Identification and analysis of worker safety hazards in Midwest agribusiness construction work sites

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Identification and analysis of worker safety hazards in Midwest agribusiness construction work sites

by

Nurhaizan Mohd Zainudin

A dissertation submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Industrial and Agricultural Technology

Program of Study Committee:
Gretchen A. Mosher, Major Professor
Steven A. Freeman
Dirk E. Maier
Jennifer S. Shane
Jeffrey D. Wolt

The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this dissertation. The Graduate College will ensure this dissertation is globally accessible and will not permit alterations after a degree is conferred.

Iowa State University
Ames, Iowa
2019

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DEDICATION

To

Ayah, Mama, Yong, and Adik
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<td>FTA</td>
<td>Fault Tree Analysis</td>
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<td>MCS</td>
<td>Minimal Cut Sets</td>
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<td>GEAPS</td>
<td>Grain Elevator and Processing Society</td>
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<td>PPE</td>
<td>Personal Protective Equipment</td>
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<td>NSC</td>
<td>National Safety Council</td>
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I would like to extend my sincere gratitude to my major professor, Dr. Gretchen Mosher, for providing me the opportunity to earn my doctoral degree. Her guidance, support, trust, and insights throughout my years of completing the doctoral program have kept me motivated to continue on the journey.

I thank my committee member, Dr. Jennifer Shane for supporting me and never stop believing in me even when I moved into a different home (i.e. switching from Civil Engineering Department to Agricultural and Biosystems Engineering Department). I would also like to thank Dr. Steven Freeman, Dr. Dirk Maier, and Dr. Jeffrey Wolt for serving on my program of study committee and for their continuous guidance, comments, and support throughout the course of this research.

In addition to the committee, I would also like to thank my friends and colleagues, Saxon Ryan, Chad Dolphin, and Anne Dohmen for providing encouraging advice and for creating Elings 3332 a fun place to be. I thank Fatemeh Davoudi Kakhki, Sesong Jeon, and Noor Intan Shafinas Muhammad who have taken time to comfort, give encouragement, and provide constructive comments on my work. I also thank Hasyimah Mohd Amin, ‘Aishah Othman, and Noraidah Nordin for providing a safe place to rant and share frustrations, and also for providing the calm and encouragement I needed to continue on.

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Alhamdulillah.
The construction industry is characterized by high fatality and injury rates. The dynamic nature of construction projects has exposed its workers to multiple safety hazards and risks, resulting in high fatality and injury rates on sites. Agribusiness construction is a sub-classified area of the construction industry. Agribusiness construction incidents are thought to contribute to the high fatality and injury rates in the construction industry, yet little empirical work has been done to confirm this hypothesis. A lack of available data to address fatalities and injuries specifically focused on agribusiness construction sites has hindered many efforts to improve safety management within the industry. Worker safety hazards for agribusiness construction sites and their contributing factors are important in the development of tailored preventative safety measures to reduce safety incidents in the future. Because safety incident can be attributed to multiple factors, research on worker safety incidents must encompass the depth and breadth of the area, specifically concerning underlying contributing factors, through the application of effective research approach. This study aimed at identifying worker safety hazards commonly present at agribusiness construction sites and their contributing factors using a mixed method approach and fault tree analysis (FTA). Purposive sampling was utilized to gather sample. Industrial experts and academic professionals were approached to participate in semi-structured interviews and surveys. Participants were asked to identify worker safety hazards and their contributing factors during the interview sessions and then quantify and rank order the hazards and factors through the surveys. FTA was then used to further analyze the contributing factors to the worker safety hazard. The research results provide a better understanding of worker safety hazards occurring in agribusiness...
construction projects, identification of contributing factors to the hazards, and comparison of safety research data and census data relative to worker safety hazards in agribusiness construction industry. Safety professionals, construction companies, and training developers will be able to use the research results to develop safety plan tailored for agribusiness construction sites.
CHAPTER 1. GENERAL INTRODUCTION

The dynamic and dangerous nature of construction projects have exposed workers to a wide range of safety hazards and risk. As a result, high rates of occupational incidents and injury and fatality rates characterize the construction industry (Albert, Hallowell, & Kleiner, 2014b). The construction industry consistently leads other industries as one of the top industries in the number of total worker deaths (Bureau of Labor Statistics, 2017a). Agribusiness construction incidents are thought to form part of the total worker deaths, yet little empirical knowledge has confirmed this hypothesis. Goh and Chua (2009) reported that the inability of construction workers to recognize and respond to hazards contributes to the high injury rates.

Well-identified hazards may reduce the fatality rates and improve the safety management (Ramaswamy & Mosher, 2017) of construction projects. However, hazard identification and safety analysis in agribusiness construction projects is a challenging issue. A lack of available data to specifically address agribusiness construction injuries and fatalities has hindered many efforts in identifying the root causes of incidents and the completion of a comprehensive safety analysis in construction projects (Yang et al., 2017).

Various factors may place construction workers, including agribusiness construction workers, at higher risk for workplace injury. The dynamic nature of construction projects, in which the projects are subject to rapid changes, contribute to a wide array of occupational exposures for construction workers as the projects progress (Lipscomb et al., 2006). As the project reaches its peak, a number of different trades are present on site. The construction workers performing tasks simultaneously in a close
proximity are exposed to substantial work hazards. Additionally, construction sites generate debris throughout the construction process. The U.S. Environmental Protection Agency (2018) reported that the construction and demolition generation in the United States include concrete, steel, wood products, gypsum wallboard and plaster, tiles, and asphalt shingles and asphalt concrete. Debris at construction sites introduce more hazards to workers going in and out of sites to perform construction tasks (Lipscomb et al., 2006).

Previous research has demonstrated agribusiness and grain handling as high-hazard environments (Mosher, 2011; Swanton, Young, & Peek-Asa, 2016; Ramaswamy, 2017), but limited empirical works have been completed on agribusiness worker risks. Agribusiness workers are exposed to numerous hazards, including machinery, animals, chemicals, noise, and physical stress.

Further, agribusiness construction workers, when injured, may face challenges in accessing medical services, as agribusiness construction projects are often located in rural environments (Swanton, Young, & Peek-Asa, 2016). Researchers know that construction and agribusiness hazards and injuries are occurring, yet hazards specifically pointing towards agribusiness construction workers have little emphasis in the research literature. Even available data from the Bureau of Labor Statistics has no specific data recorded for agribusiness construction workers (Bureau of Labor Statistics, 2018a).

Safety management in industrial setting involves four elements: identification, communication, assessment, and selection of appropriate safety measures (Albert, Hallowell, & Kleiner, 2014b). Effective safety management is said to be achieved when hazards are properly identified, communicated, and assessed to allow for appropriate safety measure being implemented. Published safety research has focused on construction
hazards (Chi, Lin, & Ratna, 2014; Li et al, 2017; Hola & Szóstak, 2017) and root causes to construction safety incidents (Abdelhamid & Everett, 2000; Akhmad, Duff, & Peckitt, 2001), as well as on hazard identification skill in construction industry and how hazard identification process can improve safety management in construction projects (Albert, Hallowell, & Kleiner, 2014a; Albert, Hallowell, & Kleiner, 2014b; Albert et al., 2014c; Albert et al., 2017). Missing from the published literature is a characterization of worker safety hazards and their contributing factors in agribusiness construction projects. More information on these hazards is important to hazard mitigation, as the hazards faced by the agribusiness construction workers are hypothesized to be as detrimental as non-agribusiness commercial construction workers.

For this study, agribusiness construction refers to construction work of new agribusiness facilities as well as refurbishment or add-on works to existing agribusiness sites. Agribusiness facilities include grain storage bins, elevators, and lifts, in which these facilities support the operation of businesses engaged in the commercial grain handling and storage industry or in agribusiness related products and services (Davoudi Kakhki, 2018). While safety analysis in the construction industry is typically performed using safety records and incidents reports, obtaining such data specifically for agribusiness construction projects proved to be challenging. Therefore, this study utilized a mixed method approach through semi-structured interviews and survey deployment with a purposeful sample of professionals from the industry and academia. The semi-structured interview and the survey were developed with questions addressing all hazards occurring on sites that could lead to either recordable injuries and first aid injuries. Based on the definition provided by OSHA (U.S Department of Labor, 2019), recordable injuries or
illnesses refer to any work-related fatality that results in loss of consciousness, days away from work, restricted work, or transfer to another job. First aid injuries refer to injuries that require a non-prescription medication at nonprescription strength.

This is then followed by the development of a fault tree of contributing factors to worker safety hazards and an analysis of the fault tree to provide insight on worker safety hazards on agribusiness construction projects and to identify contributing factors of safety incidents for future safety intervention development.

**Purpose of Research**

Workers in the agribusiness industry are threatened by numerous hazards at their workplace. This is not surprising since agribusiness industry is considered as one of the most hazardous industries (Davoudi Kakhki, 2017) and has one of the highest fatality rates in the United States (Swanton, Young, & Peek-Asa, 2016). The trend of high fatalities and high injury rates is not new in either construction or agribusiness, yet calls for improved safety intervention have emerged from both industries. Although heavy safety research has been conducted on construction and agribusiness related areas, the fundamental requirement to improving safety (i.e. hazard identification) has received little attention in the research literature. Particularly, in agribusiness construction projects, almost no research has been completed to discuss the hazards exposure to the construction workers and the contributing factors of hazards existing in agribusiness project sites.

A hazard is any real or potential condition that can cause injury, illness, or death to personnel or damage to and loss of equipment, property, and environment (OSHA, 2002). Bahn (2013) mentioned that hazards include events associated with people’s actions, equipment characteristics, dust, and chemicals that contribute to workplace risks.
These hazards also reflect “the potential for harm” and include “all aspects of technology and activity that produce risk” (Manuele, 2010, p. 33). From a purely physics perspective, Albert et al. (2017) defined hazards as sources of energy which are required to lift, transport, and assemble materials but upon release and exposure may cause injury or death. The source of energy can be found stored or transferred by hoist, cranes, equipment, tools, and workers themselves. Based on various opinions in framing the word hazard, the authors extracted three main ideas underlining the definition of hazards in workplace: 1) a harmful source that could potentially cause injuries and fatalities, 2) hazard-related incidents contribute to workplace risks, and 3) people or workers are potential agents to hazards at the workplace. These ideas framed this study and were used as the baseline in understanding the term “hazard” for this study.

Construction work and elements involved in agribusiness construction projects are not different from the other commercial construction sites and the hazards exposure to workers can be presumed to be similar to that of commercial building construction. Exposure refers to people, property, system, or other elements present in hazard zones and therefore vulnerable to potential losses or harms (CeCC, 2011). This study defined hazards exposure as a state of a worker or workers being threatened with potential losses or harms when there are protective measures taken.

There are several inherent elements of agribusiness construction projects that separate them from the other commercial constructions. For example, organizational structure and relationship involved in commercial building construction where traditional project delivery system includes project owner, contractors, and designers in construction team is not often the case in the agribusiness construction projects.
To overcome the limitation of data available to perform hazards identification in the agribusiness construction hazards, this study was developed using a mixed method approach by conducting semi-structure interviews followed by a survey to a purposeful sample. This study addressed three research objectives: 1) To utilize qualitative and quantitative research tools to identify and rank worker safety hazards in agribusiness construction projects, 2) To use fault tree analysis to identify contributing factors to the highest estimated risk level hazard in agribusiness construction projects, and 3) To compare data collected by safety researchers with census data from government and industry sources.

The results of this study provide an improved understanding of hazards in agribusiness construction projects, an identification of worker safety hazards, and the identification of the most significant contributing factors to worker safety hazards in agribusiness construction projects. Findings of this study can be used by various stakeholders such as policy makers, construction companies, and training developers to plan for better safety strategies and to improve safety measures specifically targeting the agribusiness construction projects.

**Research Questions**

This study focuses on the hazards identification in agribusiness construction sites and utilization of fault tree analysis (FTA) to identify contributing factors for worker safety hazard in agribusiness construction projects. Three separate studies are included in this dissertation, with each study addressing specific research objectives.

The first study explored worker safety hazards as perceived by those who work in or with the industry and the contributing factors. Data were gathered using a mixed method approach. The research questions examined were:
i. What are the safety hazards identified by construction personnel and academic professionals for agribusiness construction projects?

ii. What are the contributing factors to the occurrence of safety hazards in agribusiness construction projects?

The second study focused on utilizing fault tree analysis to identify the contributing factors of the highest estimated risk level hazard in agribusiness construction projects using results gathered in the first study. The highest estimated risk level hazard indicated high severity and frequency of the hazard occurring on the construction sites.

The research questions examined were:

i. Which safety hazard is estimated as the highest by agribusiness construction workers and academic professionals when considering the probability to occur on work sites?

ii. How could the safety hazard occur on site?

iii. Why does the safety hazard occur on site?

The third study aimed at comparing the findings from the first two studies with the census data on construction injuries and fatalities. Data collected by the authors (considered as safety researchers) were opinions and perceptions of the industrial experts and academic professionals on agribusiness construction. Census data were used to validate their opinions and to estimate on the probability of the event occurring on construction sites. The research questions examined were:

i. What is the probability of the safety hazard to occur on agribusiness construction sites?

ii. How closely does hazard identified by safety researchers align the census data?
Scope of Study

This study will address the following topics, but is not limited to:

- Construction industry and agriculture industry. The Standard Industrial Classification (SIC) codes included was SIC 1541 General Contractors – Industrial Building and Warehouses
- Construction of agribusiness projects
- Risk management of agribusiness projects
- Safety management of agribusiness projects
- Academic professionals with agriculture, safety and/or construction background

Measurement and Methodology

The methodology to gather information needed to answer the research questions was organized in three parts: first, a semi structured interview with industrial experts and academic professionals; second, a questionnaire survey; and third, an examination of census data from the National Safety Council (NSC). A mixed method approach adopted and modified from Grover, Chopra, and Mosher (2016) was used for this study for two main reasons: (1) this approach suits the need and nature of this study, where the industrial experts and academic professionals are more accessible through interviews and survey and (2) this approach allows the authors to utilize both qualitative and quantitative tools to gather richer and deeper descriptions on issues of interest in this study. The
survey was used to corroborate data from the interviews to help better interpretations and writing of research findings.

Participants to interviews and survey include industrial experts and academic professionals with agriculture, construction, and/or safety backgrounds. A purposive sampling with criterion, snowball, and convenience sampling strategy was employed to develop the sample of this study. The Grain Elevator and Processing Society (GEAPS) directory was used to identify industrial experts. Professors and graduate students from the Department of Agricultural and Biosystems Engineering and the Civil, Construction, and Environmental Engineering Department at Iowa State University were contacted to participate as academic professional sample of this study. Table 1 summarizes related information on study participants.

Table 1 Summary of research participants

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<tr>
<td>Industrial experts</td>
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<td>213</td>
</tr>
<tr>
<td>Academic professionals</td>
<td>Semi-structured interview</td>
<td>5</td>
</tr>
<tr>
<td>Academic professionals</td>
<td>Survey</td>
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An interview protocol was established prior to starting the interview sessions. All participants were briefed on the research project and ensured of absolute confidentiality of the process. Consent to conduct the interviews were obtained from all participants. Each interview session lasted from 40 minutes to 90 minutes. An audio recording device was used together with hand written notes to record the interview sessions.
Audio records were transcribed verbatim immediately by the interviewer. A second native English speaker was appointed to validate the transcriptions. A third reader, also a native English speaker, was appointed to validate selected phrases and words of the transcriptions. A three-stage coding was used to categorize data gathered from the semi-structured interviews. To generate coding categories for the data, the author used a grounded theory approach. All data and transcripts were analyzed and coded by the same author/interviewer to eliminate inter-coder bias (Debnath, Blackman, & Haworth, 2015).

Data gathered and analyzed from the semi-structured interviews were used as basis to develop the survey instruments of this study. A 13-item questionnaire was developed using Qualtrics, an online survey tool. The survey was reviewed, approved, and classified as an exempt study by Institutional Review Board (IRB) (see IRB notes in Appendix C). The survey composed of two sections: (1) worker safety hazards and (2) demographic. Participants were asked to define ‘hazards’, estimate the level of severity and the likelihood of occurrence of worker safety hazards occurring on sites, and rank order the contributing factors to worker safety hazards. Except for one question asking participants to estimate for numerical probability of hazards, each question asked in the survey was provided with options for answers to select from. Descriptive analysis was used for data gathered from the survey.

Based on the hazard with the highest estimated risk level identified by survey participants, the second study, presented in Chapter 2, began by developing a fault tree for the contributing factors for the hazard. Several studies have utilized FTA as a tool to identify factors or root causes to safety incidents and to conduct safety analysis (Kingman...
& Field, 2005; Chi, Lin, & Ratna, 2014; Jones, Brusewitz, & Goforth, 1989; Demichela et al., 2004; Khanh Nguyen, Beugin, & Marais, 2015; Chiacchio et al., 2011). However, there is no literature on utilizing FTA to identify contributing factors to safety hazards in agribusiness construction projects.

Development of the fault tree was guided by the Fault Tree Handbook, NUREG-0492 written by the U.S. Nuclear Regulatory Commission (U.S. Nuclear Regulatory Commission, 1981). The handbook outlined how a fault tree should be constructed and evaluated. A simplified eight-step procedure for the construction of fault tree outlined by Pandey (2018) was followed by authors in developing the fault tree for this study. Two intermediate events for Level 1 of fault tree were identified based on extracted data from interview transcriptions and other research completed on construction hazards (Chi, Lin, & Ratna, 2014; Lipscomb et al., 2006; Winge & Albrechtsen, 2018; Hola & Szóstak, 2017). Successive branches were further explored until the tree model was completed.

The third study, presented in Chapter 3, aimed at validating the findings from study one and two with census data from the National Safety Council (2017). There are two main challenges in safety analysis for agribusiness construction: (1) census data for injuries and fatalities rates were not recorded under specific heading of agribusiness construction, rather the injuries and fatalities rates are summed up as total construction injuries and fatalities rates, and (2) no insurance data (or other reliable data) was available with sub-classification of agribusiness construction. These two situations limited the authors access to a reliable data set to facilitate an accurate estimation for the probability of events occurrence in the fault tree.
To estimate the probability of event occurrence in the fault tree, census data obtained from the National Safety Council (2017) for occupational injuries were used. The injury data published by the National Safety Council (2017) reported workplace falls in two categories: fall to lower level and fall on the same level. The data included nonfatal injuries involving days away from work and fatal occupational injuries for 2014. Fall hazards used in both the first study and the third study referred to fall injuries occurring on sites which include both fatal and nonfatal injuries.

Estimating the probability of event occurrence involved several sources of data: 1) injury data on from the National Safety Council, 2) Bureau of Labor Statistics (BLS) reports and 3) GEAPS directory. Since there was no record of injuries under the agribusiness construction classification, the authors performed data transformation based on the data available for construction industry and calculated the probability numbers for agribusiness injuries.

**Organization of Dissertation**

This dissertation was written in the alternative manuscript format as defined by Iowa State University’s Graduate College. Indicative contents for each chapter are as follows:

Chapter 1 – General introduction which outlines the key elements of the research and frames the objectives of research.

Chapter 2, 3, and 4 – Three manuscripts formatted for submission to specified journals.

Chapter 5 – General summary and interpretation of findings, recommendations for future research, and conclusions.
References


Blek, A. (2016, March 9). Re: When is it appropriate to describe research as “recent”? [Web log comment]. Retrieved from https://academia.stackexchange.com/questions/64806/when-is-it-appropriate-to-describe-research-as-recent


CHAPTER 2. IDENTIFICATION OF WORKER SAFETY HAZARDS IN AGRIBUSINESS CONSTRUCTION SITES

To be submitted to: Safety Science

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Abstract

Hazard identification is integral to every safety management activity. Unidentified hazards present unacceptable and unmanageable risks. Agribusiness construction projects are as highly hazardous as other type of construction works but limited attention has been given on hazard identification within this area. The aim of this paper was to utilize qualitative and quantitative research tools to identify and rank worker safety hazards in agribusiness construction projects. Most studies in construction industry have utilize safety records or accident reports in the hazard identification process. Due to limited literature and available data for agribusiness construction, this study employed a mixed method approach to identify hazards to worker safety on agribusiness construction sites. Semi-structured interviews were conducted with industrial experts and academic professionals from the Midwestern region of the United States. A three-coding stage with a grounded theory approach were utilized to thematically categorize themes for worker safety hazards and their contributing factors. An online survey was developed based on the identified themes. Using Qualtrics®, the survey was disseminated to 220 participants and 22 completed the survey, which included industrial experts and academic professionals. Participants were asked to estimate the risk level of a list of hazards and to rank order the contributing factors to these. The most significant and high-risk hazards
identified for agribusiness construction projects included falls with estimated probability to occur at 0.2. Participants ranked poor decision making, carelessness, and underestimation of risk associated with assigned tasks as top ranked contributing factors to worker behavior that could lead to safety incidents. Assigning workers to unfamiliar tasks, a lack of worker training, and inadequate time for worker to complete tasks were ranked as top contributing factors by participants when they were thinking about management or organizational factors that could result in safety incidents. The findings of this study are useful for safety practitioners and construction teams to improve their safety management plan for agribusiness construction projects.

**Introduction**

The safety and health of construction workers has been and still is an important and relevant topic for researchers. Although there have been significant improvements in worker safety and health programs in the construction industry, incidents still occur on construction sites, and fatality and injury rates have been higher than in other industries (Bureau of Labor Statistics, 2017a; Hola & Szóstak, 2017). Agribusiness construction activities contributed to these fatality and injury rates. Workers constructing new agribusiness facilities or refurbishing or adding to existing agribusiness facilities are exposed to multiple safety hazards from agribusiness and construction sites.

Good understanding of hazards is a crucial determinant in safety assessment (Hola & Szóstak, 2017). An effective safety assessment can be achieved when workers and safety professionals understand hazards, sources of hazards, and how to reduce or mitigate exposure to hazards at the workplace. Through deep understanding of hazards, better strategies can be directed to the improvement of safety interventions. Goh and Chua (2009) also suggested that safety knowledge plays a significant role in the
development process of individuals and organizations, ensuring they will not repeat past safety-related mistakes. However, previous statistics and reports on construction industry fatalities suggest that the industry has not learned from its past experience and safety incidents (Goh & Chua, 2009). One reason for this could be a lack of a comprehensive investigation process for safety incidents happening in construction industry.

Abdelhamid and Everett (2000) stated that the incident investigation in the construction industry could be improved with a better understanding and proper characterization of past safety incidents. Information and data from these events provide a solid foundation for intervention strategies to reduce workplace fatalities and injuries (Cohen et al., 2006, Ramaswamy & Mosher, 2017). To identify and characterize the root causes of safety incidents, workplace hazards must be identified and studied, including contributing factors that affect safety performance and the effectiveness of safety management. Hazards in the workplace need to be properly recognized, communicated and assessed to maximize the potency of safety management and safety prevention programs (Albert, Hallowell, & Kleiner, 2014b; Holt 2001).

Research on hazard identification has been published for several industries. Studies on roofing contractors identified falls from elevations as the main hazard to workers, while similar studies in construction also identified fall, trip and slip as main hazards for construction workers (Fredericks et al., 2005; Lipscomb et al.,2006). Chi, Yang, and Chen (2009) analyzed electrical fatalities in the construction industry and reported the patterns for electrocution hazards. In another study, the authors developed and utilized building information modeling (BIM) and a collective sensing approach to detect and identify hazards in construction projects (Zhang et al., 2015; Yang et al.,
Bahn (2013) conducted two workshops to evaluate the hazard identification level of workers in an underground mining operation and found that training for managers and employees in hazard identification and management was crucial for increased organizational safety performance. In other industries, such as hospital machinery manufacturing, its workers generally agreed that hazard identification process implemented in the hospital sector supported better risk management (Tremblay & Gauthier, 2018).

However, to date, there have been few studies completed that discuss worker safety issues related to agribusiness construction projects. Given the documented hazard levels of the agribusiness and construction industries, it seems logical that workers in agribusiness construction would deal with hazards on the job. A better understanding of potential hazards that exist on agribusiness construction projects, as well as the contributing factors that may affect worker safety on worksites could assist both researchers and industry practitioners.

Additionally, safety intervention and safety management are significantly influenced by industrial experts and academic research. In the process of knowledge integration, the involvement of practitioners in academic research is essential (Stake, 1995). The involvement of both industrial and academic parties provided perspective and context on the theory of agribusiness construction safety as well as the practice. Several studies have shown that interactions between industrial experts and academic professionals promote a pragmatic application of research findings (Charanwanitwong & Fraszczyk, 2018). In their study, Charanwanitwong and Fraszczyk (2018) studied the perception of Thai policy makers and academics towards rail liberalization in Thailand.
and found that rail transport problems could be addressed by knowledge exchange, dialogue, and integrated perspectives of practitioners and academic professionals. Pramanik et al. (2015) investigated organizational adaption with multiple stakeholders when responding to crises. While the Pramanik et al. (2015) study focused on how several organizations managed a crisis, the authors suggested that the inclusion of multiple knowledge resources and capabilities would likely produce better research results. Therefore, for this paper, a mixed method approach was considered to explore industry and academic perspectives in safety management of agribusiness construction projects.

**Agribusiness construction industry and worker safety**

The construction industry is generally known as one of the most hazardous industries in terms of worker injuries and fatalities (Chi & Han, 2013; Feng et al., 2014; Sousa, Almeida, & Dias, 2014; Man, Chan, & Wong, 2017; Li et al., 2017). The International Labor Organization (ILO) estimated that over 60,000 fatal injuries occur on construction project sites around the world each year (Lingard, 2013), at a rate of one fatal accident every 10 minutes. Although limited studies are available on the agribusiness construction industry, one can assume that the construction work completed for the agribusiness industry is at least as hazardous as the other commercial construction projects. There are multiple worker activities that may lead to fatalities and injuries on construction sites including constructing, assembling, dismantling, and repairing (Census of Fatal Occupational Injuries [CFOI], 2017). Anecdotal information gathered through conversations with agribusiness workers also suggest that agribusiness construction sites are hazardous, with little intervention attempted to address these hazards.
According to data from the Bureau of Labor Statistics (2017a), the construction industry recorded four cases of workplace injuries and illnesses per 100 full-time workers in 2015 (BLS, 2017a). This figure has been consistent for the construction industry for several years. Furthermore, the number of workers projected to be employed by the construction industry is expected to rise to 6.9 million by 2024 (Bureau of Labor Statistics, 2017b). Approximately a quarter million construction workers will likely experience injuries while working on construction sites. Also, 985 fatalities cases were recorded from the construction industry in 2015 and this figure has also been increasing.

Agribusiness constructions likely contributed at least somewhat to the injury and fatality rate, given that the agriculture industry has many similar hazards to construction sites including exposure to chemicals and gases, and electrical, noise, and slip, trip, and fall hazards (Van Fleet et al., 2013; Ramaswamy & Mosher, 2017). Although there is a growing awareness of the importance of worker safety on construction sites, fatalities and incident rates in the construction industry remain higher than those in most other industries (Man, Chan, & Wong, 2017). This may be the result of multiple reasons: one being the high-risk and complex characteristics of construction work and the lower education level of most construction workers (Fung, et al., 2010; Sousa, Almeida, and Dias, 2014).

Several unique characteristics of the construction industry distinguish it from other industries. Some inherent complex characteristics of the construction industry contributing to worker fatalities and incidents include: i) a highly fragmented industry, ii) multiple parties involved in one construction project working simultaneously and in close proximity, and iii) industry culture (Fredericks, et al., 2005). While the relationships
between these characteristics and fatalities rates have not been supported by published empirical evidence, their identification in the literature is based on a sound theory of injury and fatality patterns and years of field observation (Hallowell, 2008).

One complexity of the construction industry is its fragmentation. Multiple parties from different organizations are involved in most projects and work together temporarily for different phases of a construction project trying to achieve a common project objective (Boton & Forgues, 2017). Considering the traditional design-bid-build project delivery system, often a variety of stakeholders are involved in building projects, including design teams, engineering teams, clients, contractors, and project management teams. While each party invests a significant outlay of capital, in the form of time, resources or financial support (Jin et al., 2017), their participation also influences and shapes the progress of any project.

The nature of each team’s influence can either benefit or threaten the success and safety of a project. Fragmentation also may result in loosely tied and conflicting project objectives (Tatum & Korman, 2000). Gambatese et al. (2008) further explains that utilizing the traditional project delivery system, opting for integrated contracting methods such as design and build provides more opportunities for various parties to be more collaborative and well-coordinated, which in turn will lower accident rates.

While other industries may have well-established, consistent operational procedures, the work environment on construction projects is often unique, temporary, and dynamic (Sousa, Almeida, & Dias, 2014). Similar to commercial construction workers, agribusiness construction workers are exposed to constant changes of work environment and stochastic elements such as weather conditions and soil characteristics.
During the execution of a project, multiple activities performed by multiple teams and trades simultaneously and in a close proximity also contribute to the higher risk of safety incidents occurring on a construction site. These factors can significantly contribute to an increase in fatalities rates while working on an agribusiness construction project.

Work culture among the construction workers also plays substantial role in explaining the disproportionate injury and fatality rates within the construction industry. Hallowell (2008) explained that machismo, substance abuse, and language barriers are among the cultural factors contributing to the negative safety culture on construction sites thus increasing the likelihood of incidents. The same situations may also be true for agribusiness construction workers. In addition to the different work elements and types of building or facilities they are constructing, agribusiness construction workers may have also experienced similar negative safety culture on their project sites.

The high fatalities and injury rates in the construction industry are also motivated by the economic and financial issues concerning the implementation of safety interventions. The economic situation is frequently characterized by limited financial resources for safety improvements, often hindering the implementation of safety interventions. Construction workers are exposed to high risk tasks and are three times most likely to die and two times more likely to suffer work-related injuries than other workers (Sousa, Almeida, & Dias, 2014), yet limited funds and unfavorable economic situations do not help in implementing safety interventions for construction workers across all areas of construction, agribusiness construction workers included.
Hazards Identification for Agribusiness Construction Project

A hazard is any real or potential condition that can cause injury, illness, or death to personnel or damage to and loss of equipment, property, and environment (OSHA, 2002; Fan & Lu, 2012). Hazards faced by contracted workers in agribusiness construction projects are as detrimental as in other type of projects, yet limited research has been conducted within agribusiness construction work sites. This is true even though worker safety hazards and risk management are emerging areas of interest in the agribusiness industry (Ramaswamy & Mosher, 2017; Davoudi Kakhki, 2018). By looking at the fatality rates and considering the need to contribute to the body of knowledge in safety management for agribusiness construction workers, there is a pressing need to provide innovative risk management strategies and improved approaches in safety management for the agribusiness industry. The need for more information and research to support safety interventions is especially strong for agribusiness construction workers.

Risk is the result of hazard and exposure (OSHA, 2018). Risks at the workplace can be reduced when the hazard is controlled or eliminated or when the workers’ exposure to hazards is reduced. Risk management is a systematic approach and practical means to eliminate or mitigate risk by identifying hazards and implementing controls within the workplace (Carter & Smith, 2006; Tripathy & Ala, 2018). There are three parts to the risk management process: context establishment, risk assessment, and risk treatment (IRM, 2018). Hazard identification, analysis, and evaluation are all included in the risk assessment process. The output of this process aids in the decision-making process and enhances the effectiveness of the risk management plan (Valis & Koucky, 2009).
Hazard identification requires an individual to recognize the obvious and emerging hazards (Perlman, Sacks, & Barak, 2014; Albert, Hallowell, & Kleiner, 2014a; Albert et al., 2014c). When hazards are identified, the workers are more likely to be aware of their safety at their workplace and may better manage workplace hazards. However, the effectiveness of a risk assessment process could be negated by unidentified hazards (Carter & Smith, 2006). An incomplete or inaccurate hazard identification process will likely result in an ineffective risk management plan.

**Purpose of the Study**

This study aims to utilize quantitative and qualitative tools to facilitate worker identification and prioritization of safety hazards for workers in agribusiness construction projects. Three major areas of interest were explored: 1) safety hazards faced by the agribusiness construction workers; 2) dominant and frequent worker safety hazards occurring in agribusiness construction sites; and 3) contributing factors to worker safety hazards. Interviews of personnel in the agribusiness construction industry and academic experts in agribusiness construction were used to establish the list and classification of hazards. This was followed by a survey instrument administered to personnel in the agribusiness construction industry and academic professionals in the Midwest region, USA.

Data gathered were qualitatively and quantitatively analyzed to identify worker safety hazards and contributing factors of these hazards. Questions asked in this study were open ended thus data gathered were mainly perceptions of the participants in regards to the area of interest. In addition to identifying worker safety hazards, participants also ranked the factors that significantly contributed towards worker safety hazards among agribusiness construction workers.
The findings of this study seek to fill a significant gap in the current literature by establishing a knowledge base for hazards inherent to agribusiness construction projects and to articulate how these hazards differ from those in the building construction trade. The results will be used as a basis for the mitigation of worker safety hazards in agribusiness construction projects.

**Method and Procedures**

This study followed a mixed approach by adopting a methodology used by Grover, Chopra, and Mosher (2016). A better understanding of research issues can be attained through a mixed method design than through either qualitative or quantitative alone (Palinkas et al., 2011). While quantitative methods provide engaging and interesting data to discuss, they are somewhat lacking of ‘story’ behind those numbers (Silverman, 2013).

The aim of this study was to quantify aspects of worker safety in agribusiness construction, but also tell the story of what safety management looks like for the agribusiness construction workforce from various perspectives. Accordingly, this study employed a mixed approach method, incorporating semi-structured interviews and survey instruments to identify worker safety hazards while working on agribusiness construction projects, determine the most dominant and frequent safety hazards, and rank the contributing factors to these hazards in agribusiness construction projects.

One strong feature of doing a qualitative research is its sense of context. The authenticity and subjectivity of human experience can be explored within the qualitative research (Silverman, 2013). Through interview sessions, the unique ‘voice’ of participants describing their perspectives and diverse experience with hazards in agribusiness construction projects can be captured. Participants are encouraged to use
their own words to express opinions and experiences during interviews, allowing the qualitative research to achieve an in-depth examination of research results (Chen & Chan, 2013).

Descriptive statistics were used to quantitatively describe or summarize the data gathered in the survey. Participant responses to survey were analyzed for the frequencies and means to describe the major hazards in agribusiness construction projects. The major components of the mixed methods approach are characterized in Figure 1.

![Figure 1 Research methodology (adopted from Grover, Chopra, & Mosher, 2016)](image)

The first component of the research utilized a qualitative approach. Eleven participants from the Midwest region of the United States, representing either the construction industry or academic professionals made up the sample of those interviewed. Personnel who were specialists in construction, agricultural safety, and agribusiness facilities design participated in the semi-structured interviews. Data collected from the interviews were analyzed and worker safety hazards and contributing factors were identified.
A three-stages coding process was employed, which included open, axial, and selective coding (Corbin & Strauss, 2015). Nine codes for worker safety hazards in agribusiness construction projects and 29 codes for contributing factors were identified from the interviews after the open and axial coding was completed. The 29 contributing factors codes were grouped into four themes using the selective coding.

A grounded theory approach was used to develop context-based descriptions and explanations (Orlikowski, 1993) and to construct the coding scheme for safety hazards (Man, Chan, & Wong, 2017). Grounded theory allowed the authors to organize and classify emerging data from the interview transcriptions and find a common theme for related pieces of data (Mullen, 2004).

Identified hazards and contributing factors were used to develop the survey instrument. Questions were structured for participants to assign risk level to the identified hazards and rank their contributing factors based on their contribution towards worker safety hazards. The survey was used to quantitatively analyze the major worker safety hazards in agribusiness construction and their contributing factors. Two hundred twenty surveys were distributed to construction workers, safety personnel, and academic professionals. The eleven interview participants were also included in the survey. This methodology resulted in worker safety hazards in agribusiness construction projects with assigned probability and severity and prioritized contributing factors.

**Research participants**

Sampling methods are employed in academic research in order to enhance efficiency and validity of research results (Palinkas et al., 2016). The method used must be consistent with the aim of the study. For this study, purposive sampling was chosen over more commonly used techniques (i.e. random sampling) because it allowed the
researcher to select participants that had the expertise needed to provide valid data from a variety of occupational settings (Mullen, 2004).

Criterion, snowball, and convenience strategies were employed to form the study sample (Creswell & Poth, 2018). Criterion sampling strategy ensures the participants meet the set criteria. The snowball or chain strategy assists in identifying participants from people who know others who know participants with experience and knowledge on agribusiness construction safety. The participants targeted for selection in this study were 1) employees of construction companies which had undertaken or currently working in agribusiness construction projects and 2) faculty and graduate students who had industrial experience working on construction projects and had expertise in building construction, agricultural facilities design, or agricultural safety. Studying hazards and worker safety from two hazardous industries: agriculture and construction – was expected to provide a rich array of information about worker safety hazards and why such hazards occur on agribusiness construction sites.

All participants in the semi-structured interview representing the agribusiness construction industry were male, holding managerial positions with extensive experience in agribusiness construction, project management, and safety. Participants representing the academic experts were all male and had held an engineering position in the construction industry previously. Graduate students included in the academic group were from civil engineering with substantial industrial and construction background. Some participants from the academic group had construction experience working with international projects located outside the United States.
Registered members of the Grain Elevator and Processing Society (GEAPS) were the base of the sample formation for survey dissemination of this study. The GEAPS directory was used to pool a sample and purposive sampling was employed, beginning with members who were working with construction companies, grain elevators, or as safety personnel. This study was intended to cover the U.S. Midwestern region, hence members whose current location was in the Midwest and fit the aforementioned criteria were included in the sample.

**Interviews**

This study used a qualitative method of interviewing in order to gain rich information about hazards and safety management in effort to understand the root causes of safety incidents in agribusiness construction projects. A semi-structured interview was conducted to obtain individual perceptions and experiences at agribusiness workplaces relating to worker safety and their contributing factors. The semi-structured format of the interviews allows questions to be asked in different sequences, depending on the flow of the interview (Choudhry & Fang, 2008). As a result, issues related to research interest emerged naturally throughout the conversation with the participants.

In the semi-structured interviews, the participants were asked to describe their own experiences and observed actions since the primary goal was to identify hazards and determine the contributing factors. It is important to extract information from a personal point of view as well as the rationalized perception on why incidents occur in order to establish the knowledge about worker safety hazards on agribusiness construction sites.
**Interview questions**

The research questions were developed to identify worker safety hazards in agribusiness construction projects and to establish contributing factors to safety incidents on agribusiness construction sites. McCracken (1988), as cited by Mullen (2004), suggested the guidelines for conducting an interview are for the questions to be developed in a way that allow the participants to ‘tell their own story in their own terms’ and to ensure that the questions are phrased ‘in a non-directive way’ but clear enough for participants to understand. Mullen (2004) proposed that non-directive questions can be achieved through “grand tour” question such as, “Are there any other situations you can describe as hazardous to workers’ safety?”

Prompts were used by the authors to engage the participant throughout the interview session. An interview is where “knowledge is constructed in the interaction between the interviewer and the interviewee” (Brinkmann & Kvale, 2015, p.4), thus participant engagement is critical to ensure the research questions are answered during the interview session. Planned prompts were used when the topic of interest did not appear spontaneously during the interview, while floating prompts were used to allow the participants to expand on certain ideas or opinions (Mullen, 2004). Floating prompts were created through repeated key words used by the participants. For example, one participant mentioned ‘need to train your people’ several times throughout the session and the interviewer used the key words to create more questions in trying to understand his point.

Aside from the demographic data, responses were collected from participants in three major categories: 1) understanding of risk assessment and hazard identification processes, 2) safety hazards in agribusiness construction projects, and 3) contributing factors to safety hazards in agribusiness construction projects. The questions were pre-
tested with academic professionals who had expertise in construction and safety to ensure the questions were understandable and were able to draw rich information for the study. Their feedback was used to improve the precision and conciseness of the survey instrument.

**Interview procedure**

The semi-structure interviews were conducted from June to October 2018. Eleven semi-structured interviews were conducted; two sessions were conducted in a group of three and the remaining sessions were personal face-to-face or telephonic interview. The length of each session was 40 minutes to 90 minutes. The interview was conducted away from the worksite and other personnel in order to provide a conducive environment for participants to express their opinion freely and recount their experiences.

Each participant received an interview protocol prior to the start of the interview, explaining the research project and objectives. In an attempt to minimize potential response bias, participants were informed that they had right to not answer the questions and to drop out of the interview at any time (Man, Chan, & Wong, 2017). They were ensured of absolute confidentiality of the process. Informed and written permissions were obtained for the authors to use the data for academic purpose only. Handwritten notes and a recording device were used to record the conversation.

The conversations were then transcribed verbatim by the interviewer. Transcription was done as soon as the interview was completed in effort to include detail and rich description of the interview session. After recording eleven interviews with the participants, saturation was reached. Saturation is achieved when the interviewer could no longer find new information from new participant that adds to an understanding of research interest (Creswell & Poth, 2018).
To validate language meanings used by interviewees during the interviews, a native English-speaker was appointed as a second reader for the interview transcriptions. A third reader, also a native English speaker, was appointed for selected words and phrases in the transcriptions. The second and third reader were treated as peers who reviewed the transcription documents and ensured that the interviewer was transcribing and interpreting the recorded data appropriately. The readers also asked questions on the context of interview questions and interviewer’s interpretations on the data. This process helped to validate the data and ensured that the interviews were interpreted appropriately by the interviewer (Cresswell & Poth, 2018).

**Thematic analysis**

All handwritten notes from the face-to-face interviews and telephonic interviews and verbatim transcriptions were collectively gathered and organized into a Microsoft Word ® document. Due to resource constraints and to eliminate inter-coder bias, all data and transcripts of interviews were analyzed thematically and coded by the same interviewer (Debnath, Blackman, & Haworth, 2015). The same interviewer had conducted all interviews and therefore had a sufficient and strong understanding of the common themes arising in the interviews.

A grounded theory approach consisting of three phases of coding - open, axial, and selective (Corbin & Strauss, 2015) was used to identify emerging themes from the data. For open coding, the interviewer examined the notes and transcriptions line by line (Draucker et al., 2007) for particular pieces of information that were common or related to each other (Mullen, 2004). The data was coded into unit of meanings or concept (Man, Chan, & Wong, 2017) such as “…can’t recognize what’s happening and that can become an issue, but we try actively to manage that, to keep an eye on them…” are “labeled as
unable to recognize unsafe situation” and “pay attention to workers”. Next, codes that are highly similar were grouped into analytic concepts. This analytic concept is a combination of codes that are theoretically relevant, whereby a category can be identified. For example, “no person to hold accountable” and “lack of leadership” are theoretically relevant thus grouped as “poor leadership” – one category identified as a contributing factor to safety hazards.

The second phase, the axial coding is a process of putting fractured data together by making connection between categories (Corbin & Strauss, 2015). For this phase, categories emerged during the open coding phase were grouped based on their nature. The grouping will create axes (or relationship) for further development (Man, Chan, & Wong, 2017). For example, “poor leadership” and “lack of management support”, the categories which emerged during the open coding phase, were grouped into “safety attitude”. Codes generated from the open coding phase became the sub categories to the categories generated during the axial coding phase.

The selective coding was the final step in the qualitative analysis. Data were examined with the intention of identifying the core category, which was the central event of this study (Corbin & Strauss, 2015). Through this process and with reference to the literature, a meaningful relationship in the data can be achieved in understanding worker safety hazards and their contributing factors in agribusiness construction projects.

**Survey**

Questionnaire surveys have been a widely used method to study safety management (Fang, Chen, & Wong, 2006; Li et al., 2017). An online survey was designed as part of this study to quantitatively measure workers’ safety hazards in agribusiness construction projects. A weighted multi-voting method was used to rank
order (Grover, Chopra, & Mosher, 2016) the contributing factors of worker safety hazards in agribusiness construction projects.

**Design of survey**

The 13-item questionnaire was composed of two sections: 1) worker safety hazards questions and 2) individual demographic questions. The survey questions were developed based on the data from the qualitative analysis conducted earlier, with reference to other studies conducted in the construction industry (Mullen, 2004; Kemei, Kaluli, & Kabubo, 2017; Work Safe Australia, 2015). The first section of the survey was designed to seek the view and understanding of construction workers, safety personnel, and academic professionals on worker safety hazards in agribusiness construction projects.

Two questions were developed to understand participant perceptions of hazards in general. Participants were asked to characterize a ‘major’ and a ‘minor’ hazard and they were given options to choose from. The other two questions asked the participants to estimate the level of severity and the likelihood of occurrence for nine identified hazards in agribusiness construction projects. For each question, participants were given a severity scale and a likelihood of occurrence scale to choose from. The scales were modified from Clemens and Simmons (1998). In the next question, participants were asked to estimate the frequency of hazards occurring in agribusiness construction projects. A scroll bar ranging from 0 to 100 was provided for participants to estimate the frequency of each hazard occurring on site. The last two questions for the first section of the survey asked the participants to rank order contributing factors of worker safety hazards in agribusiness construction projects. The contributing factors were presented in two themes: organizational factors and worker factors.
The second section of the survey consisted of six questions on personal information, including current and prior working experience, education level, and other personal characteristics such as current position and industry where he/she was working. The second section of the survey was designed to understand the potential relationship of the findings with the characteristics of the sample.

Survey dissemination

The survey was disseminated using Qualtrics ®. The Qualtrics ® is a widely used online survey dissemination and analysis software. The survey was first disseminated in early December 2018 for 227 participants. Eighteen emails bounced back for various reasons, including misspelled emails and invalid addresses. After researching for alternative addresses and correcting the necessary misspelled addresses, a second-round email was sent to 11 participants. The author was not able to identify an alternative address for the other 6 participants. Thus, the final number of disseminated survey was 220.

A cover letter and a consent notification were included in the survey. The electronic consent was set in a way that the participant would immediately leave the survey if he/she disagree to participate in the survey.

Survey Analysis

All survey responses were anonymously recorded in the Qualtrics ® software. Recorded data were imported into Excel data sheet and were analyzed using Microsoft Excel for descriptive analysis. Classification of industrial participants and academic professionals was done through the demographic questions on current position and relevant industry of the participants.
Results

Interview findings and analysis

Demographic information of interview participants is listed in Table 1. Fifty-five percent (6 out of 11) of participants were industrial experts, and 45% (5 out 11) were academic professionals. The majority of the participants were from a safety management background, with most holding a managerial position in their respective companies. Two faculty professors and three graduate students with industrial background made up the academic professionals.

Table 1 Profiles of the interview participants

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Position</th>
<th>Background Industry</th>
<th>Years in Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>IE 1</td>
<td>Manager</td>
<td>Safety management</td>
<td>Over 30</td>
</tr>
<tr>
<td>IE 2</td>
<td>Engineer</td>
<td>Safety management</td>
<td>0 – 5</td>
</tr>
<tr>
<td>IE 3</td>
<td>Director</td>
<td>Safety management</td>
<td>Over 30</td>
</tr>
<tr>
<td>IE 4</td>
<td>Project manager</td>
<td>Construction</td>
<td>6 – 10</td>
</tr>
<tr>
<td>IE 5</td>
<td>Engineer</td>
<td>Safety management</td>
<td>0 – 5</td>
</tr>
<tr>
<td>IE 6</td>
<td>Director</td>
<td>Safety management</td>
<td>Over 30</td>
</tr>
<tr>
<td>AP 1</td>
<td>Graduate student</td>
<td>Civil engineering</td>
<td>0 – 5</td>
</tr>
<tr>
<td>AP 2</td>
<td>Graduate student</td>
<td>Project management</td>
<td>0 – 5</td>
</tr>
<tr>
<td>AP 3</td>
<td>Graduate student</td>
<td>Construction</td>
<td>6 – 10</td>
</tr>
<tr>
<td>AP 4</td>
<td>Professor</td>
<td>Construction</td>
<td>20 – 25</td>
</tr>
<tr>
<td>AP 5</td>
<td>Professor</td>
<td>Facilities design</td>
<td>10 -15</td>
</tr>
</tbody>
</table>

IE, Industrial experts; AP, Academic professional

The research questions were aimed at identifying worker safety hazards in agribusiness construction sites and determining their contributing factors. The interviews revealed several common hazards in agribusiness construction sites resulting from worker behavior and his everyday work practices. The emerging contributing factors were not expressed by every individual, but some factors were more common than others. While
many hazards and contributing factors emerged from the data, it is significant to acknowledge that each factor plays different role between individuals (Mullen, 2004).

The transcript analysis identified several organization and worker factors that explained why incidents happened in construction sites. The contributing factors were classified into four themes: organizational factors, uphold image, unsafe work practices, and unsafe work condition.

**Common hazards in agribusiness construction sites**

It was evident that agribusiness construction sites are hazardous to its worker, similar to other construction sites. The majority of the participants reported falls from heights as the major hazard in agribusiness construction sites. Comparable to commercial building construction, agribusiness construction workers are also working with heights most of the time. Agribusiness construction structures require workers to work on scaffolding and temporarily-raised platforms to build agribusiness facilities. Thus, most workers are exposed to fall hazards.

*The major one like I said is the fall protection. If you are not wearing your fall protection, when you fall bad things are going to happen to you. Especially in high heights, probably...big chance you could lose your life (experienced safety director).*

Working in construction sites require its workers to wear protective personal equipment (PPE) at all the times while on sites. The specific issues noted were respiratory problem due to silica dust (from concrete), falling or flying objects, and construction debris.
Sweeping up concrete sometimes after some kind of concrete pour, with the new silica dust standards, there’s a lot that goes into that with respiratory protection (experienced project manager).

Some participants revealed that the most concerning hazard that could happen to construction workers was electrocution. Participants reported that as an agribusiness construction worker, many times the worker need to work in somebody else’s facilities. Working in an unfamiliar facility could confuse the worker, especially in performing the lock out/tag out procedure.

Well, when somebody is in the facilities you don’t know necessarily if the motor effect from that panel or this panel. I think it’s right there, right? We hit the on button and it didn’t go. Well, did it not go because somebody had pushed the E stop over there or they actually had the energy locked out, right? (experienced project manager).

Working with machines and equipment had exposed the construction workers to many equipment hazards. Participants reported a lot of incidents on site resulting from improper use of machines or equipment. There were incidents that resulted from broken machines and equipment where workers were injured because they did not realize that the machine was broken.

Participants also revealed that excavation work could be a hazard source to construction workers. Many safety incidents resulted from working in excavation trenches where trenches caved in on workers or where workers were crushed inside the trenches were reported on construction sites. Unknown conditions of soil could lead to this safety hazard.
Another worker safety hazard common among participants was the housekeeping hazard. Working in facilities with poor housekeeping could lead to multiple safety incidents. While some participants stated that it is difficult to keep construction sites clean from construction debris, others stated that a good housekeeping is when everything is in order and in its proper place and that everyone follows safety procedures, rather than just trying to maintain the sites clean.

**Contributing factors to worker safety hazards**

**Organizational factors**

The first theme that emerged from the interview data analysis was organizational factors. These factors were significantly affected by organizational safety culture as well as individual safety behavior. There are four categories included in this theme: 1) safety attitude, 2) pressure to perform, 3) performance over safety, and 4) perceived risks.

The attitudes of both management and workers towards safety contributed to various safety hazards exposure. Participants revealed that a lack of management support leads to safety incidents. When an organization does not show any concern for employee safety and displays negative attitudes regarding work safety for both employees and management, safety will be compromised. One participant said “if you have a complicated program, don’t discipline your employee because you fill out an incident form versus a near miss form” and argued that management’s complicated approach in managing safety is discouraging for workers. Another participant reported that because agribusiness construction projects are commonly located in remote areas, management is far away and therefore, less committed to safety procedures.
Coercive pressure to get the job done within the stipulated time was another contributing factor to worker safety hazards in agribusiness construction sites. Working in construction sites means working with datelines. Project performance is measured by its performance to complete construction work within stipulated project duration. Project delay is an issue a construction team takes seriously. Because of that, construction workers were pressured to perform in a timely manner. When the construction team and workers are pressured to complete the work, workers are assigned to multiple tasks and this leads to role overload. One participant stated, “when workers are rushed, that is when safety is compromised”. Workers will tend to take short cuts and disregard safety procedures in this kind of situation.

It was evident that some companies realized the importance of safety procedures and tried to display good safety cultures. However, there are companies that over complicate safety procedures. Hierarchical reporting procedures, complicated paperwork, and complex safety procedures were mentioned by participants as overwhelming for many workers. Rather than encouraging workers to conform to safety procedures, workers tend to ignore complicated safety procedures, leading to unsafe work practices and hazards at work places.

It was found from the participants that majority of workers were aware and informed about risks involved in their work.

**Uphold image**

There are two categories under this theme: 1) continue to engage unsafe work practice and 2) competence. Participants mentioned various reasons as to why workers continue to engage in unsafe work practices. One reason stated by participants was lack of worker involvement in safety management. When describing a situation when the
worker is showing lack of commitment and not very keen to involve in safety management (e.g. participate actively in safety training and effectively implement safety procedures while working), participants mentioned how a lack of support from management contributed to this situation.

One participant mentioned how his company had an initiative to provide incentives and bonuses for workers who were actively involved in safety management. This was done to show workers that management is supportive of workers and to encourage workers to participate in safety management. It was also expressed by participants that a lack of training, combined with low education level can lead to poor decision-making by workers. As a result, the worker continuously engages in unsafe work practices without realizing the consequences of his actions.

Some participants stated that in order to not look weak in front of other co-workers, a worker tended to act tough by ignoring safety procedures. Some workers always want to look competent and superior to others, especially on construction sites, leading to workers behaving poorly with regard to safety procedures. Participants revealed that some workers even thought that if one performs a task without wearing proper PPE, he would look tough and superior.

One of the participants mentioned that agriculture workers like to think themselves as ‘a worker with pride’ which arguably affected their work practices in both positive and negative ways. When describing the worker’s attitude and pride at the work place, the participant stated that agriculture workers tend to have an ‘I got this’ and ‘I have been doing this for years, I know how’ attitude.
Optimistically, the pride upheld by the worker could result in high performance of their tasks. On the other hand, to maintain the pride, worker tend to sacrifice safety procedures and proper work procedures, resulting to safety incidents. Participants also mentioned about some of the workers at his construction sites may be even willing to take greater risk and perform unsafe work if it means maintaining their pride and improving the competency image. This suggests that in order to maintain one’s pride and image, workers may be willing to take extra risks and violate or ignore safety procedures at work place.

**Unsafe work practices**

This theme included unsafe behavior and worker disengagement to safety. It was evident that the worker’s behavior was one of the contributing factors to safety hazards in the work place. Participants revealed that unsafe worker behavior included being lazy, taking short cuts, not giving full attention while working, ignoring safety procedures, being irresponsible, and not learning from previous mistakes. These unsafe behaviors were repeatedly mentioned by participants as factors that need management attention in managing safety on agribusiness construction sites.

Multiple reasons could lead to disengagement of worker with safety procedures. Participants expressed that worker’s lack of skills and abilities to understand hazards and risky situations were among the contributing factors to worker starting to get disengaged with safety procedures. One participant mentioned about the importance of communication and interaction, especially in safety training, to get the worker involved in safety management. Another participant revealed that some workers felt it was not their responsibility to manage safety and that the management was accountable to ensure their safety at workplace. This situation illustrates how the support from management to
get workers involved and committed in safety management could prevent workers from being irresponsible and performing work unsafely at work place.

**Unsafe work conditions**

From the data, it was revealed that the environment and operational management of a workplace affected the way workers behaved at the workplace. Participants revealed that a poor operation plan by management through the assignment of multiple tasks to workers and long working hours would influence safety behavior of workers. Long working hours would result in fatigue and workers could get demotivated from working. In this situation, workers would be less productive and pay less attention to safety. One participant mentioned there were cases where workers were assigned to work for more than 10 hours in a day. He stated, “when you start working so many days in a row, the guys get tired and it doesn’t take long to get tired and productivity goes down and then their awareness of hazards starts to go away.”

Housekeeping was reported as a long-standing issue in construction sites. One participant revealed that one indicator for a good safety audit for him was the housekeeping. He mentioned about how some workers think of housekeeping as something less important when compared with their tasks, thus they pay less attention to keeping the sites in good condition and maintaining a good housekeeping record. Multiple incidents have happened due to bad housekeeping. One participant mentioned, ‘it drives me crazy when someone cut some metal, some wood and throw it on the ground.’ He stated that a worker could trip on the debris if they were not properly thrown into the dumpsters. Participants reported that on top of training, good leadership is important to the culture and to good safety behavior among workers. This in turn makes them realize that a workplace with good housekeeping is a safe work place.
Based on the analysis, data on worker safety hazards and their contributing factors were used to develop a survey instrument for this study. While findings from the interviews were important, the main findings for this study were intended to help consolidate ideas and provide the basis for the survey development.

**Survey findings**

Out of 220 surveys sent to participants, 22 completed the survey. This represents 10% of response rate. The survey questions were open ended and participants were not prompted with working definitions for specific terms such as hazard. Therefore, the authors considered the responses as perceptions of the participants on the situation. The survey was included in this study with the intention to gather information on prioritized worker safety hazards in agribusiness construction sites and their contributing factors.

The survey was also intended to serve as the basis for the creation of a fault tree analysis. It was not the intention of the authors to generalize to the population through the survey, rather the data were used to give insights on what is happening in the industry. Participants to both the semi-structured interviews and survey were treated as representatives of the construction and agriculture industries to provide viewpoints and opinions on issues of interest for this study. Their insights together with information from the previous literature were used to develop FTA of this study.

There were 13 questions included in the two sections survey. The first section listed out seven questions on worker safety hazards and the second section included six demographic questions. Participants were asked to select answers from given options, estimate the probability of event occurrence, and rank order contributing factors to worker safety hazards.
Forty-one percent of the total participants (9 of 22) were from construction industry, 36% were from agriculture handling and processing, and 14% were consultant engineers. Nine percent (2 of 22) were academic experts. Looking at the position distribution of the participants, 23% of the participants were currently in a director position at their respective organization, 18% were senior managerial officer, 14% were vice presidents, 14% were project managers, 9% were presidents, and 9% were junior managerial officer. One safety director, one full time student, and one professor were also included in the total number of participants to the survey.

Participants were asked to provide information on their working experience. Twenty seven percent of the participants had 10 to 14 years of experience, 27% had 15 to 19 years of experience, and 18% of the participants had less than five years working experience. Two of total participants had more than 35 years of working experience, another two had 30 to 35 years of experience, and one had 25 years working experience while another one had 18 years working experience.

Majority of the participants had either an undergraduate degree or graduate degree. Eighteen percent (4 of 22) completed a 2-year technical degree and 9% of the participants finished high school degree. Eighty one percent (18 of 22) were experienced in construction industry or had worked or is working in construction related organizations. Four participants did not possess construction background or had worked in construction related organization.

The first two questions of section one concerned each participant’s perception on hazards and how they characterize a major and a minor hazard. Ninety-five percent of participants (21 of 22) characterized a major hazard as something that has the potential to
result in a severe injury. Only one participant responded that a major hazard is something that occurs frequently and results in a severe injury. Eighty six percent of participants (19 of 22) described a minor hazard as something that has a potential to result in a minor injury. Fourteen percent of participants indicated a minor hazard as something does not occur frequently and results in a minor injury.

A few of the survey questions were concerned with risk assessment due to the indicated hazards on agribusiness construction sites. Risk is measured based on the product of the probability of an event and the severity level of that event (Clemens & Simmons, 1998). The probability of an event is referred as the likelihood of that event to occur. The severity level of an event is calculated by estimating the impact of that event if it occurred.

Participant were asked to indicate the severity level and the likelihood of nine hazards: fall, struck-by, caught-in/between, electrocution, machine/equipment, personal protective equipment (PPE), confined space, excavation and earthwork, and housekeeping. Severity level ranged from fatal, critical, serious, marginal, and negligible. Participants indicated injury from electrocution hazard would result in the most severe injury of all the hazards listed. The severity level for injury due to electrocution hazard described by participants as critical to fatal injury. Injuries due to fall hazard and confined space were indicated as critical by the majority of the participants. Housekeeping hazards were regarded as marginal to critical by participants.

To measure the probability or the likelihood of an event occurring, participants were given options of frequent, probable, occasional, remote, and improbable to choose from. Participants indicated fall and struck-by hazards as probable. Electroecution, PPE,
and excavation hazards were regarded as occasional. Based on the severity level and likelihood of each hazard, the estimated level risk level was calculated by the authors.

Table 2 Estimated risk level for worker safety hazards

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Severity Level</th>
<th>Likelihood</th>
<th>Estimated Risk Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Critical</td>
<td>Probable</td>
<td>High Risk</td>
</tr>
<tr>
<td>Struck-by</td>
<td>Critical</td>
<td>Probable</td>
<td>High Risk</td>
</tr>
<tr>
<td>Caught-in</td>
<td>Critical</td>
<td>Occasional to Probable</td>
<td>Medium to High Risk</td>
</tr>
<tr>
<td>Electrocution</td>
<td>Critical to Fatal</td>
<td>Occasional</td>
<td>High Risk</td>
</tr>
<tr>
<td>Machine</td>
<td>Serious to Critical</td>
<td>Occasional to Probable</td>
<td>Medium to High Risk</td>
</tr>
<tr>
<td>PPE</td>
<td>Serious</td>
<td>Occasional to Probable</td>
<td>Medium Risk</td>
</tr>
<tr>
<td>Confined space</td>
<td>Critical</td>
<td>Occasional</td>
<td>High Risk</td>
</tr>
<tr>
<td>Excavation</td>
<td>Serious to Critical</td>
<td>Occasional</td>
<td>Low Risk</td>
</tr>
<tr>
<td>Housekeeping</td>
<td>Marginal to Serious</td>
<td>Occasional to Probable</td>
<td>Low Risk</td>
</tr>
</tbody>
</table>

Table 2 summarizes the worker safety hazards in agribusiness construction sites and their estimated risk level. Fall hazards were indicated as high-risk by participants, along with struck-by, electrocution, and confined space.

The survey also contained a question in which participants were asked to estimate the probability of occurrence for each hazard. Rather than assigning severity or likelihood level, participants were given the option to estimate a numerical probability of each hazard occurring on sites. Participants indicated that there was a 40% probability of hazards due to PPE and housekeeping that could occur on construction sites during a one-week period of work, which is considered as high probability of potential occurrence. Fall, struck-by, caught-in, and machine/equipment were estimated at 20% probability of occurrence, given a one-week work period. Other hazards such as electrocution, confined space, and excavation estimated at 10% probability to occur on construction during a one-week period of work (see Table 3).
Table 3 Probability of occurrence of worker safety hazards

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>0.2</td>
</tr>
<tr>
<td>Struck-by</td>
<td>0.2</td>
</tr>
<tr>
<td>Caught-in</td>
<td>0.2</td>
</tr>
<tr>
<td>Electrocution</td>
<td>0.1</td>
</tr>
<tr>
<td>Machine</td>
<td>0.2</td>
</tr>
<tr>
<td>PPE</td>
<td>0.4</td>
</tr>
<tr>
<td>Confined space</td>
<td>0.1</td>
</tr>
<tr>
<td>Excavation</td>
<td>0.1</td>
</tr>
<tr>
<td>Housekeeping</td>
<td>0.4</td>
</tr>
</tbody>
</table>

The questions concerning contributing factors asked the participants to rank order the factors based on the level of contribution of each factor to safety incidents in agribusiness construction sites. There were two questions: one question asked participants to rank the organizational-related factors and the other question asked participants to rank worker-related factors.

Ten organizational-related and eight worker-related contributing factors were presented for participants to rank using multi-voting process. The participants prioritized the contributing factors by assigning numbers to the contributing factors based on their contribution to safety incidents at workplace. The rankings were based on participants perceptions on which factors contributed the most to the occurrence of safety incidents.
Table 4 Ranking for contributing factors to worker safety hazards

<table>
<thead>
<tr>
<th>Ranking for organizational-related contributing factors</th>
<th>Ranking for worker-related contributing factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Lack of familiarity in assigned task</td>
<td>1) Poor decision making by the workers</td>
</tr>
<tr>
<td>2) Lack of worker training and education</td>
<td>2) Workers being careless or not thinking</td>
</tr>
<tr>
<td>3) Not having enough time to do work safely</td>
<td>3) Underestimated risk associated with assigned tasks</td>
</tr>
<tr>
<td>4) Lack of supervision and management support</td>
<td>4) Poor safety consciousness from workers</td>
</tr>
<tr>
<td>5) Long hours of work</td>
<td>5) Unsafe work practices or procedures in work place</td>
</tr>
<tr>
<td>6) Poor decisions by the management</td>
<td>6) Workers afraid to look weak in front of colleagues/supervisor</td>
</tr>
<tr>
<td>7) Lack of enforcement on safety regulation</td>
<td>7) Repetitive or boring work</td>
</tr>
<tr>
<td>8) Unsafe work conditions</td>
<td>8) Workers tendency to violate safety procedures to portray a competent image</td>
</tr>
<tr>
<td>9) Lack of management support</td>
<td></td>
</tr>
<tr>
<td>10) Complicated safety procedures</td>
<td></td>
</tr>
</tbody>
</table>

Number one was assigned to factors with the greatest contribution and larger number was assigned to factors with lesser contribution to the occurrence of safety incidents. Factors with smaller numbers indicate higher ranking and significant contribution to safety incidents and factors with larger numbers consider as the least contributing factors to safety incidents thus were ranked lower. The assigned ranking number for each factor was calculated for average ranking number and the contributing factors were ranked, from the most significant contributing factors to the least significant contributing factors (as shown in Table 4).

Looking at the ranking for organizational-related factor, majority of participants ranked the lack of familiarity in assigned task as a number one factor that contributed the
most to the occurrence of safety incidents on agribusiness construction sites. The participants ranked complicated safety procedures at number ten, indicating that the factor contributed the least to the occurrence of safety incidents. In other words, the participants perceived that lack of familiarity in assigned task will most likely lead workers to safety hazards while working on sites.

Similarly, majority of the participants perceived that poor decision making as the greatest worker-related contributing factor to safety incidents on sites thus assigned number one to the factor. Worker tendency to violate safety procedure was perceived as the least contributing worker-related factor that could contribute to safety incidents and majority of participants assigned number eight to the factor. In other words, based on their perceptions, the participants identified that poor decision making by the worker as the most significant underlying factor that would lead to safety incidents.

Discussion

This study employed a mixed method approach in order to gain deeper and broader perspectives from two viewpoints: industrial experts and academic professionals on the story of what is happening related to occupational safety on agribusiness construction sites. A qualitative tool, semi-structured interview was used to gather information and richer descriptions on worker safety hazards and their contributing factors. The resulting information was used as basis for development of survey for this study.

The survey was utilized with a purposeful sample as a quantitative tool of this study where participants determined the risk level of worker safety hazards and rank ordered the contributing factors of those hazards. The questions included in the survey were open ended and participants were not prompted with working definitions for
specific terms such as hazard. Thus, the responses were perceptions of the participants on the situation. This approach demonstrated a significant potential for future use in safety analysis, especially for specific construction classifications such as agribusiness construction where empirical data are very limited.

The findings on worker safety hazards in agribusiness construction sites of this study were consistent with findings of Ramaswamy and Mosher (2017), who had identified that falls, trips, and slips were the most significant hazards in agriculture handling facilities and with Hola and Szóstak (2017), who had identified fall from height as the most common safety incident in construction industries. Some of the interview participants also mentioned personal protective equipment (PPE) as another hazard significant to agribusiness construction sites. While hazard is defined as any real or potential condition that can cause injury, illness, or deaths to workers (OSHA, 2002), the inclusion of PPE as a hazard demonstrated misunderstanding and questionable perceptions of what constitutes a hazard among the participants. PPE is a safety measure to control hazards and improper wear of PPE may expose workers to risks while working, but it should not be perceived as a hazard.

There were several factors that contributed to fall injuries. Chi and Han (2013) reported in their study that based on OSHA accident reports, working surface condition was a key factor in falls from an elevation. Since this study focused on the Midwestern region of the U.S., climatic conditions of the region were identified as one of the significant contributing factors to safety incidents at work place. Icy ground during the winter season was a condition that the Midwesterners manage, including agribusiness
construction workers. It was expected that the participants would identify fall as a high-risk hazard when working in agribusiness construction sites.

Looking at the findings for severity level and likelihood of an event to occur, participants of this study estimated that electrocution hazard would result in a fatal injury but the probability of electrocution hazard to happen was estimated to be not as frequent. While electrocution hazards would result in a severe injury, participants estimated falls as the most significant hazard in agribusiness construction sites. Fall hazards were estimated as high-risk where severity level was identified as high and the likelihood of fall hazard to happen on sites was also high. Housekeeping was an issue that concerned participants during the interview sessions. As trivial as the issue might seem, participants of interviews were concerned that housekeeping hazards could expose workers to multiple of safety hazards. However, results from survey revealed that housekeeping was estimated as low risk by participants of the survey. This finding suggests some disconnect between safety leaders and workers on agribusiness construction sites regarding factors influencing safety.

This finding was not surprising given that Mullen (2004) specified that a person would perceive higher risk for a job when he/she had previous experience associated with the hazard. A worker would perceive that a fall is highly likely to happen at the workplace and he/she could become injured from the fall hazard thus estimate a higher-level risk for that hazard. Mullen (2004) explained that shocks from experiencing or seeing the incident happen had resulted in workers becoming more aware of safety at workplace and improving their safe work practices. These findings also explained the perceived definition by participants on a major and a minor hazard at construction sites.
The majority of the participants defined a hazard based on its impact on an individual, rather than considering both the impact and the likelihood of a hazard to occur. The findings from the hazard definition by the participant revealed that workers become more conscious of safety when they realize and recognize the potential consequences of unsafe behavior or unsafe condition at the work place.

The numerical probability assigned by participants indicated fall hazards to occur at 0.2 probability. As discussed earlier, fall hazards were estimated to be high risk when the participants qualitatively considered the likelihood and severity level of the hazard. In comparison, PPE and housekeeping hazards were estimated at 0.4 probability, which were 20% higher than fall hazards. The contradictory findings between these two questions in the survey revealed some level of disconnection among the participants in understanding hazards in agribusiness construction sites or a misunderstanding of survey questions by the participants. The findings also demonstrate the inconsistent and often contradictory way workers perceive workplace hazards (Walker, 2010). In his study, Walker (2010) explained that most workers, over time and experience, come to term with pain and injury associated with their tasks and this acceptance often leads them into thinking the essential safety measures such as the PPE as unnecessary.

Four main themes emerged from the interviews on the contributing factors to safety hazards in agribusiness construction sites. The contributing factors were then consolidated and arranged into two survey questions. Mullen (2004) suggested that investigation on safety incidents and their underlying factors should cover two aspects: 1) organizational factors and job design and 2) worker behavior. Thus, the survey had one
question was focused on organizational-related factors and the other focused on worker-related factors.

Participants of this study mutually agreed that worker behavior was the most prevalent factors to contribute to safety incidents at workplace. Overall, participants ranked the factors related to workers higher than the average ranking for factors related to management or organization. While this study found that worker behavior such as poor decision making and being careless as the underlying key factors to safety incidents, organizational factors such as lack of familiarity in assigned task and lack of training and education should not be ignored (Mullen, 2004).

The organization or management is responsible for planning task assignments and to update job trainings for workers. Assigning workers to tasks that they are not familiar with, or not considering worker skills and abilities before assigning tasks was suggested by participants as one of management mistakes that could lead to safety incidents. Participants of the study also suggested that a lack of training and knowledge transfer offered by the management to workers as one contributing factor to worker safety hazards.

Workers preparedness to perform assigned tasks and their safety attitude at workplace are associated with giving proper training, exposure, and experience to perform tasks on sites (Loosemore & Malouf, 2019). Rodríguez-Garzón et al. (2015) also concluded in their study that training was a major factor to improve safety climate, safety perceptions, and safety behavior on construction projects. However, the reason to why management is lacking in giving proper training and preparing worker to enter job sites is beyond the scope of this study.
Underestimating risk associated with assigned task was ranked third highest in worker-related factors. Choudhry and Fang (2008) supported this finding where they stated that level of experience and education combined with worker behavior could result in the underestimation of safety risk in construction sites. Worker safety behavior and the normalization of deviance become more likely when the worker underestimated risk associated with his/her assigned task (Pandit et al., 2019). Pandit et al. (2019) illustrated that an experienced worker using a ladder in their previous work such as a painter or a roofer will have the inclination to become less sensitive to the risk of falls over time even when a fall hazard is very relevant to his/her work. In this situation, based on his/her working experience, the worker underestimated the risk associated with his/her work, leading to safety incidents at workplace.

**Conclusions**

The aim of this paper was to utilize qualitative and quantitative research tools to identify worker safety hazards and rank order their contributing factors in agribusiness construction sites. From the semi-structured interviews, nine hazards were identified which were common to agribusiness construction sites and four themes for contributing factors to those hazards were determined. A survey was developed based on the findings from the interviews, to determine top hazards in agribusiness construction sites and most significant contributing factors to the hazards. Based on the survey findings, fall hazard was qualitatively considered as the most common and a high-risk type of hazard by majority of the participants. However, the participants quantitatively estimated fall hazards to occur on sites with 0.2 probability, a lower level than other hazards. Lack of familiarity with assigned task was ranked the highest for organizational-related factor and
poor decision making by worker was ranked the highest for worker-related factor to safety incidents on sites.

The results of the study suggest that worker safety hazards in agribusiness construction sites are similar to other construction sites. However, perceptions clearly differ among participants in defining a hazard for increased safety management within the agribusiness construction field. The limited data available for this field and the diverse perceptions made forming a baseline of data in the field difficult. However, the findings on the contributing factors to worker safety hazards distinguished an agribusiness construction site from another commercial construction site. Agribusiness industries are more extensive in the Midwest region of the U.S. as compared to the other parts of the country. Climatic conditions of the Midwest region play a significant factor to worker safety in agribusiness construction sites. For example, icy ground during winter season was considered as a prevalent factor to fall, trip, and slips hazards, beside other factors such as worker acting unsafe behavior on sites. The findings gathered through this study are useful for multiple stakeholders: safety training developers, safety practitioners, construction companies, as well as academia to further improve safety management within this industry.

Agribusiness construction is a sub-classification of the construction industry that has been given less attention by research community. The safety statistics are alarming but less work has been done to examine worker safety on agribusiness construction sites as compared to other construction and agriculture sectors. This study helps the construction team, management, and safety practitioners to design and plan for a project plan and implicate safety interventions to lower safety incidents, at the same time,
achieve project goals. Understanding the contributing factors to safety incidents specific to agribusiness construction sites will have significant impact for project planning and safety management for safety practitioners and project managers. A tailored safety training and project planning for agribusiness construction projects will significantly improve the safety management and lower safety incidents for agribusiness construction sectors.

Academia and research community are benefitted from this study in a way the results add more information to the literature and offer insightful reference for future research work. The identification of common hazards for agribusiness construction sites and their contributing factors deepens the knowledge about agribusiness construction industry.

The mixed method approach employed by this study exhibits the effectiveness of the method to gather data for research within this area. Safety analysis and related research are commonly associated with the utilization of accident reports or safety records, which was a challenge to obtain for a sub-classification and specific area such agribusiness construction industry. Deeper understanding on worker safety hazards were gained throughout the research process and this helps in providing insightful findings and discussion of this study. The stories offered during the interview sessions add depth to the discussion and provide detailed explanation on safety events in agribusiness construction sites. The quantitative approach in analyzing the survey data provided significant accountability to interview findings.

Limitations and future works

This study is limited to its sample size and composition. The nature of the survey and the questions addressed for this study were intended for specific group of people.
This study focused on agribusiness construction industry, which is a very specific classification of construction industry. Therefore, similar approach could be adopted to analyze worker safety hazards in specific area of operation such as grain elevators or feed manufacturing facilities. Better safety measures and improved safety intervention can be developed through findings of this approach. Future work can include a study on specific hazards such as falls in grain elevators and its contributing factors. A detailed explanation and findings of how and why falls happened in grain elevators would help in better risk management and safety analysis to mitigate the risk of fall incidents from happening.

References


CHAPTER 3. GRAPHICAL FAULT TREE ANALYSIS FOR FATAL FALL IN AGRIBUSINESS CONSTRUCTION SITES

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Abstract

Agribusiness construction is as hazardous as any other commercial construction. Agribusiness construction workers are exposed to various hazards while working on sites. High injuries and fatalities rates are commonly associated with the construction industry and agribusiness construction has contributed to these numbers. Previous studies have examined construction injuries and fatalities as well as the multiple factors contributing to incidents, but limited research has examined agribusiness construction. In an effort to develop intervention strategies and recommendations for improved safety performance within agribusiness construction, root causes for safety incidents need to be identified and communicated. Agribusiness construction refers to construction taking place on new agricultural-related facilities and refurbishment or add-on work to existing agricultural facilities. This study aims to address this gap and identify contributing factors to worker safety hazards on agribusiness construction sites. In preliminary research, fall hazards were identified as the number one hazard resulting in employee injury and fatalities in agribusiness construction sites. For this study, fault tree analysis (FTA) was utilized to identify contributing factors to fatal fall hazards on agribusiness construction sites. The tree was populated with information gathered from interview transcriptions with industrial experts and academic professionals together with available literatures on fatal
fall hazards. Two fatal fall scenarios in agribusiness construction sites were identified: 1) falls from elevation, 2) falls at the same level. Contributing factors associated with each fall scenario were presented in a fault tree to provide an overview of basic causes of fall incidents in agribusiness construction sites. The graphical FTA demonstrated relationships of the contributing factors. FTA is a useful tool for the investigation of agribusiness incidents. FTA will improve interdisciplinary discussion of risk management and the communication of safety incidents among frontline managers.

**Introduction**

Agribusiness construction work, like other types of construction work, is a highly hazardous and risky occupational area. Reports by the Bureau of Labor Statistics (2018) indicate higher workplace fatalities and injuries rates in the construction industry than in other industries. In 2016, the construction industry reported an average of 4 injuries and fatalities per 100 full time workers (Bureau of Labor Statistics, 2018) and this rate has been constant for years, despite many improvements in the safety and health management area. In the United States, construction activities were responsible for 991 fatal work injuries in 2016, the highest after transportation and warehousing industry and agriculture, forestry, fishing, and hunting industry with 825 and 593 cases respectively (Bureau of Labor Statistics, 2017). Fatal falls were recorded as the leading cause of work-related deaths in construction, where 370 of the 991 recorded fatalities in 2016 were from fatal falls (Centers for Disease Control and Prevention (CDC), 2018).

Understanding industrial incidents has been and will always be an utmost priority in industrial safety management. A review of the literature on construction safety reveals that many efforts have been directed at identifying hazards and root causes of construction incidents and on the development of hazards identification framework for
construction projects (Abdelhamid & Everett, 2000; Suraji, Duff, & Peckitt, 2001; Carter & Smith, 2006; Goh & Chua, 2009; Fung, et al., 2010; Abdelhamid, Narang, & Schafer, 2011; Albert, Hallowell, & Kleiner, 2014; Perlman, Sacks, & Barak, 2014; Albert et al., 2017). While these studies present important findings on how to improve worker safety in the construction industry through effective actions, solutions, or knowledge to reduce workplace injuries and fatalities, limited research has examined agribusiness construction related hazards and injuries.

The agricultural industry in the United States is as hazardous and dangerous as other industries (Issa, Cheng, & Field, 2016). A study on workplace injuries in the grain handling industry by examining the workers’ compensation reveals that the highest number of injuries are associated with slips, falls, and trips (Ramaswamy, 2017; Ramaswamy & Mosher, 2017; Davoudi Kakhki, 2018). Agribusiness construction activities contributed to these numbers of claims. It is the responsibility of all those involved in both construction and agribusiness industries to improve the safety management situation by taking effective actions to identify hazards and minimize the risk exposed to workers.

Accident causation models are commonly used to perform safety analysis in the workplace. There are two vital questions to be answered in the effort to determine the likely cause of failure when using the safety analysis model (Suraji, Duff, & Peckitt, 2001): 1) How do accidents happen? 2) Why do accidents happen? Only through investigation on the direct causes (the “how” question) and the root causes (the “why” question) of accidents can fully effective and appropriate preventative actions be proposed to improve the safety management on construction sites. However, published
literature presents little and limited work on attempts to model contributing factors of worker safety hazards in agribusiness industries. Efforts to understand the root causes of worker safety hazards in agribusiness construction projects can potentially offer valuable guidance for effective risk mitigation strategies and a worthwhile reference for policy makers and other stakeholders.

Published literature suggests Fault Tree Analysis (FTA) as a post-incident tool to identify contributing factors (Kingman & Field, 2005). FTA has been utilized for known incidents such as Three Mile Island nuclear power plant mishap, the space shuttle Discovery explosion, and the Titanic sinking. Besides being an effective tool to handle data and interrelations between components and process (Jones, Brusewitz, & Goforth, 1989), FTA also provides an excellent framework to show causal relationship in a system by relating a system fault to its associated failure events (Khanh Nguyen, Beugin, & Marais, 2015).

In addition to the study by Kingman and Field (2005), limited work has been completed on agribusiness construction sites and the risks posed to agribusiness construction workers. The objectives of FTA development are to improve the understanding of worker safety hazards and offer guidance on effective accident prevention measures and safety management for agribusiness construction projects. Based on this motivation, this study aims to utilize FTA to identify and graphically map the contributing factors to worker safety hazards in agribusiness construction sites. This study focused on the graphical mapping of FTA as the first step to managing fall hazards in agribusiness construction sites.
Workers’ Safety Hazards in Agribusiness Construction Projects

For the purpose of this study, agribusiness construction focuses on the construction of new agribusiness facilities such as grain storage bins, elevators, and lifts, and facilities refurbishment or add-ons to existing sites. These facilities play a significant role in the agricultural industry in the United States, particularly in the Midwest region (U.S. Department of Agriculture, 2017). As with the other types of construction, the agribusiness construction projects expose workers to a range of hazards while working on sites. In some cases, with agribusiness construction projects, workers are contracted by a third party, which raises questions about the responsibility for safety training, risk management, and transfer of knowledge on work sites (Cecchini et al., 2018).

The literature addresses a wide range of techniques on hazard identification in industrial settings. Among the techniques used include cause and effect diagram, fault tree analysis (FTA), hazard analysis and critical point control point, job safety analysis, failure modes and effects analysis, and “what if” analysis (Kingman & Field, 2005); case-based reasoning (Goh & Chua, 2009); fuzzy signal detection theory (Abdelhamid, Narang, & Schafer, 2011); fuzzy fault tree and analysis hierarchy process (AHP) (Shi, Shuai, & Xu, 2014); real-time construction hazard identification and transmission technique (HIT) (Albert, Hallowell, & Kleiner, 2014); 3-sided virtual reality CAVE (Perlman, Sacks, & Barak, 2014); and high-fidelity augmented virtual environment (Albert et al., 2014).

Of the various techniques available to characterize hazards, FTA was selected for the current study because it has been previously used in identifying contributing factors in agricultural industry. Further, Kingman and Field (2005) recommended FTA as a useful technique for identification of hazards related to engulfment in grain, a common
risk at agribusiness facilities. While the focus industry is different from the study conducted by Kingman and Field (2005), the FTA concept can also be applied in the identification of contributing factors to worker safety hazards in agribusiness construction projects.

**Fault Tree Analysis for Workers’ Safety Hazards**

Fault tree analysis (FTA) is commonly used for the estimation of reliability systems (Ahmad Ali & Risza, 2014) and is extensively practiced as a deductive analysis method, where a compact graphical description is provided to show the logical functional relationships between components and subsystems in a system (Shi, Shuai, & Xu, 2014). FTA offers a graphical representation of various possible combinations of basic failures that would result in the occurrence of undesirable top event – in the case of this study, the worker falling from an elevation or falling at the same level. Previous studies have utilized FTA to represent the causal relationships among events and their contributing factors and to perform safety analyses. For example, Chi, Lin, and Ratna (2014) developed a graphical FTA to represent the causal relationships of fatal falls in the construction industry. Under the assumption that fatal falls were caused by multiple contributing factors, they examined the integration of all possible cause combinations and described how minimal cut set (MCS) can be applied to reduce the redundancy of basic events.

The standard FTA is a static tool (Khan, Rathnayaka, & Ahmed, 2015) and can only evaluate the safety and reliability of a static system (Kabir, 2017). Static systems refer to those systems which operate on a single mode and exhibit constant nominal and failure behaviors. Therefore, the standard FTA is more convenient for small scale and simple systems. The main objective of this study was to depict the relationships of
multiple contributing factors to worker safety hazards in agribusiness construction projects thus the standard FTA was adequate to perform the analysis.

**Standard fault trees**

Fault tree analysis (FTA) was first invented in 1961 in Bell Telephone Laboratories by H.A. Watson and M. A. Mearns (Kabir, 2017; Khan, Rathnayaka, & Ahmed, 2015). It was used as a technique to perform the safety evaluation of US Air Force’s Minuteman missile system. Kabir (2017) also mentioned that David Haasl from the Boeing Company has successfully implemented the techniques to evaluate the company’s entire system and presented a paper on fault tree construction at the System Safety Symposium in 1965. Kingman and Field (2005) also added that FTA was used effectively as a technique to model safety analysis and to qualitatively analyze a safety system.

The construction of FTA begins with the top event and proceeds through to the basic events in a top-down manner (Kabir, 2017; Chi, Lin, & Ratna, 2014; Durga Rao et al., 2009). A basic event is an initiating fault or contributing factor to the top event. The results of FTA show how different basic events or failure components can combine together to result in the hazard happening (Kabir, 2017). There are two levels of analysis in the fault tree (Kabir, 2017; Khan, Rathnayaka, & Ahmed, 2015): a qualitative level and a quantitative level.

The qualitative analysis of a fault tree involves performing minimal cut sets (MCS) analysis. MCS are defined as the combination of basic events that could cause the top event. The MCS analysis aims to disjoint the smallest combinations that could lead to the top event. The objective of the quantitative analysis of a fault tree is to mathematically calculate the probability of occurrence for the top event, given the
probability of individual components of the system (Kabir, 2017; Khan, Rathnayaka, & Ahmed, 2015).

There are three types of nodes involved in the development of a fault tree: events, gates, and transfer symbols (Kabir, 2017). Different symbols are used to represent different events in a standard fault tree. Symbols used in FTA adapted from the Fault Tree Handbook, NUREG-0492 (U.S. Nuclear Regulatory Commission, 1981) are shown in Figure 1. A more complete reference for the traditional symbols in FTA can be found in the Fault Tree Handbook.

![FTA Symbols](U.S. Nuclear Regulatory Commission, 1981)

A basic event, represented by a circle symbol, indicates a basic initiating fault which does not require further development or expansion (U.S. Nuclear Regulatory Commission, 1981). A combination of basic events leads to intermediate events (Kabir, 2017). An intermediate event is a result of logical combinations of other events occurring in a fault tree. A conditioning event serves as a special condition to certain types of gates.
The OR and AND gates are logic gates. The OR gate indicates that the output events occurs only if one or more of the input events occur (Kingman & Field, 2005). Figure 2 shows the result of the OR gate, reflecting the independent actions of the input events. The OR gate does not represent a causal relationship between the inputs and outputs (Kabir, 2017).

![Image of OR gate](image)

Figure 2 Example OR gate used with output and input events (U. S Nuclear Regulatory Commission, 1981)

On the other hand, the AND gate requires all of the input events to occur in order to produce an output. In other words, the output of an AND gate is true if all of the input events are true (Kabir, 2017). As illustrated in Figure 3, the input events are dependent to each other to cause an output in an AND gate event.
The inhibit gate is a special case of an AND gate. The gate will produce an output only when the input is true in the presence of a conditioning event. In developing a fault tree, if the tree is too big to fit a single page, the transfer event is used to spread the fault tree to another page (Kabir 2017; U.S. Nuclear Regulatory Commission, 1981).

Given the lack of relevant estimates for probabilities of conditional events, we report here the FTA in qualitative terms through construction of graphical flow of events leading to falls within agribusiness construction operations. This represents a necessary first step toward a quantitative FTA and in itself provides a useful tool for managers and workers to initiate actions to recognize and address fall hazard root causes within the agribusiness construction industry.

**Materials and Methodology**

This study used data collected in a previously completed study for a larger project. Semi-structured interviews and survey were utilized on industrial experts and academic professionals to collect information for FTA. Worker hazards and their contributing factors were extracted from interview transcriptions and rankings of hazards
from survey results were used for the development of the fault tree. The contributing factors were identified as the known events leading to fall incidents in agribusiness construction sites.

**Construction of the fault tree analysis (FTA)**

General procedures for the fault tree analysis (FTA) consist of eight major steps (Pandey, 2018). First, the system of interest is defined where boundaries and initial conditions of the system were outlined. For this study, the system is an agribusiness construction project, focusing on worker safety systems in agribusiness construction projects. Then, the top event for the analysis was defined. Based on data collected earlier, the fall hazard was ranked as the most frequent hazard and most significant hazard occurring in agribusiness construction projects. Specifically, the number of injuries on sites that resulted from fatal falls were of interest (Centers for Disease Control and Prevention (CDC), 2018). For this reason, the top event for the fault tree was identified as fatal falls.

In the third step, the treetop structure is defined, in which the intermediate events that directly lead to the top event were identified. The previous study identified two conditions that could lead to the top event: 1) fall from elevations and 2) fall at the same level. These two instances of falls were selected based on the extracted information in the previously reported root causes for safety incidents on project sites (Chi, Lin, & Ratna, 2014; Hung et al., 2013; Haslam et al., 2005). Chi, Lin, and Ratna (2014) identified structure and equipment as the main accident causes in the construction industry in Taiwan. Haslam et al. (2005) reported supervisors lack of awareness and poor understanding as the leading cause to accidents, while Hung et al. (2013) studied the need for training among subcontractors. Further down the tree, three intermediate events were...
identified for falls from elevation: fall from floor and platform, fall from scaffolding, and fall from ladder. For each intermediate event, another two intermediate events were identified, which were unsafe acts and unsafe conditions. The unsafe acts included worker behavior and co-worker behavior. The unsafe conditions included working space, structure, and equipment.

The fourth step started by exploring each branch of the tree in successive level of detail. Events and conditions that most directly led to the intermediate event were determined. The process was repeated at each successive level until the fault tree model was completed. From there, the fault tree was examined for possible combinations of events and conditions that can result in the top event. This is the stage where minimal cut sets (MCS) analysis was performed. Next, the fault tree and the list of MCS were examined for potential dependent failures. Dependencies are referred to as single occurrences that may cause the occurrence of multiple events or conditions at the same time (Pandey, 2018).

Figure 4 Mapping Structure of FTA (Khakzad, Khan, & Amyotte., 2011)
The next two steps of the fault tree involve the calculation of probability and implementation of results in decision making. Figure 4 illustrates the simplified mapping structure of FTA

**Application of Fault Tree Analysis (FTA) on Fall Hazards in Agribusiness Construction Sites**

The resulting fault tree analysis (FTA) diagram for fall hazards in agribusiness construction sites is shown in Figure 5. An external validation was sought to determine the completeness of the FTA. A group of agribusiness insurance experts and an industrial expert validated the FTA as presentative of agribusiness construction sites.

The top event, based on data collected study, was fall incidents in agribusiness construction sites. For this study, the development of the FTA focused on fatal falls, which referred to only recordable fall injuries that resulted in worker fatalities on agribusiness construction sites. The FTA diagram was divided into two main conditions: falls from elevation and falls from the same elevation.

The two conditions of fall incidents were adopted from Hola and Szóstak (2017) and Chi and Han (2013), who had identified and discussed that fall incidents often occurred from fall from elevated floors and platforms and fall at the same level. For the purpose of discussion and to improve the reader’s ability to review the events, the branch was extracted from the main diagram. Basic events for the FTA were presented in codes, which was summarized in Table 1, Table 2, Table 3, and Table 4.
Figure 5 FTA diagram of contributing factors to falls in agribusiness construction sites
Fall from elevated floor and platform

Figure 6 Extracted FTA branch for falls from floor and platform

Figure 6 illustrated an event where a victim could fall from elevated floor or platform with conditional event coding presented in Table 1. The event of a victim from floor and/or platform was preceded by two intermediate events: 1) victim walks on the floor or platform and 2) defective hazard sources present on site. Before the victim walks on the floor or platform, the victim is either unaware of the danger or is aware but disregards the hazard. The defective hazard sources were precipitated by openings or holes on the site or floor or platform (which is often a temporary structure) collapsed on site. Each of these two events was determined to be the result of unsafe conditions on site or unsafe acts performs on site.
Table 1 Basic events of fall from floor and platform

<table>
<thead>
<tr>
<th>Code</th>
<th>Description for Unsafe Condition</th>
<th>Code</th>
<th>Description for Unsafe Act</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC 1</td>
<td>Opening was properly covered</td>
<td>FA 1</td>
<td>Provided weak plates to cover openings</td>
</tr>
<tr>
<td>FC 2</td>
<td>Barrier failure</td>
<td>FA 2</td>
<td>Poor work practices</td>
</tr>
<tr>
<td>FC 3</td>
<td>Failure of structure to support weight of worker</td>
<td>FA 3</td>
<td>Removed safety device</td>
</tr>
<tr>
<td>FC 4</td>
<td>Plates/platform were not properly attached</td>
<td>FA 4</td>
<td>Insufficient attention</td>
</tr>
<tr>
<td>FC 5</td>
<td>Edge protection was not properly attached</td>
<td>FA 5</td>
<td>Poor work practices</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FA 6</td>
<td>Failure to warn or secure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FA 7</td>
<td>Removed safety device</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FA 8</td>
<td>Poor work practices</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FA 9</td>
<td>Took unsafe position/posture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FA 10</td>
<td>Improper use of PPE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FA 11</td>
<td>Failure to warn or secure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FA 12</td>
<td>Improper use of PPE</td>
</tr>
</tbody>
</table>

**Openings and holes**

For openings and holes events, the unsafe conditions attributed to openings or holes not properly covered and the failure of the barrier to prevent the worker from falling due to the openings or holes. The unsafe acts preceding the openings or holes event were attributed to two events: unsafe acts by workers or unsafe acts by co-workers. Two preceding events to worker acting unsafely on site were 1) worker being inexperienced or worker was lacking in training, or 2) worker misjudged the hazardous situation (also associated with worker underestimate the hazardous situation).

In the event of a worker being inexperienced, he might provide weak plates to cover openings or holes and perform poor work practices, which would lead to a fall from elevated floor or platforms. Similarly, in the event of a worker misjudged a hazardous
situation, he might remove his safety devices and pay less attention to his surroundings, which would result in a fatal injury when he fell. In the event where a co-worker was acting unsafely on agribusiness construction sites were attributed to co-worker performing poor work practices and his failure to warn or secure while working together on sites.

**Floor collapsed**

Unsafe conditions and unsafe acts performed on site also influence the event where a floor collapsed on site. The victim ends up in the unsafe condition as a result of three basic events: 1) the failure of the structure to support the weight of the worker, 2) plates or platforms that were not properly attached, and 3) edge protection that was not properly attached. The unsafe acts preceding the collapsed of floor event was determined to be the result of unsafe acts performed by either the worker or the co-worker working around the temporary floor or platform.

A worker could be performing unsafely due to 1) underestimating or misjudging the hazardous situation and 2) being inexperienced or lacking in training. A worker underestimating a hazardous situation was attributed to the basic events of the worker 1) removing a safety device and 2) performing poor work practices. A worker being inexperienced was attributed to the basic events of the worker 1) taking an unsafe position or posture while working on a temporary floor or platform and 2) using improper PPE to work on the temporary floor or platform. All events could lead to a fatal fall injury.

The opportunity for a worker to fall from a collapsed floor was also dependent on the unsafe acts performed by a co-worker. The unsafe acts of a co-worker were determined by the basic events of the failure of a co-worker to 1) warn and secure the
victim from a hazard source – in this case the collapsing floor and 2) use proper PPE while working on a temporary floor or platform.

**Fall from scaffolding**

![FTA for fall from scaffolding](image)

Figure 7 Extracted branch of FTA for fall from scaffolding

The second branch characterizes a fall from elevation, representing the event where the victim works on a scaffolding as illustrated in Figure 7 with conditional event coding presented in Table 2. The event where a victim could be injured from a fall from a scaffolding was preceded by two intermediate events: 1) the victim worked on a scaffolding and 2) a defective source of hazard was present on the worksite. Two proceeding basic events lead to a victim who works on a scaffolding 1) the victim was unaware of the danger or 2) the victim disregarded the danger that was present on site.
Three intermediate events preceded the defective sources of hazard, including 1) floor deficiency, 2) working outside of scaffolding, or 3) scaffolding overturned while a worker was working on it.

Table 2 Basic events for fall from scaffolding

<table>
<thead>
<tr>
<th>Code</th>
<th>Description for Unsafe Condition</th>
<th>Code</th>
<th>Description for Unsafe Act</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC 1</td>
<td>Floor was in poor condition</td>
<td>SA 1</td>
<td>Unsafe climbing</td>
</tr>
<tr>
<td>SC 2</td>
<td>Scaffold flor was not properly attached</td>
<td>SA 2</td>
<td>Improper use of PPE</td>
</tr>
<tr>
<td>SC 3</td>
<td>Equipment was inappropriate for operation</td>
<td>SA 3</td>
<td>Removed safety device</td>
</tr>
<tr>
<td>SC 4</td>
<td>Failure to provide edge protection</td>
<td>SA 4</td>
<td>Poor work practice</td>
</tr>
<tr>
<td>SC 5</td>
<td>Tight work space</td>
<td>SA 5</td>
<td>Failure to warn or secure</td>
</tr>
<tr>
<td>SC 6</td>
<td>Uneven ground condition</td>
<td>SA 6</td>
<td>Poor work practice</td>
</tr>
<tr>
<td>SC 7</td>
<td>Too much weight on the scaffold</td>
<td>SA 7</td>
<td>Took unsafe position/posture</td>
</tr>
<tr>
<td>SC 8</td>
<td>Object falling/moving</td>
<td>SA 8</td>
<td>Improper use of PPE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA 9</td>
<td>Poor work practice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA 10</td>
<td>Failure to warn or secure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA 11</td>
<td>Poor work practice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA 12</td>
<td>Failure to provide proper anchorage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA 13</td>
<td>Took unsafe position/posture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA 14</td>
<td>Improper use of PPE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA 15</td>
<td>Unsafe climbing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA 16</td>
<td>Took unsafe position/posture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA 17</td>
<td>Poor work practice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA 18</td>
<td>Failure to warn or secure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA 19</td>
<td>Moved scaffold when worker was on top</td>
</tr>
</tbody>
</table>

**Floor deficiency**

In the event of the floor of the scaffolding becoming deficient, a victim could fall due to two intermediate events: 1) the worker was working in unsafe condition or 2) the worker or co-worker were performing unsafe acts while working on a scaffolding. Three
basic events that were determined as unsafe conditions that could result in a worker falling from scaffolding were 1) the floor of the scaffolding in poor condition – poorly maintained, 2) the scaffolding was not properly attached or the scaffolding floor was not properly installed, or 3) equipment used was inappropriate for the operation. Another dependent event to floor deficiency was a worker or a co-worker performing unsafe acts while working on scaffolding.

A worker performing unsafe acts while working on scaffolding might be the result of two events, including 1) an inexperienced worker or 2) the worker underestimated or misjudged the hazardous situation. A worker being inexperienced was attributed to the basic events of the worker 1) performing unsafe climbing on the scaffolding and 2) using inappropriate use of PPE. When a worker underestimates or misjudges a hazardous situation, a fall incident could happen due to the worker 1) removing safety devices, despite working on scaffolding and 2) performing poor work practices while working. Another dependent event to unsafe acts while working on scaffolding was from co-worker, where in the event a scaffolding floor deficiency, a co-worker 1) failed to place a warning or secure the space around the hazard source – in this case, it is on the floor deficiency and 2) performed poor work practices while working together on scaffolding.

**Working outside of scaffolding**

As reported in some incidents, some victims felt it was difficult to perform their tasks while standing on the scaffolding, so they decided to work outside of the scaffolding. A worker could fall while working outside of a scaffolding as a result of: 1) unsafe conditions or 2) unsafe acts. In the event where a worker was in unsafe conditions were determined to be the result of two basic events, including 1) failure to provide
proper edge protection for the worker working on scaffolding and 2) working in tight space.

In another branch, a worker was exposed to a fall from working outside a scaffold when he or his co-worker performed unsafe acts while working. A worker performing unsafe acts was a result of a worker 1) taking unsafe position or posture, 2) using improper PPE for working in heights, and 3) performing poor work practices while working on top of scaffolding.

A worker could also fall from working outside of the scaffolding due to unsafe acts of his/her co-worker. Two precedent events leading to unsafe acts by a co-worker were 1) the co-worker was inexperienced or lacked training or 2) the co-worker misjudged or underestimated a hazardous situation. An inexperienced co-worker was said to potentially lead to a fall from working on a scaffold when he/she 1) failed to warn or secure his/her co-worker about working outside the scaffolding structure or area and 2) performed poor work practices while working on top of scaffolding. A co-worker could underestimate or misjudge a situation, in which he/she 1) failed to provide a proper anchorage for his/her fellow worker who was working outside of the scaffolding structure and 2) took unsafe position or posture while working with another worker on top of scaffolding.

**Scaffold overturned**

A worker could fall as a result from an overturned or collapsed scaffolding on site. A scaffolding, mostly the movable scaffolding, could overturn or collapse in the event of 1) unsafe conditions present on site or 2) unsafe acts performed by either a worker or his/her co-worker while working on scaffolding. Three unsafe conditions that could result in an overturned or collapsed scaffolding included 1) uneven ground
conditions or icy ground during winter season, 2) too much weight introduced to the scaffolding, or 3) fallen objects or debris from the upper level where the scaffolding was erected.

A worker could perform unsafe acts when he/she was 1) inexperienced or 2) when he/she had many experiences that he became desensitized to the hazardous situation and started to misjudge or underestimate the situation. In a situation where a worker was inexperienced, a scaffold could overturn or collapse when a worker was 1) using improper PPE to work with heights and 2) performing unsafe climbing on scaffolding. Two basic events where a worker might misjudge a hazardous situation include 1) he/she took an unsafe position or posture such as stepping outside of the scaffolding platform, and 2) he/she performed poor work practicing while working on scaffolding.

Situations involving a co-worker performing unsafe acts on site that could result in an overturned scaffolding included two basic events: 1) the failure of a co-worker to warn or secure his/her fellow worker about a hazardous situation, and 2) when a co-worker moved scaffolding while a worker was on top of the structure.

**Fall from ladder**

The third branch of the FTA characterizing a fall from elevation was a fall from a ladder. Figure 8 illustrated the branch where two intermediate events preceded the top event of fall from a ladder with conditional event coding presented in Table 3. The first intermediate event where a worker climbs a ladder to perform task on sites was preceded by two basic events: 1) the worker was unaware of the danger climbing the ladder or 2) the worker decided to disregard the danger of climbing the ladder.
Another intermediate event was a defective hazard source. In this case, the ladder was present on site. A worker could fall from climbing the ladder due to two reasons: 1) unsafe conditions present on site while the worker was climbing the ladder or 2) unsafe act performed while the worker was climbing the ladder. Unsafe conditions that could lead to a fall from the ladder were associated with three basic events: 1) the ladder was improperly attached or assembled prior to climbing, 2) the ladder was placed against a weak structure, 3) uneven ground conditions or icy ground during winter season.

Exposure to a situation where the worker falls from the ladder was also associated with the unsafe acts of a worker and a co-worker. A worker could take an unsafe position or posture while climbing, he/she could ignore the safety procedure while performing task on top a ladder, or the worker could also be careless while climbing the ladder, all of which could result in a fall from the ladder. A co-worker could also contribute to the
exposure of a fall from the ladder by performing poor work practices such as not paying attention to the surroundings and knocking over the co-worker on the ladder. A co-worker could lead his/her fellow workers to fall from ladder if he/she failed to warn or secure the colleague about hazardous situations associated with climbing the ladder.

Table 3 Basic events for fall from a ladder

<table>
<thead>
<tr>
<th>LC 1</th>
<th>Ladder was not properly attached</th>
<th>LA 1</th>
<th>Took unsafe position/posture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ladder was placed against weak</td>
<td></td>
<td>Failure to follow safety</td>
</tr>
<tr>
<td></td>
<td>structure</td>
<td>LA 2</td>
<td>procedure</td>
</tr>
<tr>
<td>LC 2</td>
<td>Uneven ground condition</td>
<td>LA 3</td>
<td>Careless</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LA 4</td>
<td>Poor work practices</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LA 5</td>
<td>Failure to warn or secure</td>
</tr>
</tbody>
</table>

**Fall at the same level**

Situations involving a worker fall at the same level (Figure 9 and Table 4) were found to be caused by two intermediate events: 1) worker walks around the work zone and 2) worker trip, slip, or fall from walking around the work zone. A worker might walk around the work zone for one of two reasons: 1) the worker was not aware of the danger present on site or 2) because the worker decided to disregard the danger. With a trip, slip, or fall from walking around the work zone, two events could lead to this outcome: 1) unsafe conditions or 2) unsafe acts.
When a worker trip, slip, or fall is due to unsafe conditions present at the work site, it could be associated with either the work surface or the presence of an obstructive object within the work zone. Hazardous work surfaces result from two events: 1) an unsuitable ground condition and 2) a lack of safety procedure around the work zone. Unsuitable ground conditions could be associated with 1) uneven ground or weak soil condition around the work site or 2) icy ground during winter season. Inadequate guarded areas to separate the working area from the walking area, moving or falling objects around working area, and poor housekeeping were found to be the reasons why the lack of a safety procedure could expose a worker to fall at the same level. Obstructive objects were found to be another reason a worker could fall from walking around a work zone.
Poor lighting, wearing hazard-prone apparel, and improperly installed edge protection were associated with an obstructive object around the work zone that could expose a worker to fall at the same level.

**Table 4 Basic events for fall at the same level**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description for Unsafe Condition</th>
<th>Code</th>
<th>Description for Unsafe Act</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC 1</td>
<td>Uneven ground condition</td>
<td>WA 1</td>
<td>Failure to properly plan for operation</td>
</tr>
<tr>
<td>WC 2</td>
<td>Icy ground</td>
<td>WA 2</td>
<td>Improper use of PPE</td>
</tr>
<tr>
<td>WC 3</td>
<td>Inadequate guarded area</td>
<td>WA 3</td>
<td>Poor housekeeping</td>
</tr>
<tr>
<td>WC 4</td>
<td>Moving/falling object</td>
<td>WA 4</td>
<td>Insufficient attention</td>
</tr>
<tr>
<td>WC 5</td>
<td>Poor housekeeping</td>
<td>CA 1</td>
<td>Failure to warn and secure</td>
</tr>
<tr>
<td>OC 1</td>
<td>Poor lighting</td>
<td>CA 2</td>
<td>Inexperienced</td>
</tr>
<tr>
<td>OC 2</td>
<td>Wear hazard prone apparel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OC 3</td>
<td>Edge protection was not properly installed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A worker and a co-worker could be blamed for performing unsafe acts while on site that could lead to fall on site. When a worker performed unsafe acts, this could be attributed to 1) worker being inexperienced or 2) a worker was lacking safety awareness while working on a construction site. Inexperienced workers were associated with workers failing to properly plan for an operation and using improper PPE while working on sites. A worker walking around without safety boots who trips over a pile of concrete debris and incurs an injury is one example. A worker may also be lacking safety awareness, indicated by a failure to maintain good housekeeping around the work zone and a failure to pay sufficient attention to hazards while working. A co-worker could expose co-worker to hazards when 1) the co-worker failed to warn or secure fellow workers from hazardous situations that could lead to a fall, 2) was inexperienced or untrained, which is highly associated with a lack of preparation to work on site.
Conclusions

Fault tree analysis (FTA) was applied in this case to identify and categorize the contributing factors to fall hazards in agribusiness construction sites. FTA can be analyzed qualitatively and quantitatively. Qualitative analysis determines the contribution of minimal cut sets (MCS) to fatality (Chi, Lin, & Ratna, 2014), and quantitative analysis presents the probability of occurrence for the top event based on the product of the probabilities of the basic events leading to the top event (Khakzad, Khan, and Amyotte, 2011). However, the focus of this paper was to utilize the FTA to graphically map the contributing factors to fall hazards in agribusiness construction sites, excluding further analysis on the tree.

Based on the survey results, extracted information from interview transcripts, and available literature on the subject, the FTA was developed to graphically illustrate that selected basic events that may be perceived as unimportant or trivial to construction workers or management, could lead to a fatal fall at the work place. The contributing factors were classified and coded following the methods outlined in Chi, Lin, and Ratna (2014), Hola and Szóstak (2017), and Lipscomb et al. (2006). The following factors were identified through the FTA as significant contributor to falls in agribusiness construction sites:

- Unsafe conditions due to lack of management support or improper planning of the operation such as barrier and edge protection failure, defective or out-of-condition equipment
- Inexperienced workers leading another worker to take unsafe acts on site
- Lack of worker training on understanding and performing tasks safely
• Worker underestimating or misjudging hazardous situations, leading to the worker ignoring safety procedure

• Inexperienced co-workers who are unable to keep fellow workers safe

• Co-worker was not trained to perform work safely

• Miscommunication among workers, especially in communication about safety

• Worker lacked hazard recognition skills

This study presented a systematic graphical FTA encompassing the contributing factors to falls on agribusiness construction sites. Safety practitioners and agribusiness construction companies who are responsible for devising training or safety management plans should consider the contributing factors identified in this study when developing safety intervention to mitigate fall incidents in agribusiness construction. In addition, such findings can also serve as reference for future safety analysis in worker falls or in agribusiness construction, where the category can be revised or expanded, depending on the need of the organization (Chi, Lin, & Ratna, 2014).

References


CHAPTER 4. COMPARATIVE ASSESSMENT OF FALL INCIDENTS IN AGRIBUSINESS CONSTRUCTION SITES USING RESEARCH AND CENSUS DATA

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Abstract

Safety analysis in agribusiness construction has proven to be a challenge. A lack of knowledge on worker fatalities and injuries in agribusiness construction sites limits the effort by safety researchers to better understand and improve the safety management of this work sector. This study describes the approach and considerations taken to compare the probability of occurrence of fall incidents in agribusiness construction sites obtained through safety research with the probability of occurrence formulated from census data on fall incidents in the construction industry. The authors were specifically interested to examine census data for construction industry from the National Safety Council and transform the data to find the probability of fall occurrence in agribusiness construction sites. The findings from the census data were then used to validate the probability of fall occurrence gathered through safety research. The latest edition of the National Safety Council Injury Facts was examined for fall injury and injury data for 2014 were included. Eighteen thousand five hundred seventy-four fall injuries were identified in the construction industry across the U.S. The ratio of number of workers for construction across the U.S and for agricultural construction worker in the Midwest were formulated.
The ratio was applied to the number of fall incidents to find the probability of fall occurrence in agribusiness construction sites in the Midwest. The results showed a significant difference between the findings by safety researchers and the formulated probability from the census data, but these findings were drawn from a limited data set. Records of safety incidents for agribusiness constructions and other sub-classified areas should be improved and updated to facilitate improved safety improvements. However, this study makes important contributions in that the approach used to formulate probability of occurrence based on census data is also applicable to other areas, specifically in sub-classified areas where reliable data is limited.

**Introduction**

Construction workers, agribusiness managers, and roofers were ranked as the most dangerous occupations of 2018 in the U.S. (Blanchard, 2018). The U. S. Bureau of Labor Statistics (2018a) reported those types of occupations had recorded higher fatal work injury rates as compared to other occupations in other industries. Roofers recorded 48.6 fatal work injury rate per 100,000 full-time equivalent workers as compared to 17.4 fatal work injury rate for ground maintenance workers. The higher the fatal work injury rate for an industry, the higher the likelihood its workers to suffer from fatal injuries (Blanchard, 2018). Statistical evidence for the European labor force revealed the health and safety situation at work for salaried workers, workers of large organizations, and full-time workers is comparatively better than for self-employed, workers of small organizations, part-time workers, and contract-based workers (Karjalainen, 2004). It can be assumed that the construction workers are at disadvantage according to this distribution, as many construction workers are self-employed or contracted workers. Karjalainen (2004) reported that construction workers had at least 7 to 8 days absent from
work due to illness per year, where 32% were due to accidents at work. Putting this figure from the U.S labor force into perspective, for the 7.3 million in the construction workforce, 18.7 million days are lost each year due to accidents at work.

Similar to the construction industry, the agriculture industry has high worker fatality rates. The agriculture industry has seen little change in the fatality rates for years despite active safety research and interventions done for the industry (Bureau of Labor Statistics, 2018a; Ramaswamy & Mosher, 2017). The hazardous nature of agriculture industry is costly to both agribusiness and insurance firms (Ryan, Schwab, & Mosher, 2017; Ramaswamy & Mosher, 2017; Davoudi Kakhki, 2017). Ryan, Schwab, and Mosher (2017) estimated the cost of all agribusiness related injuries and fatalities each year was approximately $5.2 billion. Davoudi Kakhki (2017) reported more than 35,000 claims were recorded for severe injuries from 2008 to 2016 in workers’ compensation claims of agribusiness workers in the Midwest region of the U.S. The statistics from the U.S. Bureau of Labor Statistics (2018c) has already indicated a dangerous situation of agriculture industry – 23.2 fatal injury rates per 100,000 full-time equivalent workers in 2017. However, Leigh, Du, and McCurdy (2014) suggested that approximately 73% of injuries cases were not reported, suggesting that incident reporting should be improved.

Construction activities were responsible for at least 585 fatal injuries in 2017, a slight decrease from 2016, where 607 fatal injuries were reported in construction industry (Bureau of Labor Statistics, 2018a). Data from the U.S. Bureau of Labor Statistics showed that 386 out of 585 of fatal injuries were from fatal falls (CPWR, 2018). Falls have consistently been identified as the main contributor to fatalities in the construction industry. Although the U.S. Bureau of Labor Statistics did not suggest the proportion of
the fatal fall injuries data according to any construction sub-classification, it is assumed that at least some of the fatality data belong to agribusiness construction. Yet, the current lack of knowledge and data specific to agribusiness construction on fatality and injuries and their contributing factors limits the data available to researchers, managers, and policy-makers.

Chi, Chang, and Ting (2005) reported that non-compliant scaffolds and unguarded openings were the two main contributing factors to fall injuries from scaffolding, staging, or floor openings in the construction industry. Several other studies have also examined the cause of fatal falls in the construction industry and severity level of falling from different heights (Dong et al., 2017). However, the existing literature appears to lack studies for falls occurring in agribusiness construction.

In a previous study, a fault tree analysis (FTA) was conducted for contributing factors to fatal falls in agribusiness construction sites. The study was completed to improve the understanding of fatal incidents and offer useful insights on agribusiness construction projects so that similar events can be avoided in the future. Referring to the data from previous study, it was concluded that there were two instances leading to fall incidents in agribusiness construction sites: fall from elevated floor or platforms and fall at the same level.

The current study aimed to examine census data available online relative to construction and agribusiness industries and compare the data with the findings gathered through safety research and add value to the previously found findings. This study examined: 1) census data from National Safety Council (NSC) and Bureau of Labor Statistics (BLS), and 2) Grain Elevator and Processing Society (GEAPS) directory to
formulate assumptions and estimate for probability of fall incidents in agribusiness construction sites. The study attempted to fill certain research gaps despite limited safety-related information on agribusiness construction sites in the existing literature.

**Safety analysis for agribusiness construction sites**

Agriculture, together with construction, is often associated with a high rate of fatalities and injuries across all industries and adverse health outcome (Pawlak & Nowakowicz-Dębek, 2015; Cecchini et al, 2018; Nguyen et al., 2018). However, safety and health in the agricultural-related area are limited (Kingman & Field, 2005). Specifically, agribusiness construction has seen limited coverage within the research community, unlike other commercial industries.

Agribusiness construction is a sub-classification of construction industry. It refers to the construction works of new agribusiness facilities or refurbishment and add-on work to existing agribusiness facilities. Although some work elements are explicitly similar to commercial construction, it is fair to assume that the agribusiness construction has its own uniqueness and complexity that differentiate it from other areas of commercial construction. For example, the agriculture industry is often characterized by its low-skilled and diverse workforce and with the frequent use of contracted and seasonal workers (Cecchini et al., 2018; Boden et al., 2016; Fox et al., 2018). Safety management of agribusiness construction sites is significantly affected by this worker variable because risk assessment, the foundation of safety management in a workplace, is influenced by worker perceptions of risk. In addition, most operations at agribusiness facilities are mechanized (Shiigi et al, 2008), thus the facility layout plan together with the safety management plan of these facilities are totally different from that of residential or commercial buildings construction.
Challenges in agribusiness safety research

The Midwest region of the U.S offers a diversity of agricultural production and represents one of the most intense agricultural areas in the world (U.S. Department of Agriculture, 2017). Reasonably, with over 127 million acres of agricultural land in the Midwest region, there are hundreds of agribusiness facilities built to cater to agricultural production personnel. It is, therefore, safe to say that agribusiness construction is fairly significant in the Midwest region. However, information on the incidence and nature of fatalities and injuries in agribusiness construction is scarce. The lack of knowledge on the occurrence, mechanisms, and contributing factors of safety incidents in agribusiness construction could hinder the potential development of prevention strategies of fatalities and injuries in the future (Svendsen, Aas, & Hilt, 2014). Furthermore, Ryan, Schwab and Mosher (2017) in their study suggested the lack of primary data pertaining to agricultural production activities imposed many challenges in performing risk assessments and the same was true for this study. There is no regular surveillance and records on injuries and fatalities specific to agribusiness construction (Bureau of Labor Statistics, 2018a). The lack of data complicates the implementation of risk assessment methods (Ryan, Schwab, & Mosher, 2017). Although transformation of data was feasible, limited information was available to influence the outcome of the transformation process.

Risk assessment is a mature discipline where analysts make assumptions and simplifications, collect and analyze data, and develop and apply models to describe the studied event (Zio, 2018). Risk analysts identify hazards, analyze their contributing factors and outcomes, and characterize the risk with a proper representation of probabilities. To do so, a considerable amount of data is required to draw out relevant information and provide an in-depth understanding and knowledge of the event. Census
data retrievable from the Bureau of Labor Statistics as well as from the U.S. Department of Labor offered consistent data but limited in detail or description of events. Alternative data sources with reliable, robust, and detailed information will lead to better and effective risk assessment.

**Data**

To overcome the limited available data, the authors worked with multiple sources of data to draw out relevant and usable information for this study. Data were obtained from the National Safety Council (NSC), Bureau of Labor Statistics (BLS), and Grain Elevator and Processing Society (GEAPS). The injury data from the NSC, specifically the fall injury data for the U.S construction industry, were the main source of data. The latest edition of National Safety Council Injury Data (National Safety Council, 2017) reported fall injury across the U.S construction industry for 2014. The fall injury data represented the recordable injury data from falls, which included fatal and nonfatal falls to lower level and fatal and nonfatal falls at the same level.

Census data for provided by the BLS (Bureau of Labor Statistics, 2018a) was examined to extract the number of construction workers in the U.S. To pull a sample to represent the agriculture community in the Midwest, the authors referred to GEAPS, an international professional association of individuals who work in grain handling and processing industry. While GEAPS clearly represents the grain handling and processing industry only, the fact that this study focused on the Midwest region where grain is the main agricultural produce, GEAPS is thus considered as an acceptable source from which to pull relevant information. Table 1 summarizes the data obtained from multiple sources used for this study.
Table 1 Summary of published data used to formulate probability of fall event

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>Source of Data</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall injury counts</td>
<td>NSC</td>
<td>Injury Data for Falls, 2014</td>
</tr>
<tr>
<td>Construction worker counts</td>
<td>BLS</td>
<td>Archived Data, 2018</td>
</tr>
<tr>
<td>Ag. construction company counts</td>
<td>GEAPS</td>
<td>GEAPS 2017-2018 Directory</td>
</tr>
<tr>
<td>Ag. worker counts</td>
<td>Company website/Linkedin</td>
<td>Multiple company websites</td>
</tr>
</tbody>
</table>

Fall injury data were separated by two instances: fall to lower level and fall at the same level. Data for fall incidents extracted from the NSC Injury Data in the construction industry are shown in Table 2.

Table 2 Summary of fall injuries in construction industry in the U.S for 2014

<table>
<thead>
<tr>
<th>Variable</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total fall injuries</td>
<td>18,574</td>
</tr>
<tr>
<td>Fall to lower level (fatal and nonfatal)</td>
<td>10,285</td>
</tr>
<tr>
<td>Fall at the same level (fatal and nonfatal)</td>
<td>8,289</td>
</tr>
</tbody>
</table>

Based on the GEAPS directory, 81 agribusiness construction companies were identified. Through company websites and LinkedIn profiles, the number of workers for each company were determined. Since some websites and LinkedIn profiles were not consistent, a conservative estimate of 16,241 workers was used to represent the agribusiness construction industry. In 2014, the BLS reported a total of 6,295,000 construction workers employed for the industry.
Methodology

Since there was no record of injuries under the agribusiness construction classification, the data were transformed based on the data available for construction and agribusiness industries. Figure 4-1 summarized the data acquisition process involved in this study.

Data for fatality and injury rates for the construction industry are readily available at multiple sources such as the National Safety Council (NSC), Bureau of Labor Statistics (BLS), and Department of Labor Statistics. This study examined the injury data provided...
by the NSC for fall injuries in construction industry across the U.S in 2014. A ratio of agribusiness incident to construction incident was used to make assumptions for agribusiness construction data. With the limited data available for agribusiness construction, the simple rationing technique used for this study assumed that all work activities related to fall in other construction projects are similar to the agribusiness construction projects.

To determine the ratio, the number of agribusiness construction workers to construction workers were used. Two sources were identified to provide the data: 1) number of workers in the U.S construction industry in 2014, and 2) number of workers in the Midwest agribusiness construction industry. By considering the number of workers, the exposure level for fall hazards was indirectly measured. The identified ratio was then used with the counts for fall incidents in the construction industry in 2014 to determine the counts for fall incidents in the agribusiness construction sites. The counts for fall incidents were used to determine the probability of occurrence for fall incidents in agribusiness construction sites.

The probability of occurrence was calculated using a fractional relationship as shown in the following equation, in which the numerator is number of workers injured from a fall injury while working in an agribusiness construction site and the denominator is total number of workers injured while working in construction sites:

\[ P(i) = \frac{\text{Number of people injured from fall in ag.const.}}{\text{Number of people injured in construction}} \]

(Equation 1)
Results

The main result of this study is a probability of fall incident to occur in agribusiness construction sites. The finding from this study was compared to the result gathered from a survey in the previously conducted study. The main idea of this study is to compare how close or how different the finding gathered by safety researchers was from census data for fall incidents. In other words, this study was conducted to validate the research results conducted by safety researchers for fall hazards in agribusiness construction sites. In the survey of the previous study, participants were asked, among other questions, to estimate the probability of various hazards occurring on sites. For the purpose of this study, a comparative assessment was conducted only for fall hazards. Based on the survey findings, fall hazards was estimated at 0.2 of probability of occurrence in agribusiness construction sites.

As shown in Table 4, there are 6,295,000 workers reported by the BLS working for the construction industry in 2014 and 16,241 workers were estimated to be working in agribusiness construction related companies. A ratio of 1:388 was formulated based on the workers counts. This ratio indicated that in 388 construction workers, one worker is an agribusiness construction worker.

Table 3 Formulated worker ratio for agriculture industry to construction industry

<table>
<thead>
<tr>
<th>Construction worker counts</th>
<th>Agribusiness construction worker counts</th>
<th>Ratio (conservative estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6,295,000</td>
<td>16,241</td>
<td>1:388</td>
</tr>
</tbody>
</table>
The identified ratio was applied to determine the counts for number of fall incidents in agribusiness construction sites, thus estimate the probability of occurrence of fall incidents in agribusiness construction sites. A total of 18,574 fall incidents, which included both fatal and nonfatal falls in the construction industry, was reported in the NSC Injury Data report. By applying the formulated worker ratio, it was estimated that in 18,574 fall incidents that occurred in construction industry, 47 incidents contributed by agribusiness construction (as seen in Table 5). Equation 1 was applied to estimate the probability of fall incidents in agribusiness construction sites and the result was <0.01.

Table 4 Formulated fall incidents for agribusiness construction based on ratio

<table>
<thead>
<tr>
<th>Fall incidents for construction</th>
<th>Ratio (conservative estimate)</th>
<th>Fall incidents for agribusiness construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>18,574</td>
<td>1:388</td>
<td>47</td>
</tr>
</tbody>
</table>

Comparatively, the two probabilities were significantly different. Industrial experts and academic professionals, who were the participants to the survey, estimated fall incidents at 0.2 probability but the census data indicated that less than one percent for fall incidents to occur in agribusiness construction sites (see Table 6).

Table 5 Comparison of findings on probability of fall occurrence

<table>
<thead>
<tr>
<th>Probability of fall occurrence based on safety research</th>
<th>Probability of fall occurrence formulated from census data</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>
Conclusions and Discussion

This study described the approach that can be utilized to validate data obtained by safety researchers with census data retrieved from multiple sources. Agribusiness construction is a sub-classification of construction industry. Almost no census data were available to enable research work to be done within this specific area. However, the approached introduced in this study was assumed viable to draw out information and conclusion for fall incidents in agribusiness construction sites.

The ratio of 1:388 was based on a conservative estimate and assumptions of BLS and GEAPS data for agribusiness workers to construction workers. Based on the ratio, it was concluded that in 18,574 fall incidents occurred in construction industry, 47 fall incidents occurred in agribusiness construction sites. The probability of fall incident to occur in agribusiness construction sites was estimated at <0.01, which was considered as very low probability. Participants to the survey, who were industrial experts and academic professionals, conducted for the previous study, had estimated the probability of fall incident in agribusiness construction sites at 0.2. Comparatively, the probability identified based on the census data was significantly lower than the estimated probability by survey participants. It is concluded that the estimated probability by survey participants may not be representative and true for agribusiness construction sites.

While this study concluded that the safety research finding was not representative and true for fall incidents in agribusiness construction sites, emerging issues associated with this study needed attention and improvement. Ramaswamy and Mosher (2017) examined workers’ compensation to characterize injuries in the commercial grain elevator industry and found that fall, trips, and slips were the most significant type of injuries within the industry. This is contradictory to the findings of this study, where fall
incidents concluded to have the very lowest probability to occur on sites. The very low probability estimated based on the census data may be true, but it also suggests that further investigation needs to be completed relative to the data management within the agribusiness construction area. As mentioned earlier, the limited data available to use imposed multiple challenges to this study. The authors struggled to obtain reliable data to draw out information related to agribusiness construction. Further and deeper analysis can be conducted if researchers have access to more meaningful and appropriate data for agribusiness construction area.

However, the findings from this study may be useful for safety professionals and authorities or governmental bodies responsible for construction industry management to improve safety management and safety data on specific sub-classification areas such as agribusiness construction. Incidents in agribusiness construction are as important as incidents in other construction industries and that taking care of smaller incidents or incident components will reduce the chance for bigger or more severe incidents from happening (Bellamy, 2015). The main idea gained from this study is to prevent the most severe incidents from happening, acknowledging the facts and that smaller issues happening within the industry is important, especially in sub-classified industries. Better management of safety data for sub-classified industries is important to enable future research work done within the area.

In conclusion, having access to proper and adequate safety data would definitely help in research analysis and produce more reliable research results. The study showed a data transformation approach that can be utilized to estimate probability of safety incident to occur at workplace, specifically for sub-classified industry such as agribusiness
construction industry. However, the results could be more meaningful if more information can be accessed and included for this study. Future studies should focus on applying the same approach using more reliable data to determine probability to validate findings conducted through safety research.

References


CHAPTER 5. GENERAL CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

General Conclusions

The overarching goal of this study was to identify worker safety hazards in agribusiness construction sites and their contributing factors by employing a mixed method approach to gather data. This also involved utilizing fault tree analysis (FTA) to analyze the contributing factors. The main goal was operationalized into three separate studies presented in chapters 2, 3, and 4.

The study in chapter 2 aimed at utilizing qualitative and quantitative research tools to identify worker safety hazards and their contributing factors. A semi-structured interview was utilized as a qualitative method to gather data from industrial experts and academic professionals in construction and agricultural safety. The industrial experts and academic professionals were approached in attempt to gain richer stories, deeper explanation, and different viewpoints at issue of interest of this study. The industrial expert group represented by personnel with safety, construction, and design background holding different position in their respective organizations. The Grain Elevator and Processing Society (GEAPS) directory was used to pool the sample for the industrial expert group. This study was intended to include everyone involved in a project, however there were no response from any general labor or construction worker after being contacted by the authors. The academic professionals included faculty and graduate students with agricultural, safety, civil engineering, design, and project management background. All participants from the academic professional group have had extensive industrial background, either in construction related area or safety management.
Interview records were transcribed verbatim and a three-coding stage was employed to analyze for themes and categories of hazards and their contributing factors emerged from the interview transcriptions. Nine worker safety hazards were identified and four themes of contributing factors were determined. The nine hazards were 1) fall, 2) struck-by, 3) caught-in/between, 4) electrocution, 5) machine and equipment, 6) personal protective equipment (PPE), 7) confined space, 8) excavation, and 9) housekeeping. Four themes emerged for contributing factors were organizational factors, uphold image, unsafe work practices, and unsafe work conditions. The findings were then consolidated and organized into a survey.

The survey was disseminated to 220 participants and 22 participants responded. Based on the survey, participants rated that fall hazards were the most common hazard in agribusiness sites with 0.2 probability to occur on sites. This was not an unexpected finding, as previous similar study done in the construction industry and at grain elevators suggested falls as one of the most common hazards to occur on sites. Contributing factors such as poor decision making related to safety, carelessness, underestimated risk, a lack of familiarity with assigned tasks, lack of training, and not enough time were ranked by participants as significant contributors to worker safety hazards in agribusiness construction sites. This finding deepened the understanding of worker safety hazards in agribusiness construction sites by providing empirical evidence through analysis of interview transcriptions and survey data.

The study in chapter 3 focused on utilizing FTA to identify and graphically map the contributing factors to fatal fall incidents in agribusiness construction sites. This review reminded the reader that the study only completed the graphical map of FTA for
the contributing factors to fall incidents in agribusiness construction sites. Further analysis to the FTA will be presented in a separate study and it is not included in this dissertation. The FTA diagram was validated by a group of agribusiness insurance experts and an industrial expert.

Two events related to fatal fall incidents were analyzed further: 1) falls from elevation and 2) falls at the same level. Three circumstances leading to falls from elevation were further analyzed, which included falls from elevated floor or platform, falls from scaffolding, and falls from ladder. The tree was further branched into another two major events which were to be blamed for fall incidents: unsafe conditions and unsafe acts performed by either the worker or the co-worker.

The study found that the unsafe conditions causing multiple fall incidents in agribusiness construction sites can be attributed to managerial or organizational factors. Some of the organizational factors that had significantly contributed to fall incidents were lack of training given to workers, failure of management to properly plan and design for safe work zone, and inability of management to provide support to workers. These findings were important, and especially useful for the safety professionals to consider in designing safety plan at workplace since many of the previous studies attributed safety incidents to only the workers. Understanding the managerial or organizational related factors together with the worker factors will allow for improvement in the development of worker safety in this area.

Fall incidents in agribusiness construction sites can also be attributed to unsafe acts performed either by the worker him/herself or by his/her co-worker. Lack of training and experience, which also considered as lack of readiness or preparedness to perform
work, were among the main reasons why the worker and co-worker performed unsafe acts, leading to fall incidents on sites. Additionally, the worker’s tendency to underestimate or misjudge hazardous situations on sites often led to the worker ignoring safety procedure, thus performing unsafe acts while working on sites. Miscommunication between the worker and his/her co-worker also presented in the tree as one of the main factors leading to fall incidents on sites. These findings, both the contributing factors attributed to unsafe conditions and to unsafe acts, were important because they enhanced the understanding of worker safety hazards relative to agribusiness construction sites. The identified contributing factors will not only add knowledge to the literature, but will also help the safety practitioners as well as the related industries – construction and agribusiness industries and agribusiness related services, to plan and to develop safety intervention tailored for a sub-classified area such as agribusiness construction.

The study in chapter 4 was developed to compare the results gathered by the authors through safety research approach with census data obtained from the National Safety Council Injury Data. This is also intended to validate the probability of fall event to occur in agribusiness construction sites estimated by the participants to the survey (as presented in chapter 2). Validation of findings was expected to strengthen and increase the reliability of the research result. More importantly, the study in chapter 4 introduced the approach utilized to acquire and transform construction industry data and then apply the transformed data to the agribusiness construction industry.

Data acquisition process for this study included 1) examination of the GEAPS directory to gather the number of agribusiness construction companies, 2) identification of fall incident cases occurred in the U.S construction industry from census data provided
by the National Safety Council, and 3) identification of the number of construction workers in the Midwest region. A ratio of agribusiness worker to construction worker was formulated and applied with the number of fall incidents in the construction industry. The result was the probability of fall incidents in the agribusiness construction industry. Participants to the survey estimated the probability of fall incidents to occur at 0.2, while the result formulated from the census data showed the probability to occur at <0.01. There was a significant different between the two findings. This finding was contradictory to previous literature, where fall was estimated as frequently occurred incident in workplace.

Although the finding from the census data did not validate the finding gathered through safety research, the approach to acquire and transform the data introduced in this study exhibit usefulness for performing research in an area as specific and sub-classified as the agribusiness construction industry. The finding addressed one literature gap on agribusiness construction industry, which has received less attention from the research community and limited empirical research was done in this area. The finding also suggested that data management within sub-classified industry such as agribusiness construction need attention and improvement.

**Limitations**

As mentioned and discussed in the respective manuscripts, there were several limitations that need to be taken into consideration in interpreting the findings of this work. Agribusiness construction is a sub-classified area within the construction industry and many of the official records such as insurance claims, census data, and safety records did not classify incidents specifically under this classification.
The population is relatively small and limited. The participants for this research, specifically the participants to the semi-structured interviews, were approached at the convenience of the authors and the sample snow-balled as the research progressed. As a result, the sample size is limited and selection bias may have occurred in the sampling process. An attempt to broaden the sample size was made but encouraging participation from the industrial experts and academic professionals was a challenge throughout the project.

The small sample size for the survey was the result of complex and unfamiliar data collection process. The survey was disseminated through Qualtrics®, an online survey platform, which may have presented challenges for participants to take part and complete the survey. Missing and incomplete data points had also affected the data collected.

Data relative to agribusiness construction was almost non-existence or inaccessible by the authors, so the low probability of fall injuries and fatalities drawn from the available data set may not reflect actual conditions. Transformation data was required to formulate the data obtained for the construction industry and then apply it to the agribusiness construction industry. The transformation process as implemented may have introduced measurement error and may not actually reflect the real condition of the industry. In addition, the research instrument used is also subject to normal limitations and errors of using questionnaires.

**Recommendations for Future Work**

This is the first work done to identify and analyze worker safety hazards in agribusiness construction sites. This study has offered some initial findings and provided
the basic platform to further address more questions relative to this area. Some recommendations for future research include:

- This study gathered viewpoints from two groups: industrial experts and academic professionals. Limited discussion was drawn due to the limited and small number of samples. A larger sample size would help in drawing a more conclusive and extensive comparison of opinions on safety management in agribusiness construction sites between these two groups.

- Quantitative fault tree analysis (FTA) requires extensive and reliable data. Future work can be done by studying safety records and incident reports for agribusiness construction projects.

- The FTA was developed for the contributing factors to fall incidents. Employing the same approach, FTA can be utilized for electrocution hazards, which was also considered as high-risk hazard by the survey participants.

- The mixed method approach utilized in this work exhibited effectiveness in gathering richer and deeper data. Similar approaches can be used to understand other safety incidents in agricultural related areas, such as dust explosions in agribusiness facilities.

- Management role is important in the development and implementation of safety management at workplace, specifically in the agribusiness related areas. Mitigation of worker safety hazards is dependent on the knowledge of this area.
• Generally, construction sites are hazardous. Incidents at workplace often attributed to worker behavior. Some studies had also discussed the organizational factors that could lead to the safety incidents. However, little empirical work done with focus on project planning activities that could lead to safety incidents. For example, if a project started under major constraints in safety planning or resource management, how would it affect the safety management as the project progressed?

Most studies pertaining to worker safety were done in the construction, mining, and agriculture industries. This study is the first to reveal worker safety hazards within a sub-classified area of agribusiness construction. Knowledge on worker safety hazards and their contributing factors will help in effort to improve safety management at workplace by designing a tailored safety plan for agribusiness construction projects.
APPENDIX A. INTERVIEW PROTOCOL

Interview Protocol
Worker Safety Hazards Identification in Agribusiness Construction of Grain Handling Facilities

Time of Interview:
Date:
Place:
Method of Interview: Telephone / Face-to-face
Interviewer: Nurhaizan Mohd Zainudin

Thank you for taking the time to meet with me today (to talk with me today). I will be performing an interview on workers’ safety hazards on agribusiness construction sites. The data I am gathering will be analyzed and reported in my PhD dissertation. All responses will be classified as confidential and all participants will be recorded as anonymous.

I will be asking you a series of questions and recording your responses to correctly capture your answers. Is it OK that I audiotape our interview?
Yes ___ No ____

There are no right or wrong answers, and it is okay to say “I do not know”, or “I am not sure”. Your participation is completely voluntary. You may end the interview at any time. If you prefer not to answer a question, please let me know and I will skip the question.

Do you have any questions before we begin? [Answer question, if any]
Form of Consent for Participants

Today, I, Nurhaizan Mohd Zainudin, will be conducting an interview as part of data collection for my PhD research. The interview is designed to take about 30 – 40 minutes to complete. There are no right or wrong answers. You may end the interview at any time and ask me to skip any question that you prefer not to answer.

Your name will not be identified in the report. I will ask for your consent to audiotape the interview. Electronic and hard copies of interviewer notes and other related data will be stored in secured locations.

For the interview participant:
I am aware that my participation in this interview is voluntary. I understand the intent and purpose of this interview. If, for any reason, I wish to stop the interview, I may do so without having to give an explanation.

I have the right to decline having the interview recorded.

I am free to contact the interviewer, Nurhaizan Mohd Zainudin, at 515 598 6793 or haizan@iastate.edu if I have any questions about the interview.

I have read the above form and understand that I can withdraw at any time and for whatever reason. I consent to participate in today’s interview.

____________________  __________________
Signature of Participant   Date

____________________  __________________
Signature of Interviewer   Date
(Briefly describe the project)

Project Description:

Construction industry is acknowledged for being one of the most hazardous industries. Construction workers are constantly facing hazards in workplace. Fatalities and injuries rates in the construction industry remain higher than other industries despite the concerted efforts being done by related parties and stakeholders. There is a pressing need to provide innovative risk management approach for projects, especially in agribusiness construction projects since limited studies have been done within this area. It is imperative to identify agribusiness construction hazards for potential development of risk management and to reduce safety hazards. Thus, this study aims to identify safety hazards in agribusiness construction projects, factors contributing to the occurrence of safety hazards, and rank each hazard according to its probability of occurrence. Findings of this study will provide basis for potential development of risk management for agribusiness construction project.

Start of interview session.

I. Introduction

1) Could you begin by telling me who you are and what is your role at <insert organization name>?

Probes:

a) What is your position or job title?

b) What are your primary responsibilities?

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

II. Understanding on Risk Assessment and Hazard Identification

1) What is your understanding of risk assessment?

2) Are you familiar with risk assessment process?

3) How would you define hazard identification?

4) Have you performed a hazard identification before?
III. Safety Hazards on Agribusiness Construction Sites

1) How would you define major hazards on construction sites?
2) Can you identify situations you consider as major hazards?
3) How would you define minor hazards on construction sites?
4) Can you identify situations you consider as minor hazards?
5) Besides the situations mentioned previously, is there any other situations you can describe as hazardous to workers’ safety?

IV. Contributing Factors to Safety Hazards on Agribusiness Construction Sites

1) In your opinion, why safety failure occurs?

   Probes:
   a) How do you feel about PPE? Do you wear your PPE every time you enter construction site?
   b) How often do you review safety work procedures before you start working on construction site?
   c) What are some situations that you think that you could cut some slack and do not follow the safety procedures?
   d) How often do you check for mechanical failure or any broken part in your machines or equipment?
   e) Do you check is the tools or equipment is safe to be used before you actually use it?
   f) What do you think about safety warning, safety guardrails, and other safety protection measures on site? Are they effective?

2) Why accident still happen in construction site?

3) Is there any situation you feel unsafe when you are on site?
V. Safety Hazards Ranking

1) Which safety hazards would you rank as the top three most hazardous?

End of interview session.

Thank the individual for participating in this interview. Assure him/her of the confidentiality of responses. Inform him/her that a feedback validation will be done and he/she will receive a copy of the interview transcript to validate the information. Indicate for the potential of future interviews
APPENDIX B. SURVEY QUESTIONNAIRE

Note: The survey was modified from the online version

Workers’ Safety Hazards Identification in Agribusiness Construction of Grain Handling Facilities

Email Message:
Hello,
You are invited to participate in a web-based survey to determine major worker safety hazards in agribusiness construction projects and their contributing factors. This study is being conducted under the direction of Dr. Gretchen Mosher in the Department of Agricultural and Biosystems Engineering at Iowa State University.

Description of Procedures
If you agree to participate in this study, you will be asked to complete the survey in which you will answer six demographic questions, five questions where options are provided for selection, and one question that requires you to assign the probability of occurrence, based on your experience in the agribusiness construction industry. This survey will take approximately 20 minutes to complete.

Your participation is voluntary. You may choose to discontinue your participation in the survey at any time. There will be no record of participant identity. Each participant will be assigned a code number for classification and analysis purposes, but we will not be able to align the code number with participant identification.

If you have any questions about this study, contact Nurhaizan Mohd Zainudin (haizan@iastate.edu) or Gretchen Mosher (gamosher@iastate.edu).
This study has been reviewed by the Institutional Review Board (IRB) at Iowa State University. Any questions regarding the rights and safety of research subjects can be communicated with the Iowa State University IRB administrator at IRB@iastate.edu.
Informed Consent (Electronic)

By clicking agree indicates that:

- you voluntarily agree to participate in this study
- the study has been explained to you
- you have been given time to read the information provided on the previous page
- your questions have been satisfactorily answered

If at any given time you wish to leave the survey, you may do so without penalty or negative consequences.

Thank you.

<table>
<thead>
<tr>
<th>Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disagree</td>
</tr>
</tbody>
</table>
**Section A: Worker Safety Hazards in Agribusiness Construction Project**

1. How would you characterize a ‘major hazard’ in an agribusiness construction project?

<table>
<thead>
<tr>
<th></th>
<th>A major hazard is something that occurs frequently</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A major hazard is something that has the potential to result in a severe injury</td>
</tr>
<tr>
<td></td>
<td>A major hazard is something that occurs frequently and results in a severe injury</td>
</tr>
</tbody>
</table>

2. How would you characterize a ‘minor hazard’ in an agribusiness construction project?

<table>
<thead>
<tr>
<th></th>
<th>A minor hazard is something that does not occur frequently</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A minor hazard is something that has the potential to result in a minor injury</td>
</tr>
<tr>
<td></td>
<td>A minor hazard is something that does not occur frequently and results in a minor injury</td>
</tr>
</tbody>
</table>

3. Please estimate the average level of severity for the following hazards in agribusiness construction work environments, where severity is a measure of the resulting injury from the hazards. (F = Fatal, C = Critical, S = Serious, M = Marginal, N = Negligible)

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>C</th>
<th>S</th>
<th>M</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Struck-by</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caught-in/between</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrocution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine/equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure to use personal protective equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confined space</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excavation and earthwork</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housekeeping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. Please estimate the likelihood of occurrence for the following hazards in agribusiness construction work environments. (F = Frequent, P = Probable, O = Occasional, R = Remote, I = Improbable)

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>P</th>
<th>O</th>
<th>R</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Struck-by</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caught-in/between</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrocution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine/equipment</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Failure to use personal protective equipment</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Confined space</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excavation and earthwork</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housekeeping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Please estimate the frequency of occurrence for the following hazards during a one work week period with 100 workers.

<table>
<thead>
<tr>
<th></th>
<th>Frequency (Scroll Bar: Never = 0, Sometimes = 50, Always = 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td></td>
</tr>
<tr>
<td>Struck-by</td>
<td></td>
</tr>
<tr>
<td>Caught-in/between</td>
<td></td>
</tr>
<tr>
<td>Electrocution</td>
<td></td>
</tr>
<tr>
<td>Machine/equipment</td>
<td></td>
</tr>
<tr>
<td>Failure to use personal protective equipment</td>
<td></td>
</tr>
<tr>
<td>Confined space</td>
<td></td>
</tr>
<tr>
<td>Excavation and earthwork</td>
<td></td>
</tr>
<tr>
<td>Unsafe working environment</td>
<td></td>
</tr>
<tr>
<td>Housekeeping</td>
<td></td>
</tr>
</tbody>
</table>
6. When thinking about the organization, rank the following to indicate which contributes to safety incidents the most. (1 = Greatest Contribution, 10 = Minimal Contribution)

<table>
<thead>
<tr>
<th>Poor decisions by the management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of familiarity in assigned tasks</td>
</tr>
<tr>
<td>Lack of worker training and education</td>
</tr>
<tr>
<td>Lack of management support</td>
</tr>
<tr>
<td>Not having enough time to do work safely</td>
</tr>
<tr>
<td>Long hours of work</td>
</tr>
<tr>
<td>Lack of supervision and management support</td>
</tr>
<tr>
<td>Complicated safety procedures</td>
</tr>
<tr>
<td>Unsafe work conditions</td>
</tr>
<tr>
<td>Lack of safety regulation enforcement</td>
</tr>
</tbody>
</table>

7. When thinking about the workers, rank the following to indicate which contributes to safety incidents the most. (1 = Greatest Contribution, 8 = Minimal Contribution)

<table>
<thead>
<tr>
<th>Workers afraid to look weak in front of colleagues/supervisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetitive or boring work</td>
</tr>
<tr>
<td>Underestimated risk associated with assigned task</td>
</tr>
<tr>
<td>Unsafe work practices or procedures in work place</td>
</tr>
<tr>
<td>Poor decision making by the workers</td>
</tr>
<tr>
<td>Workers tendency to violate safety procedures to portray a competent image</td>
</tr>
<tr>
<td>The workers being careless or not thinking</td>
</tr>
<tr>
<td>Poor safety consciousness from workers</td>
</tr>
</tbody>
</table>
Section B: Demographics

Please choose the response that best describes you.

8. Which classification best describes your current position?

<table>
<thead>
<tr>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural handling or processing</td>
</tr>
<tr>
<td>Fabrication/Installation</td>
</tr>
<tr>
<td>Academia</td>
</tr>
<tr>
<td>Other (Please specify): __________</td>
</tr>
</tbody>
</table>

9. What is your position?

<table>
<thead>
<tr>
<th>President/Chairman</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vice President/Chairman</td>
</tr>
<tr>
<td>Director</td>
</tr>
<tr>
<td>Senior Managerial Officer</td>
</tr>
<tr>
<td>Junior Managerial Officer</td>
</tr>
<tr>
<td>Engineer / Project manager</td>
</tr>
<tr>
<td>General laborer / Construction worker</td>
</tr>
<tr>
<td>Professor/Lecturer/Researcher</td>
</tr>
<tr>
<td>Full time student</td>
</tr>
<tr>
<td>Other (Please specify): __________</td>
</tr>
</tbody>
</table>

10. How long have you been in your current position?

_______ years/months

11. Do you have work experience in the construction industry?

<table>
<thead>
<tr>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No (You may skip Question 12)</td>
</tr>
</tbody>
</table>

12. How long have you been in the construction industry?

_______ years/months
13. Please indicate the last grade or year in school which you completed.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>High school degree</td>
<td></td>
</tr>
<tr>
<td>2-year / technical degree or certificate</td>
<td></td>
</tr>
<tr>
<td>Undergraduate university degree</td>
<td></td>
</tr>
<tr>
<td>Graduate university degree</td>
<td></td>
</tr>
<tr>
<td>Other (Please specify): ________________</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C. IRB APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
2430 Lincoln Way, Suite 202
Ames, Iowa 50014
515-294-4566

Date: 6/23/2017
To: Nahazan Mohd Zainudin
3352 Elings

CC: Dr. Gretchen Mosher
104 Ed II

From: Office for Responsible Research

Title: Measuring and characterizing safety risks in agricultural construction projects

IRB ID: 17-260

Study Review Date: 6/23/2017

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey or interview procedures with adults or observation of public behavior where
   • Information obtained is recorded in such a manner that human subjects cannot be identified directly or through identifiers linked to the subjects; or
   • Any disclosure of the human subjects' responses outside the research could not reasonably place the subject at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.

The determination of exemption means that:

• You do not need to submit an application for annual continuing review.

• You must carry out the research as described in the IRB application. Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any modifications to the research procedures (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the inclusion of participants from vulnerable populations, and/or any changes that may increase the risk or discomfort to participants. Changes to key personnel must also be approved. The purpose of review is to determine if the project still meets the federal criteria for exemption.

Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

Detailed information about requirements for submission of modifications can be found on the Exempt Study Modification Form. A Personnel Change Form may be submitted when the only modification involves changes in study staff. If it is determined that exemption is no longer warranted, then an Application for Approval of Research Involving Humans Form will need to be submitted and approved before proceeding with data collection.

Please note that you must submit all research involving human participants for review. Only the IRB or designees may make the determination of exemption, even if you conduct a study in the future that is exactly like this study.

Please be aware that approval from other entities may also be needed. For example, access to data from private records (e.g., student, medical, or employment records, etc.) that are protected by FERPA, HIPAA or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted.

Please don’t hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.