
60	Video4	4	3	7
120		6	1	7
479		6	0	6
660		3	2	5
2040		3	2	5
2700		4	1	5
3720		4	1	5
4680		3	4	7
5280		3	2	5
5460		5	0	5
120	Video5	3	2	5
180		3	2	5
480		5	1	6
600		3	2	5
660		7	0	7
1320		6	0	6
1500		3	3	6
1740		4	1	5
2400		3	2	5
2640		4	1	5
2880		3	3	6
3240		3	2	5
4980		4	1	5
Total		285	117	402
Field Rating		71%	29%	

Relative Time (s)	9-Apr	Working	Not Working	Total Obs
1860	Video1	6	0	6
1980		6	0	6
2340		6	0	6
2700		6	1	7
2880		4	1	5
3000		5	0	5
3120		6	0	6
3300		5	0	5
3900		6	0	6
4140		6	0	6
4320		5	0	5
4560		4	2	6
4660		6	1	7
4680		6	1	7
4740		7	0	7
4860		5	0	5
4980		6	0	6
5040		4	1	5
5100		6	1	7
5340		5	2	7
5460		4	1	5
780	Video2	3	3	6
900		2	4	6
1079		2	3	5
1260		5	0	5
1800		7	0	7
1860		5	0	5
2220		6	0	6
2340		5	1	6
2400		7	0	7
2760		4	1	5
3000		4	1	5
3480		5	1	6
3600		6	0	6
4320		7	0	7
1080	Video3	3	2	5
1200		5	1	6
1259		5	0	5
2100	Video4	6	0	6
2220		5	0	5
2280		6	1	7
2340		7	0	7
2400		5	2	7
2460		5	1	6
2700		6	0	6
2940		5	0	5
3000		5	0	5
3180		5	0	5
3300		4	1	5
3600		5	0	5
3780		5	0	5
4260		6	0	6
4500		4	2	6
4620		5	1	6
4680		5	1	6
4800		6	0	6
4980		5	0	5
5039		5	0	5
5160		4	1	5
5220		5	0	5
960	Video5	6	1	7
1140		5	0	5
1920		5	0	5
2160		6	0	6
2280		6	0	6
2520		5	2	7
2880		7	0	7
2940		5	1	6
3000		6	0	6
Total		360	42	402
Field Rating		90%	10%	

Relative Time (s)	5-May	Working	Not Working	Total Obs
2040	Video1	5	0	5
2220		5	1	6
2520		2	3	5
2700		3	3	6
2820		5	0	5
2940		5	0	5
3000		6	0	6
3060		5	0	5
3120		5	0	5
3180		6	0	6
3240		4	1	5
3360		4	2	6
3480		3	2	5
480	Video2	5	0	5
1020		5	0	5
1140		3	2	5
2400		5	0	5
2520		4	1	5
2580		5	0	5
2640		1	4	5
2820		3	2	5
3060		5	1	6
3120		3	2	5
3300		2	3	5
3420		3	2	5
3840		4	1	5
3900		3	2	5
4140		3	2	5
4260		4	1	5
4439		3	2	5
4680		4	2	6
360	Video3	3	2	5
960		4	1	5
2100		2	3	5
2160		4	2	6
2460		4	2	6
3060		3	2	5
3120		2	3	5
3240		2	3	5
360	Video4	2	3	5
540		2	3	5
600		2	3	5
1200		4	2	6
1440		4	1	5
1560		4	1	5
1620		1	4	5
2100		3	2	5
2520		3	3	6
2880		4	1	5
3120		5	1	6
3180		2	3	5
3960		3	2	5
4500		3	2	5
4679		4	1	5
4680		4	1	5
4740		1	4	5
5040		3	2	5
5160		2	3	5
5220		4	1	5
5280		3	2	5
1320	Video5	4	1	5
1380		4	1	5
1560		5	0	5
1680		4	2	6
1860		5	1	6
2100		6	0	6
2220		5	1	6
2340		5	0	5
2460		5	1	6
2580		5	0	5
2640		5	1	6
2760		4	1	5
2820		4	2	6
3000		5	1	6
3240		5	1	6
3360		4	1	5
Total		285	116	401
Field Rating		71%	29%	

Relative Time (s)	13-Jul	Working	Not Working	Total Obs
1920	Video1	5	2	7
2340		3	3	6
2400		2	3	5
2520		4	2	6
2580		4	2	6
3060		5	0	5
3420		4	2	6
3780		5	2	7
120	Video2	4	2	6
360		5	0	5
1140		3	2	5
1260		5	0	5
1380		3	2	5
1440		5	0	5
1620		6	1	7
1800		4	2	6
2160		4	2	6
2220		3	2	5
2280		3	2	5
2400		3	2	5
2520		5	1	6
2700		5	0	5
3180		3	2	5
3600		2	3	5
3780		4	2	6
3900		4	1	5
3960		4	2	6
4080		5	0	5
4140		5	1	6
4260		5	0	5
4380		6	1	7
4680		4	1	5
4980		6	0	6
5040		6	0	6
5160		2	3	5
1320	Video4	2	3	5
1560		5	0	5
1620		4	2	6
2040		4	2	6
2280		5	1	6
2820		3	2	5
3060		4	1	5
3840		3	3	6
4080		1	4	5
4200		5	1	6
4320		1	4	5
4380		5	1	6
4680		2	3	5
4980		3	2	5
5100		6	0	6
5280		4	2	6
5400		3	2	5
780	Video5	4	1	5
840		1	4	5
900		5	1	6
960		3	2	5
1140		2	3	5
1380		5	0	5
1440		5	0	5
2820		3	2	5
3120		5	0	5
3360		4	1	5
4200		5	1	6
4320		5	1	6
4380		2	3	5
4980		3	3	6
120	Video6	1	6	7
360		3	2	5
540		4	1	5
960		4	1	5
1020		3	2	5
1320		3	2	5
1620		3	2	5
Total		279	121	400
Field Rating		70%	30%	

Relative Time (s)	21-Jul	Working	Not Working	Total Obs
2940	Video1 P2	5	0	5
3240		2	3	5
3480		3	2	5
3540		4	3	7
3720		2	3	5
3900		3	3	6
3960		4	2	6
4140		4	1	5
4200		3	2	5
4380		4	2	6
4400		4	2	6
4440		4	1	5
4560		2	4	6
2040	Video2	3	2	5
2160		4	2	6
2280		4	1	5
2340		3	2	5
2520		4	2	6
2640		6	0	6
3300		4	1	5
3360		5	1	6
3420		6	0	6
3600		6	0	6
4260		5	1	6
4560		3	3	6
4680		3	3	6
4800		4	2	6
4920		4	2	6
4980		3	2	5
5160		3	2	5
5220		4	2	6
5460		3	3	6
5520		3	3	6
5640		3	2	5
1500	Video3	3	2	5
1860		4	2	6
2520		4	2	6
2640		4	2	6
2760		3	4	7
2940		3	2	5
3000		2	4	6
3120		2	3	5
3300		5	0	5
3480		2	4	6
3660		2	4	6
3840		3	2	5
3900		4	2	6
3960		4	2	6
4020		4	2	6
4440		3	2	5
4560		3	2	5
4680		4	3	7
4740		5	2	7
5040		3	2	5
660	Video4	2	3	5
780		4	2	6
960		1	5	6
1020		2	3	5
1380		4	1	5
1500		5	1	6
1615		1	4	5
1920		4	2	6
2040		4	3	7
2280		3	2	5
2760		4	2	6
2820		2	3	5
2880		1	5	6
2940		2	3	5
3000		1	4	5
3800	Video5	2	3	5
3860		3	2	5
4040		2	3	5
Total		241	163	404
Field Rating		60%	40%	

Relative Time (s)	20-Aug	Working	Not Working	Total Obs
1980	Video1	1	4	5
2100		4	1	5
2160		3	2	5
2220		2	3	5
2820		5	1	6
3000		3	2	5
3300		1	5	6
3360		5	1	6
3420		5	1	6
3540		4	2	6
3720		2	3	5
3780		3	2	5
3900		3	2	5
3960		5	1	6
4260		5	0	5
4380		2	3	5
4620		2	4	6
4680		5	1	6
4740		2	4	6
4920		3	4	7
4980		0	5	5
5100		2	3	5
5280		3	4	7
5460		1	4	5
420	Video2	3	2	5
840		2	3	5
1140		2	4	6
1202		2	3	5
1380		2	4	6
1620		2	3	5
1800		2	3	5
1860		6	0	6
1920		3	2	5
3420		1	4	5
3480		2	3	5
3840		1	4	5
4560		4	1	5
5340		4	1	5
300	Video3	5	0	5
480		3	2	5
780		5	0	5
840		5	0	5
900		5	0	5
1320		3	2	5
1620		2	3	5
1679		3	2	5
1800		1	4	5
1860		3	2	5
1920		4	2	6
2100		3	2	5
2340		2	3	5
2400		5	1	6
2460		6	0	6
2640		3	2	5
2760		5	0	5
3000		2	4	6
3420		5	2	7
3600		5	1	6
3900		4	1	5
2100	Video4	5	1	6
2280		5	0	5
2640		5	1	6
240		1	5	6
300		2	3	5
360		3	2	5
420		5	1	6
540		3	2	5
899		2	3	5
1019		4	1	5
1200		5	1	6
1260		5	0	5
1380		4	2	6
1500		3	2	5
1620		5	1	6
1740		3	3	6
Total		246	160	406
Field Rating		61%	39%	

Table 39 - Coder B Safety

Relative Time (s)	25-Mar	Safe	Not Safe	Total Obs
2200	Video 1	5	0	5
2460		4	2	6
2640		5	0	5
2940		6	1	7
3360		6	0	6
3600		5	0	5
3720		5	0	5
3780		4	1	5
3900		4	1	5
4140		4	1	5
4260		5	0	5
4500		5	1	6
4620		5	0	5
4980		6	1	7
300	Video 2	6	1	7
420		4	2	6
600		4	1	5
960		4	1	5
1260		4	1	5
1380		5	1	6
1500		6	0	6
2160		6	0	6
2400		5	0	5
3600		5	0	5
3840		5	0	5
4380		5	0	5
4500		3	2	5
4680		3	2	5
5160		6	0	6
5520		4	1	5
240	Video 3	4	1	5
300		5	0	5
600		5	1	6
720		5	2	7
780		4	2	6
1560		4	1	5
1620		5	1	6
1800		4	3	7
2100		5	2	7
2340		2	4	6
2400		5	1	6
2520		5	2	7
2580		4	2	6
2640		5	1	6
3540		3	3	6
3840		4	1	5
4200		4	1	5
4260		4	1	5
4560		5	1	6
4680		4	1	5
4920		4	1	5
5040		5	1	6
60	Video 4	6	0	6
119		5	2	7
480		5	0	5
660		5	0	5
4680		6	1	7
5280		4	1	5
5460		3	2	5
120	Video 5	3	2	5
180		2	3	5
480		4	2	6
600		3	2	5
660		5	2	7
1320		4	2	6
1500		3	4	7
1740		3	2	5
2400		5	1	6
2640		2	3	5
2880		4	2	6
3540		3	2	5
4800		4	1	5
Total		318	87	405
Safety Rating		79%	21%	

Relative Time (s)	9-Apr	Safe	Not Safe	Total Obs
1860	Video 1	4	1	5
1980		5	1	6
2340		5	1	6
2699		5	1	6
2880		6	0	6
3000		4	1	5
3120		5	0	5
3300		3	2	5
3900		4	1	5
4140		5	1	6
4320		5	1	6
4560		4	1	5
4680		4	1	5
4740		5	1	6
4860		4	1	5
4980		5	1	6
5040		4	1	5
5100		5	1	6
5340		5	1	6
5460		5	1	6
900	Video 2	4	2	6
1080		4	2	6
1260		4	1	5
1800		4	2	6
1860		4	1	5
2220		5	0	5
2340		5	2	7
2400		5	1	6
2760		4	1	5
3000		3	3	6
3480		4	2	6
3600		4	2	6
3720		4	1	5
4320		4	1	5
1080	Video 3	4	1	5
1200		5	1	6
2100	Video 4	3	2	5
2220		4	2	6
2280		6	1	7
2340		6	1	7
2400		4	1	5
2460		6	0	6
2700		4	1	5
2820		3	2	5
2940		5	0	5
3000		4	1	5
3180		4	1	5
3300		4	1	5
3600		5	1	6
3780		4	1	5
4260		4	2	6
4500		3	3	6
4620		5	1	6
4680		4	2	6
4800		4	1	5
4980		5	1	6
5040		3	2	5
5160		5	1	6
5220		4	1	5
960	Video 5	5	1	6
1140		4	1	5
1920		4	1	5
2160		5	1	6
2280		5	1	6
2520		5	1	6
2880		5	1	6
2940		4	2	6
3000		4	2	6
3420		5	1	6
3540		5	1	6
3660		5	1	6
Total		314	85	399
Safety Rating		79%	21%	

Relative Time (s)	5-May	Safe	Not Safe	Total Obs
2220	Video 1	5	0	5
2520		5	0	5
2580		6	0	6
2700		5	0	5
2940		4	1	5
3000		6	0	6
3120		5	0	5
3180		6	0	6
3240		6	0	6
3360		6	0	6
3480		5	0	5
3600		5	1	6
480	Video 2	4	1	5
1020		5	0	5
1140		5	0	5
2400		5	1	6
2520		5	0	5
2580		5	0	5
2640		4	1	5
3060		5	0	5
3420		5	0	5
3840		5	0	5
3900		6	0	6
4260		5	0	5
4440		5	0	5
4680		6	0	6
4860		5	0	5
960	Video 3	5	0	5
1380		5	0	5
1560		5	0	5
1980		5	0	5
2040		6	0	6
2100		5	0	5
2460		5	0	5
3060		5	1	6
3120		4	2	6
3240		5	0	5
540	Video 4	6	0	6
900		5	0	5
1200		5	0	5
1440		5	0	5
1560		5	0	5
1620		5	0	5
2520		5	0	5
2880		5	0	5
3060		5	0	5
3120		6	0	6
3180		5	0	5
3360		5	0	5
3960		5	0	5
4680		5	0	5
4740		6	0	6
5040		6	0	6
5160		5	0	5
5220		5	0	5
5280		4	1	5
1320	Video 5	5	0	5
1380		5	0	5
1560		5	0	5
1680		6	0	6
1860		5	0	5
2100		6	0	6
2220		6	0	6
2340		5	1	6
2460		6	0	6
2580		5	0	5
2640		6	0	6
2760		3	2	5
2820		5	0	5
2940		6	0	6
3000		5	0	5
3120		5	0	5
3240		5	0	5
3300		6	1	7
3360		5	1	6
Total		387	14	401
Safety Ratings		97%	3%	

Relative Time (s)	13-Jul	Safe	Not Safe	Total Obs
1920	Video 1	6	0	6
2340		6	1	7
2400		5	1	6
2520		4	1	5
2580		4	1	5
2760		4	1	5
2820		4	1	5
3060		4	1	5
3180		5	1	6
3420		5	0	5
3540		4	1	5
3780		5	1	6
3960		5	1	6
4200		4	1	5
4260		4	1	5
120	Video 2	5	1	6
180		4	1	5
360		5	1	6
1140		5	0	5
1260		4	1	5
1380		4	1	5
1440		4	1	5
1620		5	0	5
1800		5	1	6
1980		4	1	5
2100		4	1	5
2160		3	2	5
2220		4	1	5
2280		4	1	5
2400		5	1	6
2520		5	1	6
2580		5	0	5
2700		5	0	5
3900		4	1	5
3960		5	1	6
4080		5	1	6
4140		4	2	6
4260		4	1	5
4380		5	2	7
4680		5	1	6
4980		6	0	6
5040		5	1	6
5160		5	0	5
1320	Video 4	4	1	5
1560		4	1	5
1620		5	1	6
2040		4	1	5
2280		6	0	6
3060		4	1	5
3840		3	3	6
4200		4	2	6
4380		2	3	5
5100		4	1	5
5160		5	0	5
5280		4	2	6
780	Video 5	3	2	5
900		5	1	6
960		4	1	5
2220		5	0	5
2820		4	1	5
3120		3	2	5
3360		3	2	5
4200		5	1	6
4320		3	2	5
4380		4	1	5
4980		3	2	5
120	Video 6	2	3	5
360		3	2	5
540		4	1	5
960		2	3	5
1020		2	3	5
1320		4	2	6
1440		4	1	5
1620		5	1	6
Total		314	85	399
Safety Rating		79%	21%	

Relative Time (s)	21-Jul	Safe	Not Safe	Total Obs
2940	Video1 P2	4	1	5
3239		4	1	5
3480		4	1	5
3540		5	1	6
3720		4	1	5
3900		4	2	6
3960		6	0	6
4140		5	1	6
4200		5	1	6
4380		5	1	6
4440		4	1	5
4500		4	1	5
4560		4	1	5
2040	Video2	5	1	6
2160		6	1	7
2280		4	1	5
2340		5	1	6
2520		4	1	5
2640		5	1	6
3300		5	1	6
3360		5	1	6
3420		6	1	7
3600		5	1	6
4200		5	2	7
4560		6	1	7
4680		5	1	6
4780		6	1	7
4800		6	1	7
4920		6	1	7
4980		5	1	6
5160		5	1	6
5220		5	2	7
5460		6	1	7
5520		5	1	6
5640		5	0	5
1500	Video3	5	1	6
1860		6	1	7
2520		5	1	6
2760		5	2	7
2939		6	1	7
3000		6	1	7
3120		5	1	6
3300		5	1	6
3480		5	1	6
3660		4	2	6
3840		5	2	7
3900		5	1	6
3960		5	1	6
4020		6	1	7
4440		5	1	6
4560		5	1	6
4680		5	1	6
4740		5	1	6
5040		6	0	6
660	Video4	5	1	6
780		5	1	6
960		5	1	6
1020		5	1	6
1380		5	0	5
1500		4	2	6
1620		4	1	5
1920		6	1	7
2040		5	1	6
2280		5	1	6
2760		5	1	6
2820		4	2	6
Total		330	70	400
Safety Ratings		83%	18%	

Relative Time (s)	20-Aug	Safe	Not Sate	Total Obs
1980	Video 1	5	0	5
2100		5	0	5
2160		5	0	5
2220		5	0	5
2820		5	1	6
3300		5	0	5
3360		6	0	6
3420		6	0	6
3540		6	0	6
3720		6	0	6
3780		5	0	5
3900		5	0	5
3960		6	0	6
4260		6	0	6
4680		6	0	6
4740		6	0	6
4920		6	0	6
4980		5	0	5
5100		5	0	5
5280		7	0	7
420	Video 2	5	1	6
840		5	0	5
1140		5	0	5
1380		7	0	7
1620		5	0	5
1800		5	0	5
1860		7	0	7
1920		5	1	6
2040		5	0	5
3420		5	0	5
3480		5	0	5
3660		5	0	5
3840		5	0	5
180	Video 3	6	0	6
300		5	0	5
480		5	0	5
780		5	0	5
840		5	0	5
900		5	0	5
1320		5	0	5
1620		5	0	5
1680		5	0	5
1800		5	0	5
1860		5	0	5
1920		5	0	5
2400		6	1	7
2460		5	1	6
2520		5	1	6
2640		6	0	6
3000		7	0	7
3420		7	0	7
3600		5	0	5
2100	Video 4	6	0	6
2280		5	0	5
2640		6	0	6
3300		5	0	5
3360		6	0	6
3420		5	1	6
3540		6	0	6
3960		7	0	7
4380		6	0	6
240	Video 5	6	0	6
300		5	0	5
360		5	0	5
420		4	1	5
540		5	0	5
1020		5	0	5
1200		6	0	6
1260		6	0	6
1380		5	0	5
1500		5	0	5
1740		6	0	6
Total		392	8	400
Safety Rating		98%	2%	

Table 40 - Coder B Waste

Relative Time (s)	25-Mar	NLW	LW	Total Obs
2200	Observation Video 1	3	2	5
2460		4	2	6
2640		3	3	6
2940		3	3	6
3360		5	1	6
3720		5	0	5
3780		3	2	5
3900		2	3	5
4140		6	0	6
4260		4	1	5
4500		2	4	6
4620		3	2	5
4980		2	4	6
300	Observation Video 2	0	6	6
420		3	3	6
600		4	1	5
1260		5	1	6
1380		3	3	6
2160		4	2	6
2400		2	3	5
3600		5	1	6
3840		3	2	5
4380		2	4	6
4500		1	4	5
4680		1	5	6
5160		3	4	7
5520		2	3	5
120	Observation Video 3	4	1	5
240		4	1	5
300		4	1	5
600		2	4	6
720		4	2	6
780		5	1	6
1560		2	3	5
1620		2	4	6
1800		2	4	6
2100		4	2	6
2340		2	3	5
2520		3	4	7
2580		2	3	5
2640		2	3	5
3540		3	3	6
3840		1	5	6
4200		2	3	5
4260		3	2	5
4560		4	1	5
4680		1	4	5
4920		2	4	6
5040		4	2	6
60	Observation Video 4	2	4	6
120		3	4	7
480		1	4	5
660		1	4	5
1140		2	3	5
4680		1	5	6
4920		2	5	7
5040		2	4	6
120	Observation Video 5	3	2	5
180		3	2	5
480		3	3	6
600		3	2	5
660		2	5	7
1320		2	4	6
1500		3	3	6
2400		1	4	5
2640		1	4	5
4920		2	3	5
4980		2	3	5
420	Observation Video 6	2	3	5
600		2	3	5
660		0	5	5
720		2	3	5
Total		190	211	401
Waste Rating		47%	53%	

Relative Time (s)	9-Apr	NLW	LW	Total Obs
1860	Observation Video 1	3	2	5
1980		5	2	7
2340		3	3	6
2700		5	1	6
2880		4	1	5
3000		3	3	6
3120		3	2	5
3300		3	2	5
3900		4	1	5
4140		4	2	6
4320		4	1	5
4560		2	3	5
4680		4	1	5
4740		3	3	6
4860		4	1	5
4980		4	2	6
5100		5	1	6
5340		2	3	5
5460		1	4	5
780	Observation Video 2	3	2	5
900		0	7	7
1080		2	4	6
1260		5	0	5
1800		4	2	6
1860		4	2	6
2220		1	5	6
2340		3	3	6
2400		2	4	6
2760		3	2	5
3000		4	1	5
3480		5	0	5
3600		5	0	5
3720		3	2	5
4320		5	0	5
1080	Observation Video 3	2	5	7
1200		3	3	6
1260		2	3	5
2100	Observation Video 4	4	1	5
2220		4	2	6
2280		3	4	7
2340		3	3	6
2400		3	3	6
2460		4	2	6
2700		3	2	5
2820		4	1	5
2940		2	3	5
3000		1	4	5
3180		3	2	5
3300		3	2	5
3600		2	3	5
3780		3	2	5
4260		1	5	6
4500		2	4	6
4620		3	3	6
4680		1	5	6
4800		4	2	6
4980		0	5	5
5040		3	3	6
5160		3	3	6
5220		2	5	7
960	Observation Video 5	4	2	6
1140		3	3	6
1920		1	5	6
2160		4	1	5
2280		4	2	6
2520		0	5	5
2880		4	2	6
2940		1	6	7
3000		3	2	5
3420		4	3	7
3660		1	5	6
3720		3	3	6
Total		215	191	406
Waste Rating		53%	47%	

Relative Time (s)	5-May	NLW	LW	Total Obs
2040	Observation Video 1	3	2	
2220		2	3	
2580		4	1	
2700		2	3	
2940		4	1	
3000		5	1	
3120		3	2	
3180		5	1	
3240		2	4	
3360		3	2	
3480		4	2	
3600		3	3	
480	Observation Video 2	2	3	
840		1	4	
1020		0	5	
1140		1	4	
2580		5	0	
2640		3	2	
3120		3	2	
3420		3	2	
3840		1	4	
3900		1	5	
4260		3	2	
4680		0	6	
180	Observation Video 3	1	4	
240		0	5	
360		4	2	
900		1	4	
960		0	5	
1740		1	4	
2100		0	5	
2160		2	3	
2460		4	2	
2640		1	4	
3060		2	3	
3240		4	1	
180	Observation Video 4	3	2	
420		1	4	
540		5	1	
1200		2	3	
1440		3	2	
1560		5	0	
1620		2	3	
2100		3	2	
2520		3	3	
2880		2	3	
3060		4	2	
3120		3	2	
3120		2	3	
3180		0	5	
3720		4	1	
3960		4	2	
4500		3	2	
4680		3	3	
4740		1	5	
5040		2	4	
5160		1	4	
5220		4	2	
5280		1	5	
720	Observation Video 5	2	3	
1320		3	2	
1380		6	0	
1560		3	2	
1680		5	1	
1860		3	2	
2100		3	3	
2220		2	3	
2340		4	3	
2460		4	1	
2580		2	3	
2640		4	2	
2760		4	1	
2820		2	3	
3000		5	1	
3240		2	4	
3360		0	6	
Total		198	209	407
Waste Rating		49%	51%	

Relative Time (s)	13-Jul	NLW	LW	Total Obs
1920	Observation Video 1	4	3	7
2340		4	3	7
2520		3	2	5
2580		4	2	6
2760		4	1	5
2820		3	3	6
3060		4	1	5
3420		4	3	7
3780		3	3	6
120	Observation Video 2	3	3	6
180		2	4	6
360		4	2	6
1140		2	3	5
1260		5	0	5
1380		4	2	6
1440		4	2	6
1620		2	4	6
1800		5	1	6
2160		3	2	5
2220		1	4	5
2280		2	3	5
2400		3	2	5
2520		5	1	6
2700		5	0	5
3180		3	2	5
3780		1	5	6
3900		3	2	5
3960		0	6	6
4080		3	3	6
4140		4	2	6
4260		1	4	5
4380		3	3	6
4680		2	3	5
4980		4	3	7
5040		4	2	6
5159		2	3	5
1320	Observation Video 4	2	3	5
1560		3	3	6
1620		3	4	7
2040		3	4	7
2280		1	5	6
3060		5	1	6
3840		3	3	6
4200		1	5	6
4380		2	4	6
4680		2	3	5
4980		1	4	5
5100		4	1	5
5160		4	1	5
5280		2	4	6
780	Observation Video 5	3	2	5
900		2	5	7
960		2	4	6
1380		1	4	5
1500		2	3	5
2220		3	2	5
2280		1	4	5
2820		2	3	5
3120		3	3	6
3360		4	2	6
4200		5	1	6
4320		3	2	5
4380		4	1	5
4980	Observation Video 5	1	6	7
120		2	4	6
360		3	3	6
540		2	3	5
960		3	2	5
1320		3	3	6
1440		2	3	5
1620		1	4	5
Total		201	201	402
Waste Rating		50%	50%	

Relative Time (s)	21-Jul	NLW	LW	Total Obs
2940	Observation Video 1 P2	1	4	5
3240		4	1	5
3480		3	2	5
3540		1	5	6
3720		2	3	5
3900		2	3	5
3960		5	2	7
4140		0	7	7
4200		2	4	6
4380		2	5	7
4440		1	5	6
4500		1	5	6
4560		1	5	6
2040	Observation Video 2	4	2	6
2160		5	2	7
2280		3	2	5
2340		2	3	5
2520		2	4	6
2640		3	3	6
3300		5	2	7
3360		3	4	7
3420		4	3	7
3600		4	2	6
4260		4	2	6
4560		3	4	7
4680		3	4	7
4800		2	5	7
4920		4	2	6
4980		1	5	6
5160		4	3	7
5220		4	2	6
5460		1	4	5
5520		2	4	6
5640		2	3	5
1500	Observation Video 3	2	5	7
1860		4	3	7
2520		3	3	6
2640		1	5	6
2760		0	6	6
2940		2	4	6
3000		1	5	6
3120		2	4	6
3300		3	2	5
3480		4	1	5
3660		3	3	6
3840		5	2	7
3900		4	1	5
3960		5	2	7
4020		3	3	6
4440		3	3	6
4560		1	6	7
4680		3	3	6
4740		4	2	6
5040		0	6	6
660	Observation Video 4	0	6	6
780		3	2	5
960		2	5	7
1020		2	3	5
1380		2	3	5
1500		2	4	6
1620		2	3	5
1920		0	6	6
2040		1	5	6
2280		1	5	6
2760		2	4	6
2820		3	2	5
2880		1	4	5
Total		164	237	401
Waste Rating		41%	59%	

Relative Time (s)	20-Aug	NLW	LW	Total Obs
2160	Observation Video 1	3	2	5
2220		2	3	5
2520		4	2	6
2700		1	5	6
2820		2	4	6
2880		5	1	6
3300		2	3	5
3360		1	4	5
3420		3	3	6
3540		2	4	6
3720		3	3	6
3780		3	2	5
3900		2	3	5
3960		2	3	5
4260		4	2	6
4620		3	3	6
4680		3	3	6
4740		1	4	5
4920		2	4	6
5280		2	3	5
420	Observation Video 2	3	3	6
1140		2	3	5
1380		1	5	6
1560		3	3	6
1620		2	3	5
1860		5	1	6
1920		4	2	6
3420		3	2	5
3480		1	4	5
3840		0	5	5
480	Observation Video 3	4	1	5
780		1	4	5
840		2	3	5
900		5	0	5
1680		0	5	5
1800		3	2	5
1920		2	3	5
2100		3	2	5
2160		3	2	5
2280		1	4	5
2400		1	5	6
2460		3	2	5
2520		3	3	6
2580		1	5	6
2640		3	3	6
2940		2	3	5
3000		0	5	5
3180		3	3	6
3240		3	2	5
3420		1	5	6
3600		2	3	5
3720		5	1	6
3900		4	2	6
2100	Observation Video 4	2	3	5
2640		4	2	6
3300		5	1	6
3360		2	3	5
3420		4	2	6
3540		3	2	5
3780		2	3	5
3840		4	1	5
3960		2	4	6
4140		2	3	5
4200		1	5	6
4380		3	2	5
240	Observation Video 5	2	3	5
300		1	4	5
420		4	1	5
540		3	2	5
720		3	2	5
1200		1	4	5
1260		3	2	5
1380		1	4	5
1500		0	5	5
1740		3	2	5
Total		184	220	404
Waste Rating		46%	54%	