AN ABSTRACT OF THE THESIS OF

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Title: Framework for Measuring Construction Project Performance using Energy.

Abstract approved

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John A. Gambatese

Over the years, the performance of construction projects has been a main source of concern given the percentage of a project cost associated with poor project performance. As a result of the growing clamor to improve the output of the built industry, comprehensive studies have been conducted to examine the factors that affect construction productivity, cost, schedule, safety and quality. However, little has been done to quantify the cumulative effect of project characteristics on the construction workforce. This study adopts the physical property of energy as a means to understand and quantify impacts to worker performance. To conduct the study, energy and its derivatives (power and pressure) were first translated from their physical sense to the context of work operations on a construction site. Once defined for construction operations, the research included conducting a survey of construction workers across 3 construction projects in the Pacific Northwest to quantify the workforce's perspective of construction energy and how work-related energy components impact construction

workers. Specifically, the survey measured the impact of 55 components that were identified through an extensive literature search as possible constituents of energy. Craft workers, foremen, superintendents, project engineers, project managers, safety professionals, and owner representatives provided detailed insight into the energy components affecting their safety and quality of their daily output. The survey was followed by a severity analysis to determine the key components that play a major role in determining construction project performance. Analysis of the feedback from participants shows that while each work level rated the components differently, attitude of worker to safety and the use of poor quality materials were rated as the most impactful factors to safety and quality of work on a project level, respectively. Using these components, a project management framework for forecasting and evaluating safety and quality performance on a construction project utilizing energy principles as its foundation was developed and proposed. The framework may be used to plan the construction operations for optimal safety and quality.

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APPROVED:

Major Professor, representing Civil Engineering

Head of the School of Civil and Construction Engineering

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Chukwuma Nnaji, Author

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1. CHAPTER 1 - INTRODUCTION

1.1. BACKGROUND

The cyclical, dynamic, complex, and time bound nature of the construction industry makes it one of many industries prone to management fallibilities (Odeh and Battaineh 2002; Shammas-Toma et al. 1998). The construction industry, however remains a vital cog in any society's economy and is often viewed as a metric for economic growth, stagnation, or regression (A. S. Ali and Rahmat 2010; Takim and Akintoye 2002). Being an economy driver, the demand on contractors is to deliver construction projects in a timely manner, while adhering to outlined safety measures and quality control parameters. In addition, such projects should be feasible financially.

In order to achieve the desired cycle-time while maintaining quality, safety, and cost, different management theories, tools, and frameworks have been propagated to ensure that project performance does not degenerate (Alarcon 1997; Ballard and Howell 1998). Notwithstanding the tools and theories, construction project performance has stagnated, contradicting what is witnessed in most industries (Anna Dubois and Lars-Erik Gadde 2002). The high cost of poor performance on a project has further increased the emphasis on providing effective mechanisms that can cause an upsurge in project performance. This phenomenon has led to intensive research efforts geared towards identifying factors responsible for poor performance during construction. Some authors have stated different sources as the antecedent to this undesirable outcome (Ankrah 2007; Chan et al. 2004; Dai et al. 2009; Enshassi et al. 2009; Makulsawatudom and Emsley 2003; Memon et al. 2012). To form a basis for evaluating construction project performance, measurable project properties must be identified (Swan and Kyng 2004). Researchers have proposed the development of construction industry Key Performance Indicators (KPIs) to help streamline the measurable properties thereby creating a standard for construction projects to be measured against (Cox et al. 2003; Sanvido 1992). The Construction Industry Institute (CII) recommends that factors such as safety, quality, cost, schedule, changes, and productivity should be measured to determine project performance (CII 2000). Using these KPIs, tools for evaluating worker performance as a means of assessing project performance have been introduced to the industry. However, these tools measure project performance based on lagging indicators, which negates the element of proactive planning and the associated benefits that may accrue. The construction industry is yet to develop a comprehensive, easy-to-use tool capable of assessing the impact of project factors, conditions, and resources on a construction worker's performance. In addition, there are no measures for the collective impact of the aforementioned factors on the performance of personnel on a project with broad aims of personnel evaluation through pre- and post-completion of a given project. This study proposes to bridge this research gap using the physical characteristics of energy and its derivatives. Energy is defined in the context of this research study as the factors, conditions, and resources that aid in the planning, erecting, maintain and demolishing of a structure.

1.2. RESEARCH GOAL AND OBJECTIVES

The focal goal of this thesis is to develop a new tool to be used to predict potential quality and safety deviations before the commencement of a project and assess an ongoing project. The following objectives are the driver of this thesis:

i. identify factors that impact work quality and worker safety on a project,

ii. determine which factors impair and which aid work quality and worker safety on a project,

iii. determine the degree of impact of each identified factor on work quality and worker safety on a project,

iv. develop an "energy" concept with regards to construction project management, and

v. develop a process for measuring energy on a construction project.

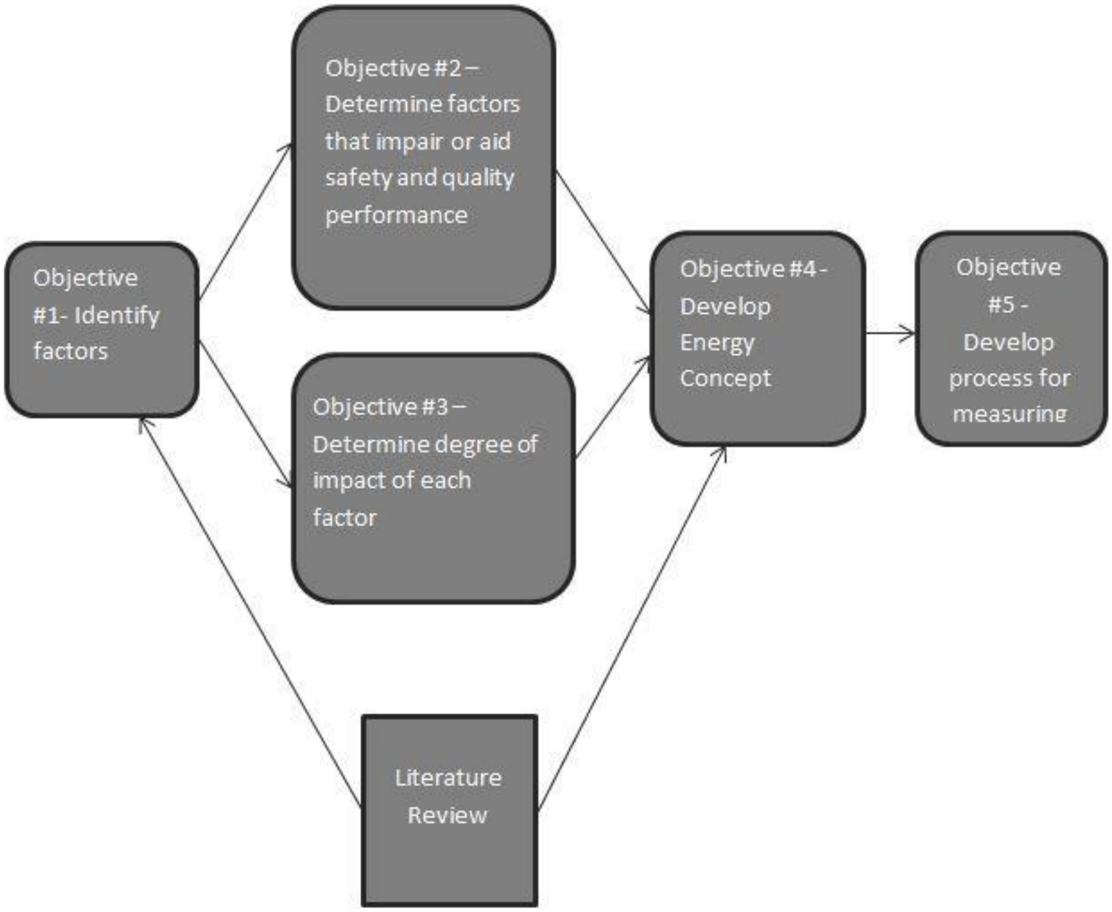


Figure 1.1: Relationship between Research Objectives

1.2.1. RESEARCH QUESTIONS

To successfully meet the research objectives, suitable research questions must be asked and answered. Below are the research questions for this study:

i. Is energy present on a construction site?

ii. Do construction operations conform to the physical properties of energy?

iii. What are the major factors that affect workers at different levels?

iv. Do the factors have the same impact on safety and quality?

v. Do the factors, when positive or negative, impact worker performance differently?

vi. How is energy measured?

1.3. THESIS STRUCTURE/OVERVIEW

To meet the set objectives of this research, different tasks were undertaken. These tasks are grouped according to chapters as shown below:

Chapter 1: Introduction

The background of the research, objectives and an overview of the thesis are covered in this chapter.

Chapter 2: Literature Review

The extensive literature study that was carried out on project performance in the construction industry with emphasis on work quality and worker safety is discussed. This section begins with an overview of the construction industry and its key attributes and then discusses project performance. The impact of advances in the construction industry is highlighted, key project performance indicators are mentioned, and an in-depth review of literature on safety and quality is undertaken.

Chapter 3: Research Gap and Introduction of Energy Concept

This chapter presents the gap in literature and the need for a new approach in forecasting and assessing quality and safety on a construction project. The term "energy" and its enablers are presented and discussed extensively.

Chapter 4: Methodology

The preferred method for obtaining data, process followed for data collection, and techniques for analyzing data are discussed in this chapter. Also, the process for developing the proposed tool is discussed.

Chapter 5: Results

Data generated from the research is presented in this chapter.

Chapter 6: Analysis and Discussion of Results

This chapter comprises detailed analysis and explanations of the results obtained from the chosen research method. The basis for the recommended framework is discussed as well.

Chapter 7: Conclusions and Recommendations

The research effort is summarized in this chapter. Conclusions that can be drawn from the study are presented as well. The limitations of the research, recommendations, and areas for further study are also discussed.

2. CHAPTER 2 - LITERATURE REVIEW

2.1. INTRODUCTION

A construction project involves various processes/operations, different phases, a considerable amount of coordination between different parties, and input from stakeholders (Chan et al. 2004). This complex system, if not properly integrated, could impair the success of the project. Over time, harnessing the resources required to deliver a successful project has proven problematic. Regardless of the reported improvements in production of most industries, combined with advances in science, technology, and construction methodology, construction projects are still riddled with poor performance (Chan et al. 2004; Hoonakker et al. 2011; Kangari 1988).

Notwithstanding these anomalies, the construction industry plays a major role in the economy of the United States, providing about 4.5% of the Gross Domestic Product (GDP) and employment for over 6.5 million people (US Census Bureau Construction Expenditures 2015; BLS 2015). Considering the significance of the construction industry to the economy, the importance of construction project performance has become noteworthy (Alzahrani and Emsley 2013). Although there are recommendations that project performance be improved, the quest for an upturn has been identified as a major challenge (Love et al. 2010; Love and Smith 2003).

In this chapter, factors that affect project performance are highlighted alongside the available methods for measuring these identified factors. Also, the impact of efforts made thus far at improving project performance is discussed. Finally, the impact of quality of work and worker safety on a project performance is thoroughly investigated through extensive literature review.

2.2. STATE OF CONSTRUCTION PROJECT PERFORMANCE

A successful construction project, although difficult to define (Lam et al. 2008; Toor and Ogunlana 2010) can be said to be one that is delivered on time, within budget, safely, to technical specification, and also meets client satisfaction (Baker et al. 1997; Cooke-Davies 2002; Morris and Hough 1987; Pinto and Slevin 1987). Project success rate regarding construction projects leaves much to be desired. This reality has led to the birth of diverse innovative methodologies and concepts geared towards creating a better work condition with the long term aim of improving overall project performance.

Traditionally, project status has been evaluated using methods such as return-on-investment, earnings-per-share, schedule variance, cost variance, earned value, and milestone variance (Cheung et al. 2004; Howes 2000; Kim and Reinschmidt 2011; KWAK and IBBS 31). These methods are used to measure the current status of a project against anticipated progress to determine if a variance is present. Although broadly used, these methods lack the predictive ability to envisage and identify problem areas thereby making the methods largely reactive (Choi et al. 2006). Furthermore, Project Managers have expressed concern regarding the ability of these methods to provide a holistic evaluation of project performance (Kaplan & Norton, 2005).

2.2.1. IMPACT OF CONTRACT PROCUREMENT METHOD ALTERATION

Alhazmi and McCaffer (2000) state that for a project to be successful, the selection of a procurement system should take into consideration project-specific characteristics. Altering the contracting method from the traditional system (Design-Bid-Build) was considered an effective way of improving project success rate through reducing cost (Business Roundtable and Construction Industry Cost Effectiveness Task Force 1982). Contract types such as Design-Build, Construction Manager at Risk, and Integrated Project Delivery (IPD) encourage early involvement of contractors in design which improves schedule performance by approximately 12% and reduces manhours required by 5.5% (Song et al. 2009). Likewise, Hinze and Rabound (1989) argue that the traditional method of bidding increases the injury rate on a project. To further expound on the impact of design on project performance, Arditi et al.(2002) theorize that the decisions made in the design phase of a project play an important role in determining the end quality of the project. These propositions firmly assert that early constructability inputs from contractors have a positive influence on project performance given the disjointed, complex, and unique nature of the industry. This industry fragmentation leads to limited exposure of designers to the quintessence of the construction process, thereby curtailing their ability to create designs with optimum constructability, improving safety and quality of work while reducing cost at a given schedule (Arditi et al. 2002; Burati et al. 1992; Gambatese et al. 2005; Ghaderi and Kasirossafar 2015; Hadikusumo and Rowlinson 2004; Lopez and Love 2012; McGeorge

1988; Song et al. 2009). This assertion synchronizes with research carried out by different scholars (CII 1986; Pocock et al. 2006; Wiezel and Oztemir 2004) who state that optimizing the design process by including construction knowledge and the project use-lifecycle is one way of increasing proficiency. Alongside advocating the modification of contracting method to include involvement of experienced contractors in the design process, other methods of improving specific key project indicators are highlighted and recommended by researchers.

2.2.2. IMPACT OF PREVENTION THROUGH DESIGN/DESIGN FOR SAFETY

The concept of Prevention through Design (PtD) was proposed as a new approach that aimed to reduce exposure of construction workers to hazardous conditions which could lead to an accident on a construction site (Gambatese et al. 1997). This process encourages the designer to take construction worker safety into consideration when designing a structure. The benefits accrued to the project owner and contractor using this principle include reduction in site hazards, leading to fewer injuries and fatalities, reduction in loss time and worker compensation premiums. This approach also helps to increase productivity and encourage collaboration between designers and constructors (Gambatese et al. 2005). To maximize the benefit of this principle, the designer is required to either eliminate or substitute any design element that could construe a hazard (Gambatese et al. 2005), which is in concordance with the best methods of controlling safety as seen in Figure 2.1.

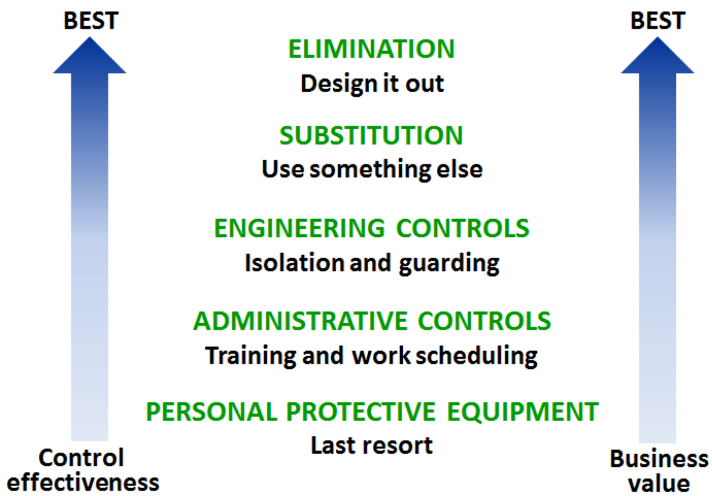


Figure 2.1: Safety Control Hierarchy (http://www.cdc.gov/niosh/docs/2013-136/)

In European Union countries and Australia, the designers are required by law to design for safety (Toole and Gambatese 2008). Opinions about and acceptance of PtD are divided in the US (Toole 2005). A major reason for this resistance in the construction industry is the issue of liability (Gambatese 1998). Designers do not want to be held liable for any accident that occurs on a construction project. Other reasons for the hesitancy are, lack of construction operation knowledge, lack of safety training, lack of desire to change from the construction norm, and the lack of interaction between designers and contractors within the traditional contracting process (Gambatese et al. 1997). To facilitate the acceptance rate of the prevention through design concept and improve designer's knowledge of the construction operation process, different tools have been created to assist designers in implementing this concept. Tools such as SliDeRulE, CII's Design for Construction Safety Toolbox, Safety in Design tool, and PtD online training tool are now used in the construction industry to bridge the designer's knowledge gap. To further buttress the need for safety to be considered in design, Holmes (1999) pointed out that the manner in which risk is perceived by people could be skewed as a result of schedule and budget constraints and, therefore, risk should be considered and identified prior to the construction phase of a project.

2.2.3. IMPACT OF LEAN CONSTRUCTION PRINCIPLE

To help promote efficiency in construction operations, Ballard and Howell created the Lean Construction Institute (LCI) in 1997. Lean construction, an offshoot of the Toyota Production System (TPS) aims in part to help reduce variability and waste in the construction industry. LCI developed the Last Planner System (LPS), Continuous Improvement (CI), and the Integrated Project Delivery (IPD) which have had a positive impact on the performance of the construction industry (Aziz & Hafez, 2013; Luis F. Alarcón, 2014.). To ascertain the impact of the lean construction principle on the safety of construction workers, Nahmens (2009) focused on the interaction between CI and safety. After surveying 141 builders in the United States, it was discovered that the presence of CI programs on a project is associated with a significant reduction in injury incident rate. Apart from reducing the possibility of accidents and fatalities, lean construction principles improve productivity, corporate image, client satisfaction, and competitive advantage (Adebayo Akanbi Oladapo 2014). Notwithstanding the benefits associated with lean construction, implementation has been poor in some countries. "Lack of adequate lean awareness and understanding, Lack of top management commitment; and Cultural & human attitudinal issues” were identified as the three most cogent draw-backs to wide spread adoption (Saad Sarhan 2013).

2.2.4. IMPACT OF INFORMATION TECHNOLOGY

Advancements in the information technology (IT) industry have impacted the construction industry. The increased use of IT on construction project operations has improved project performance through early detection of possible problems leading to improved coordination of activities. This helps save time and cost, and improves safety and quality (Zhang et al. 2013).

Thomas et al.(2004) attempted to quantify the cost benefit of Design/Information Technology (D/IT) on a construction project. To determine the presence of any correlation between D/IT and project outcome, 297 construction projects were analyzed. The outcome showed that the contractor and the owner save approximately 4% on construction cost by adopting IT. According to Kang et al. (2008), savings on schedule as a result of implementing IT on a project could range from 15%-17%.

Different software such as building information modeling (BIM), Bluebeam, and sage 300 have been identified as tools that could be used to improve project performance. Amid these software programs, BIM has garnered popularity in the construction industry over the past decade due to the variety of uses it offers. Aside from its wide application, some scholars and stakeholders have argued that the use of such information technology software comes at a steep price. Vaughan et al. (2013) carried out a case study on the cost-benefit analysis for the implementation of construction information management systems. High initial capital cost, time spent on installation, and training were mentioned as the major disadvantages of these systems. Furthermore, the lack of a tool for measuring the cost-benefit of using BIM on a project was looked into by Giel and Issa (2014). A framework to evaluate the return on investment of BIM software on construction projects was created to solve this problem. The outcomes suggested that BIM is a worthwhile investment despite the initial cost of the system, size, and complexity of a project. Apart from applying IT on a project level, IT could also be used to improve specific project factors such as material handling, document management, information management, and equipment control (Froese 2015; Hasan et al. 2015; Jang and Skibniewski 2009; Zhu et al. 2015).

2.2.5. IMPACT OF BENCH MARKING METRICS - PERFORMANCE INDICATORS

Due to project uniqueness, duration, and complexity, the construction industry has been plagued with lack of substantiated data. This has been identified as a major hindrance to continuous improvement in project performance. As part of an effort to correct this incongruity, the Construction Industry Institute (CII) was established in 1983 by contractors, project owners, and the government to create knowledge and best practices suited to improving safety, quality, cost effectiveness, and schedule thereby giving the North American construction companies a global advantage (CII 2015). One of areas of focus is to determine key project performance indicators. This investigation has received much importance by CII. The purpose of KPIs is to provide a means for measuring project and company performance in the construction industry (The KPI Working Group 2000) After extensive research, CII identified different sets of KPIs for small and large projects as seen in Table 2.1.

Table 2.1: CII's Construction Project Key Performance Indicators (CII 2009)

Small Project	**Large Project**
Cost	Cost
Schedule	Schedule
Changes	Changes
Accident and Workhours Data	Rework
Project Impacts	Accident and Workhours Data
	Project Impacts

In order to improve construction performance in the UK, The Department of Environment, Transport and Regions (DETR) published a KPI Report in 2000 identifying ten parameters for benchmarking projects. These parameters were divided into two groups, namely project performance indicators and company performance indicators as shown in Table 2.2.

Table 2.2: DETR Construction KPI's (DETR 2000)

Project Performance Indicators	**Company Performance Indicators**

Construction cost	Safety
Construction time	Profitability
Cost predictability	Productivity
Time predictability	
Defects (Quality)	
Client satisfaction with the product	
Client satisfaction with the service	

KPI’s can generally be divided into two groups: project level and company level as seen in Table 2.2. This separation is due to the variance in company and project objectives and requirements. As seen in Tables 2.3 and 2.4, KPIs differ across continents and countries. This difference could be as a result of different cultures, expectations, and methodologies. Ali et al. (2013) highlighted the different KPIs found in different countries.

Table 2.3: Project Level KPI's in Different Countries (Ali et al. 2013)

Project level			
No.	Author	Country	Performance indicators
1	Department of Environment, Transport, and Regions (DETR), 2000	UK	Time, Cost, Quality, Client satisfaction, Client changes, Business performance, and Health & safety
2	(Cheung et al. 2004)	China	People, Cost, Time, Quality, Safety, Client satisfaction, Communication, and Environment
3	(Rankin et al. 2008) and	Canada	Cost, Time, Quality, Safety, Scope,

	Canadian Construction Innovation Council (CCIC) (2007)		Innovation, Sustainability, and Client satisfaction
4	(CII 2011)	USA	Cost, Schedule, Changes, Accident, Rework, and Productivity
5	(Chan et al. 2004)	Australia	Construction time, Speed of construction, Time variation, Unit cost, Percentage net variation over final cost, Net present value, Accident rate, Environmental Impact Assessment score, Quality, Functionality, End-user satisfaction, Clients satisfaction, Design team's satisfaction, and Construction team's satisfaction
6	(D I Ikediashi 2012)	Nigeria*	Job Cost Reporting, Time performance, Quality of work, Health and Safety, Resource Management, Cost per Unit, Rework/Quality Control, and Motivation
7	(Jastaniah 1997)	Saudi Arabia	Client satisfaction, Closeness to budget, Planning period, Profitability, Staff experience, Payment, Communication, and Claims

* KPI's for Design-Build projects in Nigeria

Table 2. 4: Company Level KPI's in Different Countries (Ali et al. 2013)

Company level			
No.	Author	Country	Performance indicators
1	(El- Mashaleh et al. 2007; El- Mashaleh et al. 2006; Wang et al. 2010)	USA	Schedule performance, Safety, Cost performance, Profitability, Market share, Return on capital, Quality, Cash flow, Internal business, Reliability, Innovation and learning, Customer focus, and Environment

2	(Nudurupati et al. 2007) DETR (2000) DTI (2002)	UK	Profitability, Return on value added, Productivity, Interest cover, Return on capital employed, Ratio of value added, Repeat business, Quality, Safety, Clients satisfaction, Time, Employee satisfaction, Cost, and Environment impact
3	(A. G. Luis F Alarcón 2001; Ramı´rez et al. 2004)	Chile	Safety, Training, Productivity, Planning effectiveness, Quality, Cost variation, Efficiency of labor, Schedule variation, Rework

Taking into consideration the number of key performance indicators that were discovered through extensive research, it is important to discover vital indicators that constitute a significant amount of impact. According to Cristobal (2009) and Cox et al. (2003), time, cost, safety, and quality are significant construction project planning and controlling KPIs. These KPIs, if assessed individually, may not be perceived as critical to the overall project objective. To expose the underlying failure caused by this segregation, it was recommended that the indicators be summed up to provide a depiction of how successful or ineffective a project is (Chan and Chan 2004).

To further buttress the importance of summing up KPIs, Chan et al. (2004), argue that to improve the quality of measurement, KPIs should be divided into two groups: subjective and objective as shown in Table 2.5. The authors also state that for a project to be truly successful, both subjective and objective KPI’s should be evaluated and be found to meet the client’s requirements and industry standards.

Table 2.5: Subjective and Objective KPI's (Chan et al. 2004)

Objective Measures	Subjective Measures
Construction time	Quality
Speed of construction	Functionality
Time variation	End-user satisfaction
Unit cost	Clients satisfaction
Percentage net variation over final cost	Design team's satisfaction
Net present value	Construction team's satisfaction
Accident rate	
Environmental Impact Assessment score	

Takim and Akintoye (2002) identified that project KPIs also differ along the path of project phases and stakeholders. As seen Table 2.6, different KPIs cut across different construction phases and affect different project stakeholders.

Table 2.6: Stakeholders and Project Phase KPI's (Takim and Akintoye 2002)

Client	Consultant	Contractor	Supplier	End-user	Community
PROCUREMENT STAGE - PERFORMANCE					
➢ Client attribution ➢ Project attribution ➢ Procurement & delivery Strategy ➢ Project viability ➢ Contractual arrangement ➢ Briefing Process ➢ Communication ➢ Decision effectiveness ➢ Risks and opportunities ➢ Excessive bureaucracy ➢ Commitment from employees ➢ Interactive Process ➢ Social Obligations	➢ Project management capabilities ➢ Good working relationship ➢ Competency ➢ Consultation mode ➢ Commitment ➢ Strategic cost advise ➢ Meeting functional requirements ➢ Meeting technical specification ➢ Proper communication ➢ Interactive process ➢ Efficiency of technical approval authorities	➢ Level of experience ➢ Financial stability & financial management ➢ Past performance ➢ Management capabilities ➢ Performance of project personnel ➢ Construction method and technology ➢ Manpower and technical capabilities ➢ Project innovation	➢ Quality assurance on products ➢ Quality control system ➢ Product life span ➢ Replacement value ➢ The concept of JIT ➢ Product mechanization ➢ Track record ➢ Level of service ➢ Team turn-over rate ➢ Capabilities of key personnel ➢ Top management support	➢ Involvement in need definition ➢ Contribution of ideas and requirements ➢ Commitment via representatives ➢ Involvement in decision making process ➢ Joint evaluation on procurement selection	➢ Pressures ➢ Demands ➢ Community involvement ➢ Community Policy ➢ Battleground ➢ Closer relationship
PROJECT PHASE - PERFORMANCE					
➢ Management structure ➢ Project interfaces ➢ Fragmentation ➢ Conflicts ➢ Control measures ➢ Political, economic, social, legal & environment influences ➢ Loyalty	➢ Team Management ➢ Project interfaces ➢ Coordination ➢ Accountability ➢ Conflicts management style ➢ Communications and reporting ➢ Quality control system	➢ Performance standard ➢ Good working relationship ➢ Construction method & technology ➢ Labor utilization & relaxation ➢ Productivity rate ➢ Safety ➢ Constructability ➢ Communications and	➢ Material Procurement ➢ Co-operation ➢ Commitment ➢ Coordination ➢ Ability to deliver ➢ Product reliability ➢ Delivery time ➢ Contractual agreement ➢ Product defects	➢ Continuous participation ➢ Involvement in maintenance documentation	➢ Support ➢ Co-operation ➢ Disruptions ➢ Expedite ➢ Environmental effect

➢ Quality of work life	➢ Quality assurance ➢ Dispute resolution process	reporting ➢ Cost control mechanism ➢ Efficiency			
➢ **PHASING-OUT STAGE - EXPECTATION**					
➢ Meets pre stated objectives ➢ Meets time ➢ Meets budget ➢ Technical specification ➢ Acceptable quality ➢ Meets Corporate priorities ➢ Harmony ➢ Absence of any claims & proceedings ➢ Reduction of conflicts/ disputes ➢ Transfer of experience ➢ Investment opportunity ➢ Value for money	➢ Profitability ➢ Future Jobs ➢ Learning & growth ➢ Generated positive reputation ➢ Harmony ➢ Absence of any legal claims & proceedings ➢ Increase the level of professional	➢ Profitability ➢ Achieve business purpose ➢ (strategically, tactically & operationally) ➢ Learning and growth ➢ Settlements of conflicts ➢ Minimum risk (reduction of disputes) ➢ Business relationship ➢ New market penetration ➢ Generated positive reputation ➢ Develop new knowledge & expertise	➢ New market penetration on products ➢ Future potential ➢ Exploit technology ➢ Profitability	➢ Meets requirements ➢ Functionality ➢ Desired outcomes ➢ Free from defects ➢ Meets quality thresholds ➢ On-time deliveries ➢ Minimum cost of ownership ➢ Required future service ➢ Safety ➢ Flexibility (for future expansion) ➢ Usable life expectancy ➢ Easy to maintain ➢ Depreciation and exploitation costs	➢ Benefits ➢ Use of IT ➢ Safety ➢ Pleasant environment (blend to the surroundings) ➢ Public image

As observed in the literature presented above, project performance is routinely measured on a macro-level (project level). However, measuring the performance of personnel within the different tiers in a construction operation could as well be used as an index to determine the performance of a project. Alongside adequate project management actions, proper evaluation of project-related factors/external environment, adoption of suitable project procedures, and the performance of construction workers go a long way in determining the success of any construction project (Chan et al. 2004).

Dai et al. (2009) reported that the productivity of field workers is greatly affected by factors such as availability of tools and consumables, poor quality of drawings, lack of adequate response system, and safety concerns. In order to ensure improved performance of a field worker, the management and supervisory team should correct these factors upstream. As a result of the complex and fragmented nature of the construction industry, a high level of coordination and planning is required for a project to have any optimism of being successful. This somewhat excruciating process leads to a high amount of paperwork, a decent number of demanding meetings, and synchronization of complex logistics. The high-level control of a construction operation process is handled by a Project Manager (PM) who is saddled with the responsibility of planning out a project from inception to its completion (Müller and Turner 2010). These duties place an enormous level of demand on the PM that can influence his/her personal performance causing considerable harm to the general project performance.

Objective-related stress, burnout, and physiological stress related to workload demand were cited as reasons for a construction PM's poor performance. To prevent/reduce the possibility of having a fatigued PM, effective project staffing should be carried out as early as possible, distribution of workload within the construction team should be reasonable, routine debriefing meetings held between project stakeholders and the project management team, and stress appraisal workshops should be available to PMs (Leung et al. 2008).

In the construction industry, the impact of stress is not (synonymous) restricted to the PM. Leung et al. (2015) looked into the impact of job stressors and stress on construction workers with broad aims of determining the effect of the aforementioned phenomena on safety behavior. Accidents of construction workers were the primary focus of the study. The researchers developed an accident causation model depicted in Figure 2.2.

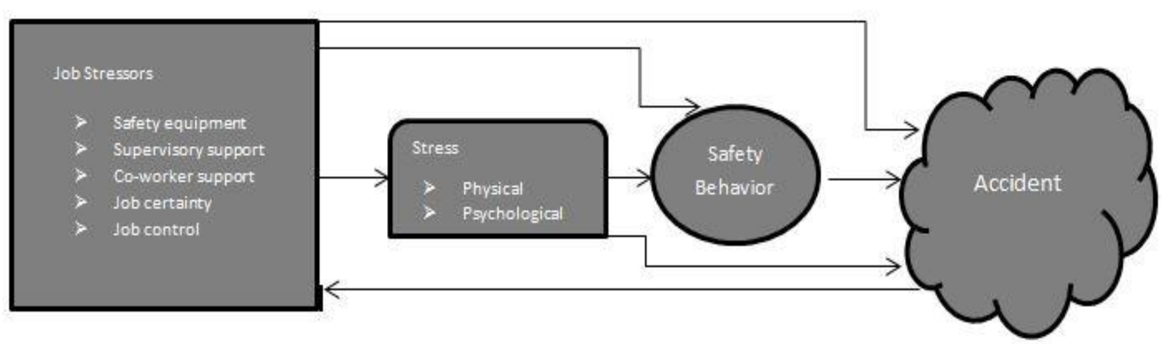


Figure 2.2: Accident Causation (Adapted from Leung el al. 2015)

To reduce the impact of job stressors and stress on construction workers, the researchers recommend that alongside proper assigning of teams and providing adequate community support, supervisors should also afford apt assistance to their workers. Job security and certainty should be provided by the management if possible to reduce worker distraction.

Literary evidence suggests that accidents/incidents on a project affect construction cost, schedule, and worker morale (Gambatese 2000a; Hallowell and Gambatese 2009; Sawacha et al. 1999). In addition, research has proven that accidents also impact the quality of a construction project (Wanberg et al. 2013). This makes safety an important project property/indicator that should be controlled without cutting corners. The impact of safety and quality on project performance will be discussed extensively below.

2.3. IMPACT OF SAFETY AND QUALITY ON CONSTRUCTION PROJECT PERFORMANCE

2.3.1. SAFETY

"Safety first" is a common slogan associated with most industries. Different researchers have questioned the validity of the use of this dictum in the construction industry. As seen in Figure 2.3, the construction industry recorded 796 fatalities in 2013 making it the industry with the highest number of worker fatalities (BLS 2014). Between the turn of the century and 2014, the construction industry accounted for approximately 20% of all fatalities that took place at work, yet employed approximately 5% of the workforce (BLS 2014; US. Department of Commerce 2014; United States Census Bureau 2014). "By any relevant measure, construction is not a safe industry and as a result has gained an unenviable reputation in relation to the health, safety, and welfare of its workers" (Ikpe et al. 2012). Furthermore, the Health and Safety Executive in 2002 stated that "construction workers are six times more likely to be killed at work than other workers" (Donaghy 2010)

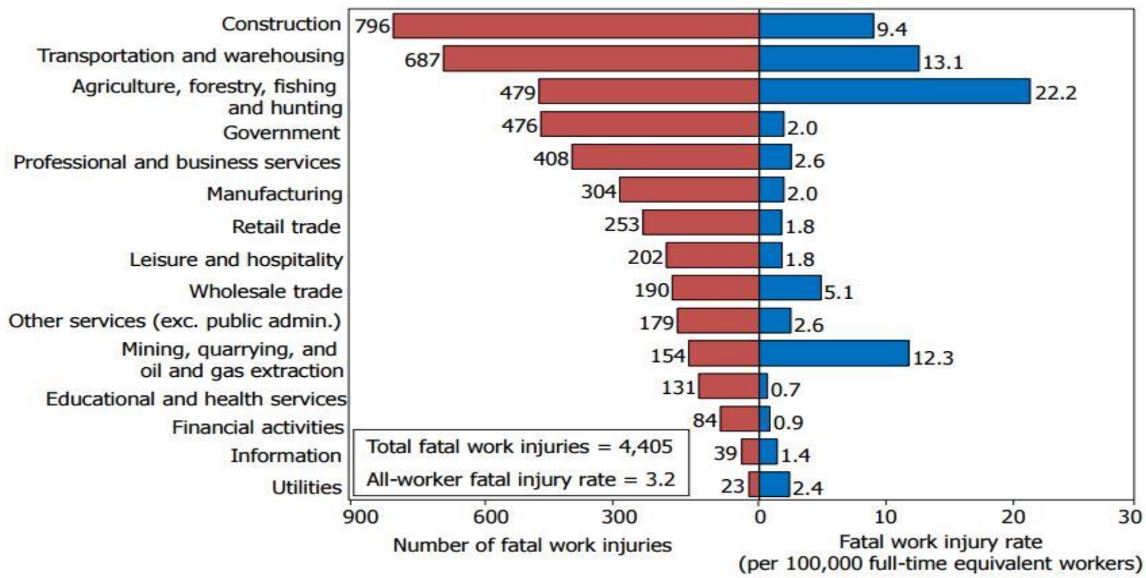


Figure 2.3: Fatalities by Industry (Image from BLS 2014)

The financial repercussions associated with accidents could easily lead to profit loss. The amount of loss could range between 7.9 and 15% of the total cost of a project (Everett and Frank 1996). This unpleasant statistic further emphasizes that safety should be paramount on every construction project. Although there has been a slight decline in fatal injuries in the construction industry in recent years as shown in Figure 2.4, more can be done to further improve safety performance (Rajendran 2013).

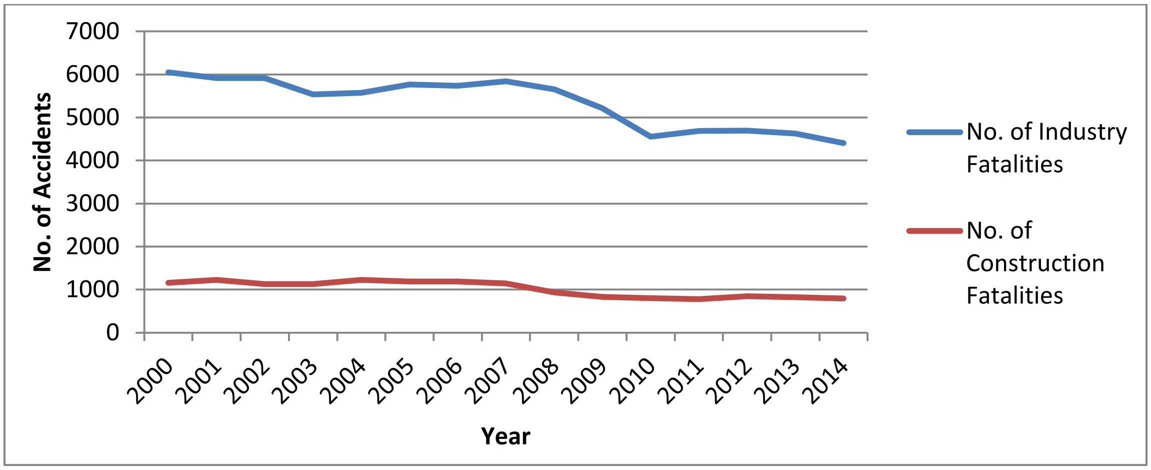


Figure 2.4: Number of Fatal Injuries in Construction, 2000-2014 (Adapted from BLS 2010)

According to the Occupational Safety and Health Administration (OSHA 2014), the major causes of accidents on a construction project are: (1) Fall from height, (2) Struck by an object, (3) Electrocution, and (4) Caught in/between (OSHA, 2014). These four sources of accidents are responsible for 58.7% of all accidents in construction (OSHA 2014). Accidents could be prevented ("zero-injury objective") if the appropriate safety control measures are put in place starting from design conception to use of the structure (Gambatese, Hinze, and Haas 1997; Hinze 1997; Hinze and Wilson 2000; Huang and Hinze 2006; Zero 1993). The importance of developing project specific safety management programs in construction cannot be overstated. Apart from the benefits of improved productivity resulting from creating a more conducive work environment, contractors save money on worker compensation and also gain a competitive edge in contract acquisition with a lower Experience Modification Rating (EMR) (Gambatese 2000b; Hallowell 2010; Kartam 1997). Ikpe (2012) suggests that for every £1 spent on accident prevention, £3 is saved on direct/indirect costs of accidents. This theory further reinforces the cost-benefit of taking adequate safety actions towards sufficient mitigation.

Currently, safety performance is measured both quantitatively and qualitatively using leading and lagging indicators. Safety assessment could be carried out on a specific project and/or on a company level. Recordable Incident Rate (RIR), EMR, Lost Time Incident Rate, and Worker Claims Frequency are quantitative indicators that could be used to measure the performance of a company (Garza et al. 1998). Qualitative analysis can be realized by involving safety agencies such as the National Institute of Safety and Health (NIOSH) and Organization of Health and Safety Association (OHSA) to determine the rating of a project or the company. A rating scale of excellent, average, or below average is typically used by the aforementioned organization to access the performance of a project and/or a company (Jaselskis et al. 1996). Qualitative and quantitative means of measuring safety performance are by no means mutually exclusive. Furthermore, it is recommended that a combination of both types of measures can prove highly effective (Jaselskis et al. 1996). OSHA mandates that a thorough assessment of safety issues be carried out prior to project commencement and suitable safety measures set in place to control issues that may arise (OSHA 2014).

To this effect, several safety forecasting tools and theories have been proposed and developed. To determine qualitative safety performance within the construction industry, standardized benchmarking systems were developed by different agencies such as the Construction Users Roundtable (CURT), OHSA, and CII. The Construction Industry Development Agency (CIDA 1995) developed the Health and Safety Continuous Improvement Matrix for the Australian construction industry to create the capacity to compare OHS performance across the industry. Such systems give a company the ability to compare its safety performance against a recognized standard. As a result of the absence of a recognized mechanism for measuring safety risks and selecting adequate safety measures to counter the identified safety concerns, Hallowell and Gambatese (2009) introduced and validated a risk-based safety and health model that assists contractors of varying sizes in selecting efficient safety programs given specific worker activities.

The continuous growth of IT in the construction industry has led to a new dynamic in accident prevention. Software such as BIM could be used in tandem with the DfS theory with the objective of eliminating hazards in the design phase of a project (Hayne et al. 2014; Kasirossafar and Shahbodaghlou 2012a). The use of visualization technology is not limited to just the design phase of a project. It could also be used to great effect in the planning of construction operations (Kasirossafar and Shahbodaghlou 2012b).

Through extensive research, questionnaires, and interviews, Gambatese et al. (1997) developed a design toolbox containing a database of copious design suggestions that will reduce or eliminate the possibility of a safety hazard on the construction site. A similar but slightly more technologically advanced safety assessment tool was built by Dharmapalan (2011). According to Dharmapalan, the choice of construction material could impact the safety of a field worker. A web-based risk assessment tool was developed to improve a designer's understanding of the impact of material choice on workers.

2.3.2. QUALITY

Over the years, there have been different definitions as to what quality refers to in the construction industry. Quality in construction was defined by Latham (1994) as the value for money spent on a project, whereas Juran and Gryna (1993) defined quality as 'fitness for purpose'. The satisfaction of the client is closely linked to the quality of the project (Latham, 1996) considering that he/she is the main benefactor from a quality project. CII (1994) defined quality as "the means of meeting the requirements of all customers". Quality has been identified as a major project performance indicator due to its tangible and non-tangible impact on a project. As seen in Tables 2.3 and 2.4, quality is a reoccurring KPI in most countries, both at the project and company levels, and across different phases of a project. Its effect on project cost, client satisfaction, schedule, and worker safety makes it a huge concern to contractors and project owners. According to Burati et al. (1992), CII (2005), Hwang et al. (2009), and Joseph and Hammarlund (1999) "Quality" (1982), between 5% - 20% of a project cost is spent on rework. If this percentage is multiplied across the yearly gross investment in the construction industry for 2014, this would amount to $15 billion- $150 billion (US. Department of Commerce 2014; United States Census Bureau 2014; Worldbank 2015). Approximately 7% of a project's total work time is also lost to rework (Josephson and

Hammarlund 1999). Not only is the cost and time related to quality an issue, the regular occurrence of acts such as construction errors that lead to rework is alarming (Boukamp and Akinci 2004). Different factors, such as project type, choice of procurement system, safety culture and perception, organization and project practices, the transient, fragmented, and complex nature of the industry, lack of standardization, conforming to minimum quality assurance requirements, profit driven mindset, inadequate supervision, etc. have been identified by researchers as the reason for poor quality performance on a project (Hoonakker et al. 2011; Lopez and Love 2012; Love and Smith 2003).

Deviation from set requirements is one major cause of poor quality on a construction project. This cause accounts for approximately 12.4% of total project cost (Arditi and Gunaydin 1998). Quality deviation is the lack of conformance of a product or result to the planned outcome, specification, and requirements. Deviation constitutes changes to the requirements that result in rework and products that do not meet stated standards. To gain further insight on the origin of deviation, Burati (1992) investigated the causes of deviation on a project and came up with the causes shown in Table 2.7.

Table 2.7: Types of Deviation on a Project (Burati et al. 1992)

Type of Deviation	**Description**
Construction change	Change in the method of construction
Construction error	Error made during construction
Construction omission	Omission made during construction
Design change/improvement	Design revision, modifications, and improvements
Design change/construction	Design change initiated by construction

Design change/field	Design change required due to field conditions (e.g., lack of as-built)
Design change/owner	Design change initiated by the owner
Design change/process	Design change initiated by operations or process
Design change/fabrication	Design change initiated by the fabricator
Design change/unknown	Design change with an unknown source of initiation
Design error	Error made during design
Design omission	Omission made during design
Operability change	Change made to improve operability
Fabrication change	Change made during fabrication
Fabrication error	Error made during fabrication
Fabrication omission	Omission made during fabrication
Transportation change	Change made to method of transportation
Transpiration error	Error made in method of transportation
Transpiration omission	Omission made in transportation

Table 2.7 highlights that quality concerns could exist in all phases of a project. As a result of the high amount of rework connected to design fallibilities (Burati et al. 1992), Davey et al. (2006) suggest that defects could be reduced through design changes early in a project. In an attempt to curtail quality-related issues on a construction project, the total quality management (TQM) concept was adopted in the 1980s. According to Rounds and Chi (1985), the typical method of controlling quality in the construction industry could not meet the need of the growing complexity associated with modern construction. Quality is a continuous process that requires constant improvement. The Plan Do Check Act (PDCA) process was developed to ensure that the quality process was improved continually. This process was previously lacking in construction. Deffenbaugh (1993) stated that issues such as lack of teamwork, poor communication, and inadequate planning and scheduling, which were notorious quality quandaries, will be corrected if TQM is implemented on a project. TQM encourages cooperation which

significantly reduces schedule related issues and punchlist items. Furthermore, researchers (Graves 1993; Lester et al. 1992; Rounds and Chi 1985) argue that TQM reduces the cost of construction, improves a contractor's reputation, and increases client satisfaction.

Having the capacity to benchmark a company's current quality performance against a recognized standard could lead to improved quality. For this to be possible, it is important to determine measurable factors that give a good picture of a project's quality performance. To this effect, a study was carried out by Stevens (1996) on behalf of CII to determine what should be measured. Deviation to QC/QA plan, amount of rework, amount of rejects, number of non-conformance notices, number and value of changes, number of punchlist items by package and number of open punchlist items at turnover were highlighted as factors that could be measured to determine the quality performance of a project. This led to the development of a matrix rating system to assist project owners and contractors determine their quality performance on a project (Stevens 1996). Over the years, other tools for measuring quality such as the Performance Assessment Scoring System (PASS) (Coffey 2008), have been developed to improve the quality of construction project quality management.

Quality comes at a cost. This fee is a measure of costs explicitly related to the conformance or non-conformance to set project requirements (ASQC 1974). Cost of quality (COQ), which metamorphosed from 'cost of poor quality', was first discussed by Juran in 1951. This is the amount of money lost by a company as a result of nonconformance to specification and requirement of clients. According to Waje (2002), cost of quality could be anywhere between 15%-40% of the project cost. To further understand the cost of quality on projects, cost associated with quality is grouped into two components: proactive (prevention and appraisal cost) and reactive costs (cost due to internal and external failures) (Kazaz 2004). It is recommended that one of the ways of reducing the cost associated with defects and rework on a project is to increase the cost associated with prevention and appraisal (Brown and Kane 1984). The cost benefit of early detection of quality concerns is depicted in Figure 2.5.

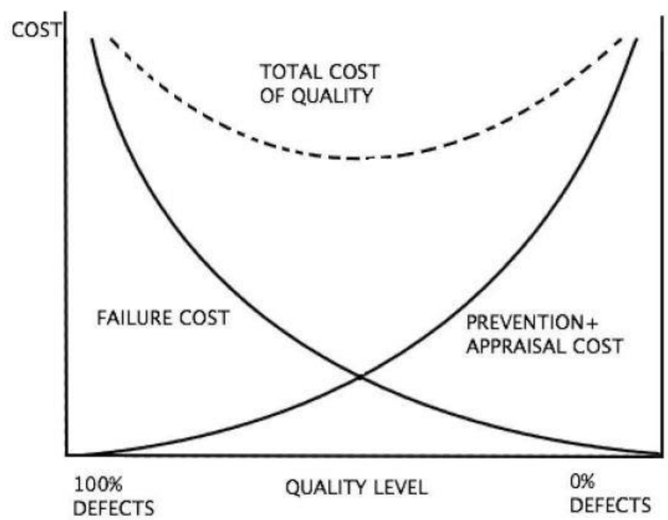


Figure 2.5: Cost of Quality (Brown and Kane 1984)

Parallel to Brown and Kanes (1984) findings, Roberts (1991) found that by spending 1% more on prevention efforts, the failure costs of construction can be reduced from 10% to 2%. Management personnel have a huge role to play in controlling quality. As seen in the TQM approach, premium quality could be achieved with a top-bottom approach. This approach requires a total buy-in of a company’s management. By doing so, the quality culture of a company will change and its impact felt on construction projects. To verify or quantify the improvement resulting from top-bottom quality approach, management staff is encouraged to periodically measure cost associated with quality. This measurement could also be seen as a project control tool that prevents or reduces quality related performance (Juran 1944).

2.4. RESEARCH GAP

As highlighted in the literature review, current project practices tend to favor measuring projects post-completion. Measuring lagging indicators could be a good way of improving performance on a corporate level. This means of project assessment gives a company an idea of what needs be done to improve delivery of the next project and improve company-based indices such as EMR. This benefit cannot be said about performance at the project level. Using just lagging indicators drastically reduces the advantages accrued to proactive management principles. The construction industry lacks a proven, simple-to-use method of predicting and assessing project performance. The extensive literature on how cost and schedule could be assessed and proactively controlled on a project is available within the built environment but little has been done to develop a tool for forecasting project performance, more specifically, the safety of construction workers and the quality of their work.

Research in construction safety has identified different factors that influence the productivity and, to some extent, the performance of construction workers at different levels. Notwithstanding this commendable progress, the lack of data on the collective conditions, factors and resources that impact workers both individually (at the construction worker level) and collectively (project level) creates a gap in construction safety literature. On the other hand, literature on quality as it concerns workers at different tiers is limited. This could be a result of how quality is widely measured: at the project level. Different factors influence the work quality of construction personnel. These factors mostly differ depending on worker level and personal characteristics. Considering the amount of money lost to quality related problems, it is paramount that different tools be developed that could work alongside the already tried and successful theories such as TQM to further drive down the cost associated with poor quality. To bridge this gap in literature, a new concept termed project "energy" takes into account an individual and collective approach in evaluating the impact of factors, conditions, and resources on the safety and work quality of construction personnel while in the process of discharging their duty. Chapter 3 consists of a detailed discussion of the energy concept and its relevance in the construction industry.

3. CHAPTER 3 - PROPOSED ENERGY THEORY

3.1. THE THERMODYNAMIC APPROACH

As mentioned previously, the lack of a substantial method of quantifying the impact of factors, resources, and conditions on the work quality and safety of a construction worker alongside the absence of a system-based approach for evaluating project performance is a major driver of this thesis. Thermodynamics, through the application of basic physics theories and concepts gives us an opportunity to achieve a system-driven methodology. Thermodynamics can be defined as "a branch of physics which deals with the energy and work of a system" (NASA 2014). This proposed methodology for forecasting and evaluating project performance takes a twofold approach. First, the performance of construction personnel at different levels is evaluated. The factors that affect the quality of work and safety of a worker are first analyzed at a "micro-level". This helps give an idea of the important conditions, resources, and factors that influence worker performance. Secondly, the interaction between work outputs of workers at different levels is assessed to determine the degree of impact that one work level has on another given the hierarchal nature of the construction industry. This can be referred to as "macro-level" assessment.

Derivatives of thermodynamics such as energy, power, and pressure are studied to help provide a means of understanding and quantifying the factors that impact worker safety and work quality. To conduct the study, thermodynamics and its derivatives (energy, power and pressure) are translated from their physical sense/form to the context of work operations on a construction site.

3.2. RELATING ENERGY TO CONSTRUCTION SITE OPERATIONS

Different sources and authors define energy in slightly different ways. Some definitions can be found below:

I. Ability to do work (Farabee 2000; Dictionary.com).
II. The ability to make something happen (Watson 2015).
III. Energy is the capacity to produce an effect or exert power (Yourdictionary.com).
IV. Energy is the ability to bring about change or to do work (BusinessDictionary.com).
V. "A fundamental entity of nature that is transferred between parts of a system in the production of physical change within the system and usually regarded as the capacity for doing work"(Merriam- Webster.com).

Considering these definitions, we can define energy as the **ability** to bring about change through performing **work**. It is noteworthy to define "work" seeing that it was repeated in most of the definitions of energy. Work can simply be defined as the process of energy transfer (Edinformatics.com).

In the construction industry, work is defined (in the context of erecting structures) as:

I. "the construction or erection of a building or structure that is or is to be fixed to the ground and wholly or partially fabricated on-site
II. any preliminary site preparation work (including pile driving) for the construction or erection of any such building or structure
III. the alteration, maintenance, repair or demolition of any building or structure

IV. *the laying of pipes and other prefabricated materials in the ground, and any associated excavation work”*

(cbserv.com)

Since work in construction can be summarized as the planning, erecting, maintenance, and demolition of structures, the ability to carry out this “work” has to be defined. After conducting a comprehensive review of available literature on related topics, the definition of “ability” used in this research is: the **factors**, **conditions**, **resources** and **activities** needed to perform “work”.

Therefore, for the purpose of this research, *ENERGY* can be defined as: the factors, conditions, and resources that aid in the planning, erecting, maintain and demolishing of a structure.

Energy as a physical phenomenon can be recognized in different forms. Some common forms of energy are chemical, mechanical, electrical, solar, magnetic thermal, heat, kinetic, potential, etc. (New Mexico Solar Energy Association 2014). So far, no limits have been set to the physical forms of energy due to the possibility of discovering a new phenomenon that violates the law of energy conservation thereby birthing a new form of energy. After closer observation of properties of the given forms of energy, physical scientists recommend that the different forms of energy could be divided into two major types: Potential Energy (PE) and Kinetic Energy (KE) (Watson 2014; US Energy Information Administration 2014). It is believed that the other forms of energy are merely different expressions of kinetic and potential energy (Watson 2014). To this effect, the present research focuses on energy through the lenses of having two extensions: Kinetic and Potential.

3.2.1. KINETIC ENERGY (KE)

Different definitions, although similar, have been recommended for KE. Some definitions of this type of energy are provided below:

I. The energy possessed by a system or object as a result of its motion. The kinetic energy of objects with mass is dependent upon the velocity and mass of the object (ahdictionary.com).
II. The energy of motion of a body, equal to the work it would do if it were brought to rest. The translational kinetic energy depends on motion through space, and for a rigid body of constant mass is equal to the product of half the mass times the square of the speed (collinsdictionary.com).
III. Kinetic energy is energy of motion. The kinetic energy of an object is the energy it possesses because of its motion (Nave 2014).

Taking the above listed definitions into context, kinetic energy can be summarized as the energy of a body with respect to its motion. This is represented mathematically as shown in Equation 1.

$$KE = 0.5mv^2 \qquad \text{(Eqn. 3.1)}$$

In Equation 3.1, *m* is the mass of the object in motion and v is its speed or velocity. Energy (both kinetic and potential) is measured in joules, which is mathematically represented with the units shown in Equation 2.

$$kg(m/s)^2 \qquad \text{(Eqn. 3.2)}$$

In construction, KE can be viewed as the work done in executing a task. The objective of a construction project, as also witnessed in other projects, is a product of the sum total of tasks carried out within the parameters set forth in a construction plan. A wide variety of tasks are required to achieve the objective of a construction project. A task is constrained by different factors that could either enhance or impede the ability of a worker to effectively undertake it. Through prior comprehensive research, task-specific factors adjudged to have considerable influence on worker output were discovered (Antunes and Gonzalez 2015; Frimpong et al. 2003). Below is a list of the findings:

I. Complexity of task- The mental and physical demand associated with an assignment differs from task to task. Complexity of a task takes the variance into account. A task is considered to be complex if it places a considerable mental and physical demand on the construction employee.

II. Predictability of task – Given that nature of the construction industry is uncertain, project managers developed methodologies to help streamline processes in construction operations. Notwithstanding the methodologies, variation associated with predictability still exists from task to task.

III. Uniqueness of task- As the construction industry shifts from regular constructions to more sophisticated structures, it is invariable that some tasks required to produce such a structure will be unique. It is likely that some construction employees will lack previous experience executing such a project. This can have some degree of impact on construction employee’s performance.

IV. Repetitiveness of task- If a task is required to be executed often by a construction staff, it is likely that the performance of the worker will be different if compared to an activity that is carried out infrequently. This could be as a result of familiarity (learning curve) developed over time.

V. Availability of needed resources- For the objectives of a project to be accomplished, resources have to be harnessed, controlled, and managed. Similarly, the execution of an activity or task requires the deployment of certain resources. This could be in form of men, machine, methods, material or/and money (BusinessDictionary).

The presence of some of these factors enhances the possibility of completion of the task with little or no trouble whereas other factors impede a worker's ability to carry out the task effectively. The relationship of the factors is summarized in Equation 3:

$$NT = \frac{(\text{Complexity})(\text{Uniqueness})}{(\text{Predictability})(\text{Repetitiveness})(\text{Availability of needed resources})} \quad \text{(Eqn. 3.3)}$$

Equation 3.3 is structured based on the relationship between each factor. An increase in complexity and uniqueness is hypothesized to have a negative impact on workers whereas increase in predictability, repetitiveness, and availability of resources should aid workers performance. All these factors fall within the nature of a task (NT) which represents "work" that has to be carried out. From a thermodynamics perspective, NT could be likened to the mass (m) of an object given that work is done when mass is in motion. Kinetic energy represents "work being done" which connotes the presence of an "active" element (velocity or speed). For work in construction to be considered "active", some level of task execution is required. Task execution can be viewed as the conversion of resources into a value adding output which could be a service or a product. "Resources could be defined as an economic or productive factor required to accomplish an activity, or as means to undertake an enterprise and achieve a desired outcome. To determine if a task is considered a "High Risk" activity, NT_{min} and NT_{max} will be calculated using Equations 3.4 and 3.5.

$$NT_{max} = \frac{(\text{Complexity}_{\text{max}})(\text{Uniqueness}_{\text{max}})}{(\text{Predictability}_{\text{min}})(\text{Repetitiveness}_{\text{min}})(\text{Availability of needed resources}_{\text{min}})} \quad \text{(Eqn. 3.4)}$$

$$NT_{min} = \frac{(\text{Complexity}_{\text{min}})(\text{Uniqueness}_{\text{min}})}{(\text{Predictability}_{\text{max}})(\text{Repetitiveness}_{\text{max}})(\text{Availability of needed resources}_{\text{max}})} \quad \text{(Eqn. 3.5)}$$

Values of NT that are closer to zero indicate that the task is low risk and the energy associated with same is low. This would be an ideal situation but is hardly possible due to the complex, unpredictable, and unique nature of the construction industry. How to estimate the minimum and maximum value of each constituent of energy will be discussed at length in Chapter 6.

Influencing peripherals are not just synonymous with the nature of the task. They are also observed when executing these tasks. The pace of work is an important factor that drives work execution. Pace of work, which can be seen as time taken to get a specified amount of work done (e.g., feet per hour) is analogous (concomitant) to productivity, a monumental consideration for any project. Each activity requires a certain amount of time to be completed. Time, as a project constraint, plays an important role in the delivery of a project. These definitions reveal the presence of an inverse relationship between pace of work and time required to do that work. In most cases, increasing pace of work results in decreased time spent on a task, and vice versa. Work done on a product is typically viewed in dollar value ($/hr). The following constituents are considered to be relevant elements that sway the pace of work:

I. *Crowding* - A construction site is considered to be crowded at a given point in time when different trades and crews are required to work on the same project within a stipulated timeframe. Other constraints such as size and location of the project are factors that could increase or decrease crowding. Crowding could be perceived differently across employee levels. A project manager may not necessarily consider having a large number of craftsmen consisting of different trades on a site to be a crowding problem. To him/her, crowding with regards to job function could be running multiple projects at the same time, having to attend to a large amount of paperwork and meetings, dealing with a considerable amount of stakeholders, etc.

II. *Interruption* - This is the when a worker has to stop work while on the job to attend to other issues related to the project. The other issues could be internal (to solve a problem that is required for the completion of the assigned task) or external (to attend to other workers' needs). Factors such as inexperienced crew, poor quality of construction drawings, availability of material/equipment, high number of overlapping work activities, slow response to RFIs, and poor quality of instruction increase the level of interruption.

III. *Distraction* - This factor is a major productivity driver. In our everyday work, distractions are a huge factor that impairs our output. Extensive studies have been carried out on the effect of distractions on worker safety. Prior research led to the creation of a safety theory known as the Distractions Theory. “Distraction theory states that safety is situational. Because mental distraction varies in nature, the responses to those distractions may have to differ for safe performance to result” (Jimmie Hinze 2006, 20). To this effect, factors such as adverse weather conditions, safety attitude/culture, location of project, excessive pressure, poor working relationship with co-workers, poor communication, work schedule, etc. are considered to be constituents of distraction of a construction worker.

IV. *Switching between tasks* - There is a considerable impact on the performance of a worker who is required to alternate between assigned tasks. Excessive switching causes loss of time which affects productivity, thereby creating a negative impact on a project. Tasks should be adequately distributed to capable personnel to reduce regular switching of workers between tasks and trades. This will reduce the amount of time a worker will spend idle or between tasks, thereby improving productivity.

Execution of the tasks (ET) can therefore be represented mathematically as shown in Equation 3.6.

$$ET= (pace)[(crowding)(interrruptions)(distractions)(switching\ between\ tasks\ )] \qquad \text{(Eqn. 3.6)}$$

Having created a construction representation of the physical form of energy known as kinetic energy, we can summarize the work needed to perform task as shown in Equation 3.7.

$$KE = \left[\sum_{i=1}^{n}(Nature\ of\ task)\right](Execution\ of\ the\ tasks) \qquad \text{(Eqn. 3.7)}$$

Summing from 1 to the nth task was introduced to the equation to account for the possibility of a worker executing more than one task.

3.2.2. POTENTIAL ENERGY

The static form of energy, referred to as potential energy can be defined as:

- The energy of a body or a system with respect to the position of the body or the arrangement of the particles of the system (Dictionary.com).
- The energy of a body or system as a result of its position in an electric, magnetic, or gravitational field (Collins English dictionary).
- The energy that exists in a body as a result of its position or condition rather than of its motion (Dictionary.com, Medical dictionary).

As a physical property, potential energy (PE) is made up three components namely mass, gravity, and height. These components are multiplied to derive the potential energy of an object. Potential energy is seen more as a passive energy due to its ability to remain inactive resulting from lack of motion. The potential energy of an object is dependent on the weight (mass*acceleration due to gravity) of the object and its distance from the earth as shown in Equation 3.8.

$$PE = mgh \qquad \text{(Eqn. 3.8)}$$

This energy can be witnessed in an apple hanging on a tree. The apple is not in motion but has the ability to do work as a result of its weight and distance from the ground. PE is transformed into KE when the apple begins falling to the ground.

From a construction operation perspective, potential energy is perceived as the effect of work (task) that has been assigned but is yet to be executed by construction personnel. High potential energy could increase the pressure on a worker leading to possible low performance.

Two elements have been identified as high-level components that determine the potential energy felt by construction personnel on a project. These energy constituents are: (i) number and nature of tasks scheduled to be carried out by a worker, and (ii) burden associated with completing the undone assigned tasks. Mirroring the physical formula for calculating potential energy (m*g*h), the impact of the number and nature of tasks to be carried out is a constant, therefore having the same characteristics as NT of KE. To determine the value of the second component which is demand to complete all tasks (DCT) (the equivalent of the multiple of gravity and height in the formula for PE), two factors are considered to have considerable influence on the level of stress felt by the worker. The two factors are as follows:

I. Time to complete all tasks:

Each activity requires a certain amount of time to be completed. As mentioned previously, time is a major project constraint that plays an important role in project delivery. If an assigned task has a time requirement or is required to be done in order for other activities to take place, it is likely that the worker will be under some degree of stress to complete the task in hand to enable him/her to move to the next task. Stress induced by undone assigned tasks is not only limited to critical activities. Stress could also be generated by the number of tasks a worker has to finish within a given period of time. As seen in the adjustment stress theorem, safe performance of a worker is compromised due to working conditions that distract a worker. It goes further to say "unusual, negative, distracting stress placed on workers increases their liability for accidents or other low quality behavior" (Jimmie Hinze 2006, 18).

II. Value of tasks

All tasks on a construction project have a dollar value which is derived through quantifying the amount of work to be done, the complexity, uniqueness, and required manpower. Whereas cost of an activity could be relatively constant in the construction industry, the value of a task could differ. A task could have an intrinsic high value on one project and not necessarily be of any value on another project. Likewise, a task on the critical path of a big dollar value project will have more relative value than that on a smaller project. In this regard, it is believed that the bigger the dollar value and complexity of a project, the more demand placed on a worker to complete the assigned tasks.

Apart from the two factors highlighted above, the time between an ongoing activity and the time remaining before the deadline of a scheduled activity that is yet to commence could also impact the energy felt by a construction personnel. If a construction project engineer is currently running the excavation of a twelve story building project in a densely populated location (see Figure 3.1), the logistics involved in coordinating activities such as formwork erection, concrete pouring, installation of steel frame, etc., will be a source of added pressure. As the inevitable activity approaches, there is a sense of anxiety (apprehension) felt by the construction worker. To account for this state of mind, Equation 3.9 was derived. This occurrence will be referred to as the demand factor (DF).

$$DF = 1 + \frac{\text{Duration of task}}{Time\ reamining\ before\ deadline} \qquad \text{(Eqn. 3.9)}$$

A project based example of the application of DF is given below:

$$DF = 1 + \frac{\text{20 days}}{32\ days} = 1.65$$

This example illustrates a hypothetical situation where an upcoming activity has duration of 20 days and is scheduled to be completed within the next 32 days meaning it has to begin within the next 12 days. As the deadline to complete a scheduled task approaches, the value of DF increases which corresponds with the example stated above. It is important to note that the value of DF also depends on the importance of the upcoming task. When the duration of the task is very short relative to the time remaining before it needs to be completed, DF approaches 1.0 (i.e., no impact). Values of DF greater than 2.0 indicate that the task cannot be completed as planned within the time remaining, a condition that would lead to extensive pressure on the worker.

Figure 3.1: Densely Populated Construction Site (source: http://www.balfourbeatty.com/)

A bigger value of DF will lead to a larger potential energy. The degree of demand of assigned tasks could theoretically increase or reduce the value of the potential energy. The Demand to complete all tasks (DCT) is directly proportional to the finance provided to complete all tasks (value of all tasks) and inversely proportional to the time required to complete all assigned tasks which can be expressed as illustrated in Equation 3.10. The value DF, which is extracted from the construction project schedule, is then multiplied by DCT.

$$DCT = \left[\frac{\text{Value of tasks}}{\text{Time to complete all tasks}}\right](DF) \quad \text{(Eqn. 3.10)}$$

Therefore, PE in terms of construction operations can be derived as shown in Equation 3.11.

$$PE = [\sum_{i=1}^{n}(Nature\ of\ task)](Demand\ to\ complete\ all\ tasks) \quad \text{(Eqn. 3.11)}$$

3.2.3. UNIT OF ENERGY

All forms of energy have a uniform unit of measurement. Joules is the common unit used for determining the rate of work done. Joules which is equivalent to newton-meter can be expressed as seen in Equation 3.12.

$$Energy = \left[\frac{\text{Kilogram}*\text{Meter}^2}{\text{Second}^2}\right] \quad \text{(Eqn. 3.12)}$$

Seeing that the unit for measuring the physical form of energy used in the current study (kinetic and potential) is given in Equation 3.12, a construction operation equivalent is required.

UNIT OF KINETIC AND POTENTIAL ENERGY

The proposed Equation for kinetic energy includes “pace of work” which is equivalent to the amount of work done (in dollar value) over a given amount of time. Similar to that, potential energy within its construction definition is determined by the value of a task over duration assigned to complete that task. Although the compositions of these two types of energy are distinctively different, they both have “work done over a given time” as constants. Therefore, the proposed unit for measuring energy in construction operation is expressed as seen in Equation 3.13:

$$Energy = \left[\frac{\text{Task \$}}{\text{Time to complete task}}\right] \qquad \text{(Eqn. 3.13)}$$

Where value of task will be in dollars ($) and time in hours (hrs)

To further ascertain the viability of using energy as a basis to create a new methodology for controlling safety and quality, the laws of thermodynamics will be analyzed to verify whether the construction operation process fits within the theories. Currently, there are four laws of thermodynamics out of which two are widely quoted. The present research study will focus its attention on the first and second laws of thermodynamics.

3.3. FIRST LAW OF THERMODYNAMICS

The National Aeronautics and Space Administration (NASA) defines the first law of thermodynamics, which is an adaptation of the law of conservation of energy, as a condition where the change in internal energy of a system is equal to the heat added to the system minus the work done by the system.

3.3.1. CONSERVATION OF ENERGY

The law of conservation of energy states that the total energy of an isolated system is always conserved; it can neither be created nor destroyed. In essence, energy can only be converted from one form into another (NASA 2014).

In a construction operation, energy is not created but transferred from one level to another (i.e., converted from one form to another). The worker who erects the formwork is not creating new energy. The field worker is only carrying out instruction (energy) passed down by the foreman who has developed a schedule of activities needed to carry out that task. On the other hand, the foreman takes part in this loop of energy transfer by getting specifications and details from the superintendent, who in turn receives project resources from the project manager who is paid by the client. Therefore, in an ideal situation, the sum of all energy within the tiers of the construction system should be equal to the project owner's energy (finance and project objective). This structure shows a clear transfer of energy as previously defined. Thus energy is not created nor destroyed. Figure 3.2 typifies the process of change in energy through the system. The figure shows the presence of a relationship between different tiers of employee and client.

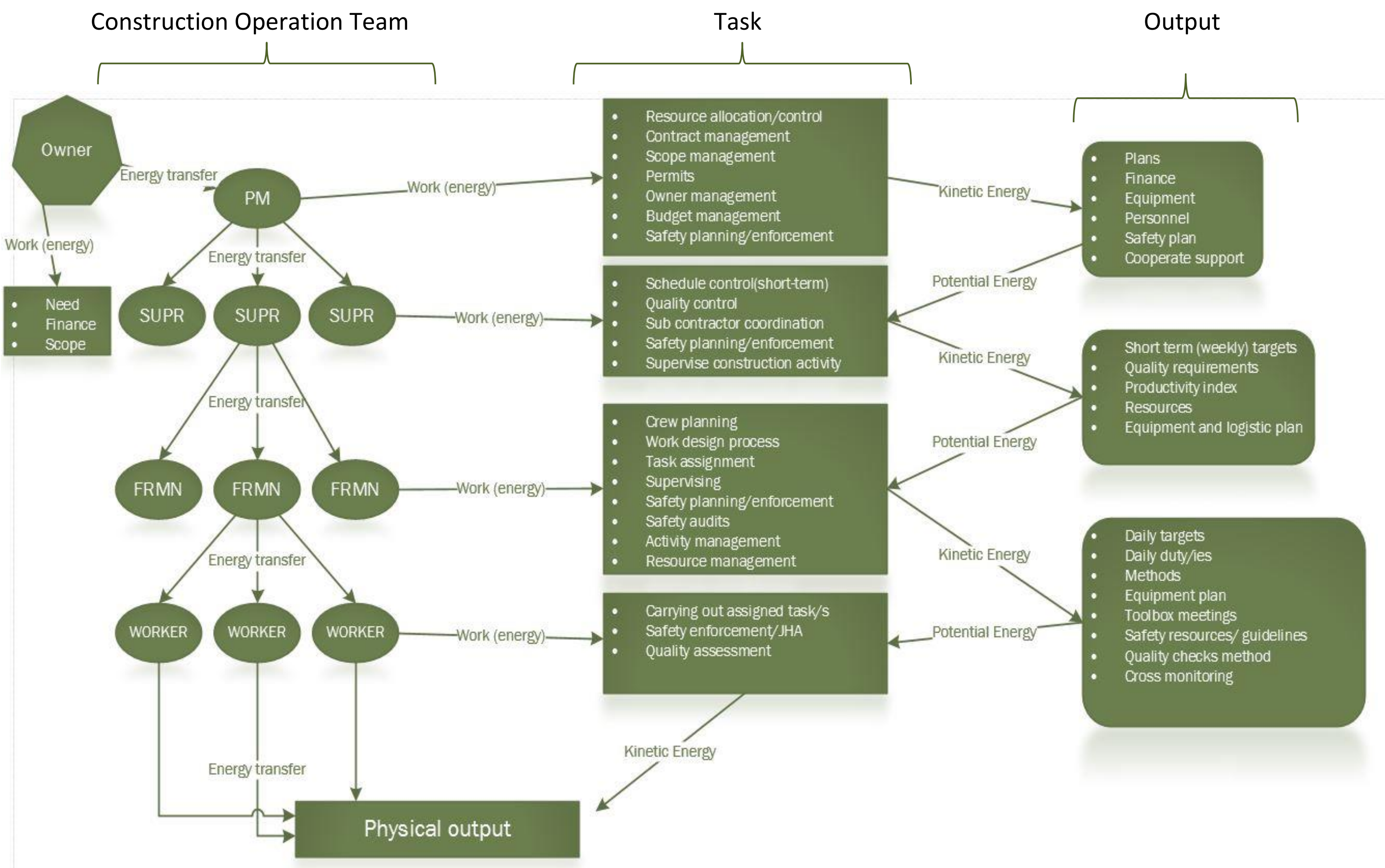


Figure 3.2: Example of Energy Transfer within a Construction Operation

3.4. SECOND LAW OF THERMODYNAMICS

The second Law of thermodynamics can be stated in different ways. Three ways of stating this theory are listed below:

i) "In all energy exchanges, if no energy enters or leaves the system, the potential energy of the state will always be less than that of the initial state." This is also commonly referred to as entropy. Entropy is the measure of disorder and tends to increase in a system that is isolated.

ii) The ability of a heat engine to convert heat to work (fuel to work) is below 100%. Some amount of inefficiency is present thereby leading to a degree of waste.

iii) Heat tends to naturally flow from a region of higher temperature to a lower temperature. To reverse this process, an external energy source is required (NASA 2014; Nave 2012).

A steam engine while converting fuel to useful energy will lose some fuel to the atmosphere. The amount of fuel lost to the environment determines the degree of efficiency of the engine. Over the years, mechanical engineers have dabbled with different methodologies on how to best improve efficiency of this timeworn process. This effort has led to considerable reduction of waste and significant improvement of engine efficiency which now ranges from 92-98% (Harvey 2013; Smith et al. 1997). Similarly, construction witnesses the same problem with regards to project performance. The finance (equivalent of fuel) committed to a project is not spent totally on value added activities. Some funds go towards things like rework, replacement, worker compensation, medical bills, fines, etc. In the eyes of a mechanical process, this could be seen as “system waste”. Mechanical engineers have found a process of fine tuning the engine system to run better thereby reducing waste. In construction, improving safety and quality performance could amount to a significant increase in efficiency of a project delivery which, from a client’s perspective, translates into better value for money spent.

Entropy, which can be defined as the degree of disorder within a system (Jessica 2010), plays a major role in an isolated system. An isolated system is one that remains closed and has no interaction with its surroundings. There is no transfer of heat (energy) between the system and its environment, thereby leading to gradual decrease in the capacity to do work within the system (NMSEA 2014). When ice melts in a warm environment, it is simply seeking equilibrium with areas of lower pressure, therefore displaying entropy.

This phenomenon can also be witnessed in a construction operation. If the project owner’s ability to fund a project is curtailed, there will be a cascading effect on construction operations. The work assigned across the tiers will gradually reduce, leading to project stagnation, increased cost, delay in schedule, and possible lawsuits. A typical example of the effect of an isolated system in construction is as follows:

> A project manager produces the plans, schedule, and resources for a section of the project which should last for 28 days and hands it over to the

superintendent. The superintendent generates short term targets and logistic plans, and assigns appropriate resources. This information is then passed down to the foreman who runs his crew using the provided information. If the finance for the project is cut, the foreman will have passed down all the work he was assigned from upstream to the field workers and have little or nothing on his table. This situation is consistent with the second law of thermodynamics, and is illustrated in Figure 3.3.

The third statement on the second law of thermodynamics overlaps with the explanation and example postulated for entropy.

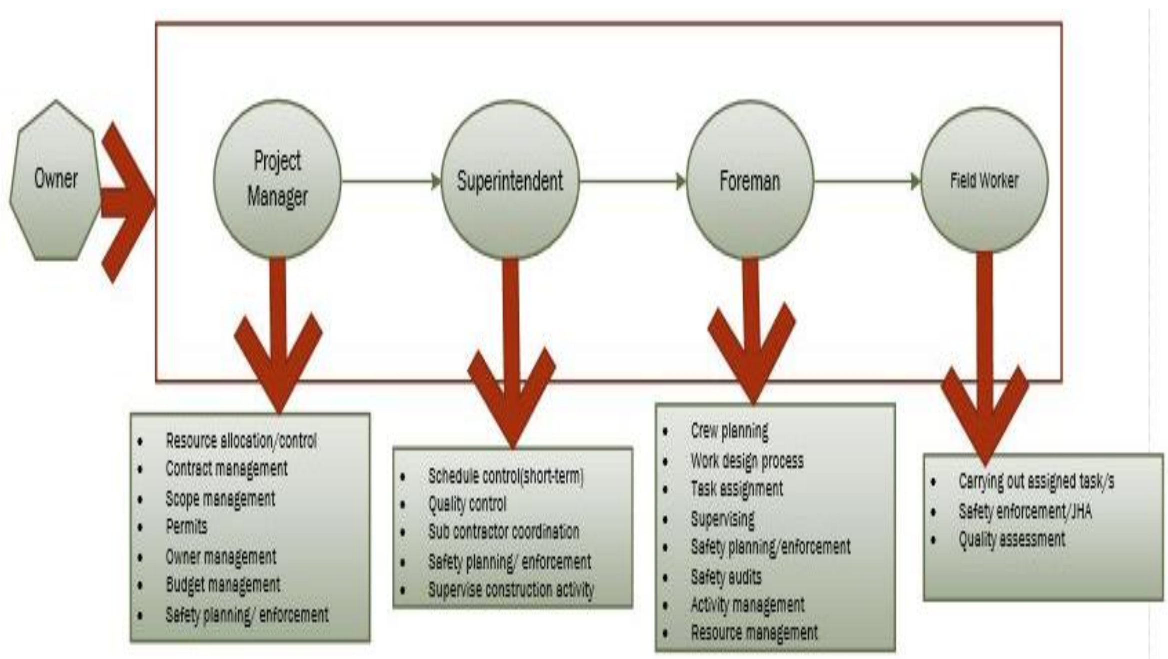


Figure 3.3: Example of an Isolated Construction Process

3.5. CONSTRUCTION OPERATION PERSPECTIVE

Energy and its constituents vary at different levels of a construction project. This variance is due to the anatomy of the "work" component of the energy concept. As defined earlier, work is the planning, erecting, maintenance, and demolition of structures. The construction production process is a hierarchical system comprised of different features which, when put in motion, produces an end result that meets a goal (building, bridges, etc.).

This process is similar to that of a car engine which is tasked with producing enough power to rotate the car wheels. To meet its set objective, the crankshaft has to transfer the required power to the wheel. For this function to be performed, the piston has to compress a mixture of air and fuel in the cylinder to generate enough power and efficiency. The fuel injector, spark plug, valves, connecting rod, timing belt, camshaft, cam gear, etc. have to work together in a particular (pre-determined) sequence to ensure that the crankshaft gets the required efficiency and power to drive the car. As seen in this example, different elements (piston, cylinder, shaft, etc.) use different resources (fuel, air, etc.) to achieve the set objective which is to make the car move.

For a construction operation, different resources at different tiers are synchronized in a hierarchical manner to ensure the delivery of a project. Construction is made up of different tiers but for this research, the levels are broken down into five perspectives, namely: (i) owner's representative, (ii) project manager and project engineer, (iii) superintendent, (iv) foreman, and (v) field worker. For energy transfer, it is assumed that the difference between the potential energy felt by a worker and the kinetic energy of that employee is the potential energy of the employee at the next level below. All energy combined would be the system energy; no energy lost, none gained (in a perfect system although we witness waste in construction which reduces the final energy produced similar to lost energy in an engine due to inefficiency of the process). The system energy arises because of the mutual forces between bodies in the system; 'One's kinetic energy leads to another's potential energy'. Since the work done at each level differs, it is expected that the factors, conditions, and resources that impact their performance varies, therefore energy should be evaluated and measured differently at each level.

3.6. PRESSURE

Pressure can be defined as the following:

I. The continuous physical force exerted on or against an object by something in contact with it (oxforddictionaries.com).
II. Force per unit area (Nave 2014).
III. Force that is put on a surface with reference to the area of the surface (dictionary.cambridge.org).
IV. The ratio of force applied per area covered (physics.info.com).
V. A measure of energy per unit volume (in liquids) (Nave 2014).

Pressure, which is measured in Pascals, is equal to force per unit area as shown in Equation 3.14 or equal to energy per unit volume in liquid (Nave 2014).

$$Pressure = \frac{\text{Force}}{\text{Area}} \qquad \text{(Eqn. 14)}$$

As seen with a sharp knife, the smaller the area, the larger the pressure created. In liquids, pressure comes from collisions of gas particles, and these particles collide more often in a gas with higher internal energy. The higher the energy per unit volume and the more collisions present, the higher the gas pressure.

In the present research, pressure has to do with the effect of the construction location, size, and type on the number of crews, trades, and equipment present within a particular time (interaction between both groups - physical limitations and project resources). The amount of pressure felt by a worker is relative to the constraints of the project being undertaken. For example, the pressure transferred to a surface by a rectangular block is different depending on which side (orientation) of the block is in contact with the surface. In the same vane, two craftsmen doing identical work on two different construction sites could have different "pressure" depending on the projects' constraints. For example, one craftsman could have an apprentice assisting him/her while another has no apprentice but is required to do the same work within a shorter time due to an accelerated schedule. This condition significantly increases the pressure on one craftsman irrespective of the assigned task being similar. Therefore,

I. Force = work (uniqueness, complexity, etc.)
II. Area = Available time, space (location), and resources

In a good number of physical situations, pressure is considered a key factor. In situations that deal with two surfaces, pressure becomes important due to its ability to severely alter the outcome. When peeling a piece of fruit with an object (e.g., knife) the amount of force applied to generate the pressure required to produce a change on the fruit (e.g., apple) is dependent on how sharp the incising object is (area of the object). A sharper knife (smaller area) will require less force and less contact area to produce enough pressure to achieve a result. The same applies to cleaning a stain with a mop with and without a stain remover, walking on high heel shoes, etc. In that same vane, increasing the force (number of tasks, complexity, etc.) and reducing the area (available time, space and resources) will cause a significant increase in work pressure.

In some cases, applying more pressure reduces the time spent on a task. Going back to the example of the apple, by using an instrument with a small area, the pressure being applied on the apple is increased. The productivity could be measured based on the least possible force required to bring about the change we want (dicing of the apple). Having that in mind, the productivity could be increased by increasing the pressure being applied. On the downside, if exorbitant force is applied on a very sharp knife, the pressure on the apple escalates and if not timed properly could lead to a cut on the wrist or scratch on a table. In construction, increasing the number of crews, overlapping activities, working longer hours, and working under adverse weather conditions could in some cases increase productivity. But as detailed in a study by (Nepal et al. 2006), there is a point at which making these changes becomes counterproductive. Project performance could suffer greatly along the lines of quality and safety if workers are pushed too hard to meet the company and project owner's targets. This demand on workers heightens the energy felt by each personnel which, in the absence of relevant controls, could lead to substantial additional cost. The present research lays the foundation for measuring the pressure associated with construction operations.

3.7. POWER

As with pressure and energy, different definitions of power have been put forward. Some interesting definitions are found below:

I. The rate at which work is performed or energy is converted (Cutnell 2012).
II. The measure of the rate at which work is done (Engineeringtoolbox.com).
III. The rate at which work is done upon an object (Physicsclassroom.com).
IV. The average amount of work done or energy converted per unit of time (Cutnell 2012).
V. Equivalent to an amount of energy consumed per unit time (Halliday et al. 2013).

If change in work (Δwork) is the amount of work performed during a period of time (Δtime), the average power (Power avg) over that period is given by Equation 15:

$$Power_{avg} = \frac{\Delta\text{Work}}{\Delta\text{Time}} \qquad \text{(Eqn. 3.15)}$$

Whenever the magnitude of energy is changing, power is present. Power tells us how fast energy is increasing or decreasing. A practical example is given below to further buttress the relationship between power and energy.

Ten boxes weighing 20 lbs each need to be moved to a location 200 meters away. The work involved in this operation is lifting and moving the boxes to the new location. The power is the change in PE of the boxes divided by the time taken to move all ten boxes to the new location. To get this work completed faster, more people could be employed to move the boxes, or better still use a truck! Power is measured in watts, but can also be measured in horsepower, btu, joules, etc. Figure 3.4 represents energy level on a project over a one year period.

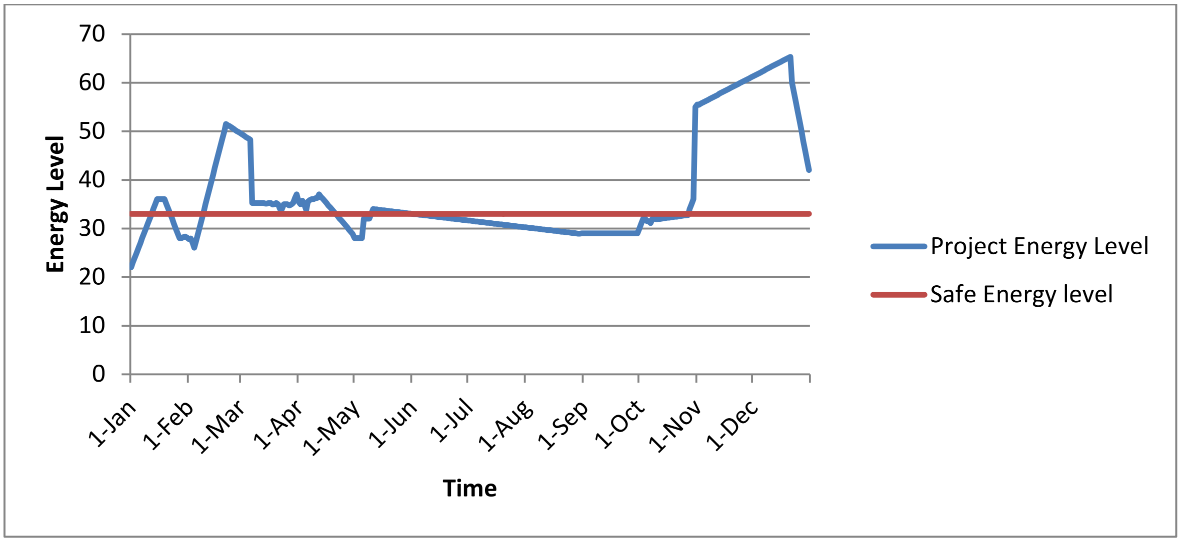


Figure 3.4: Example of Effect of Power relative to Energy on a Project

Power as defined by Cutnell (2012) is the rate at which work is done. For work to be done, energy is required. For the purposes of this research, power is defined as the rate of change in “energy” with respect to time (ability to do work over time).

The rate at which an activity or phase in a project is completed is the power associated with the activity or phase. If a project is accelerated, the power would increase. To accelerate a project, more work is required to be done within the same timeframe or reduced timeframe. This result could be achieved by having longer work hours, more work days, overlapping of activities, infusion of more workers, etc. Such a situation could have an overreaching effect on project performance. Exponential increase in power, while having its schedule benefits, is likely to come at a cost. The added cost could be associated with safety and quality. A cost-benefit analysis of increasing power on a project proactively or reactively should be looked into in future research as well as determining the maximum allowable power on a project. Figure 3.4 shows a hypothetical model of energy level on a construction project. A considerable amount of power is witnessed between February and March, and November and December. As mentioned earlier, these drastic changes come with some side effects.

3.8. SUMMARY

In this chapter, the thermodynamic concept and its derivatives were introduced. The ability of a construction operation to conform to the accepted definitions, formulas, and units was extensively discussed. In all, this chapter confirms that it is indeed possible to develop a system-based model for predicting and evaluating construction project performance with emphasis on safety and quality using thermodynamics. The next chapter will discuss the methodology for data collection and how energy components and constituents will be assessed.

4. CHAPTER 4 - RESEARCH METHODOLOGY

4.1. INTRODUCTION

One key objective of this research is to determine the factors that affect performance of construction workers with emphasis on work quality and personnel safety. Also, the presence of energy on a project is then determined through cumulative correlation of factors deemed to impact project performance. If energy is noted as present on a construction project, a method for quantifying the phenomenon is developed using Equations derived in Chapter 3.

4.2. RESEARCH DESIGN

To enhance the understanding and comprehension of the research methods and processes, a concise description of the research design is presented in this chapter. The general hypothesis behind the research is discussed and the research process described. Flow charts were developed and used to illustrate the steps, participants, processes, secondary processes, outcomes, and phases. These flow charts created a road map towards achieving the research objectives which included confirming the presence of energy through identifying factors that constitute energy while also discerning the impact of these variables on work quality and worker safety. Alongside ascertaining the presence of energy on a construction project, a description of how energy can be measured is introduced and discussed in detail. Finally, a process for measuring energy using the results of analysis on retrieved data is proposed. To achieve these objectives, the process set forth in Figure 4.1 was deemed appropriate.

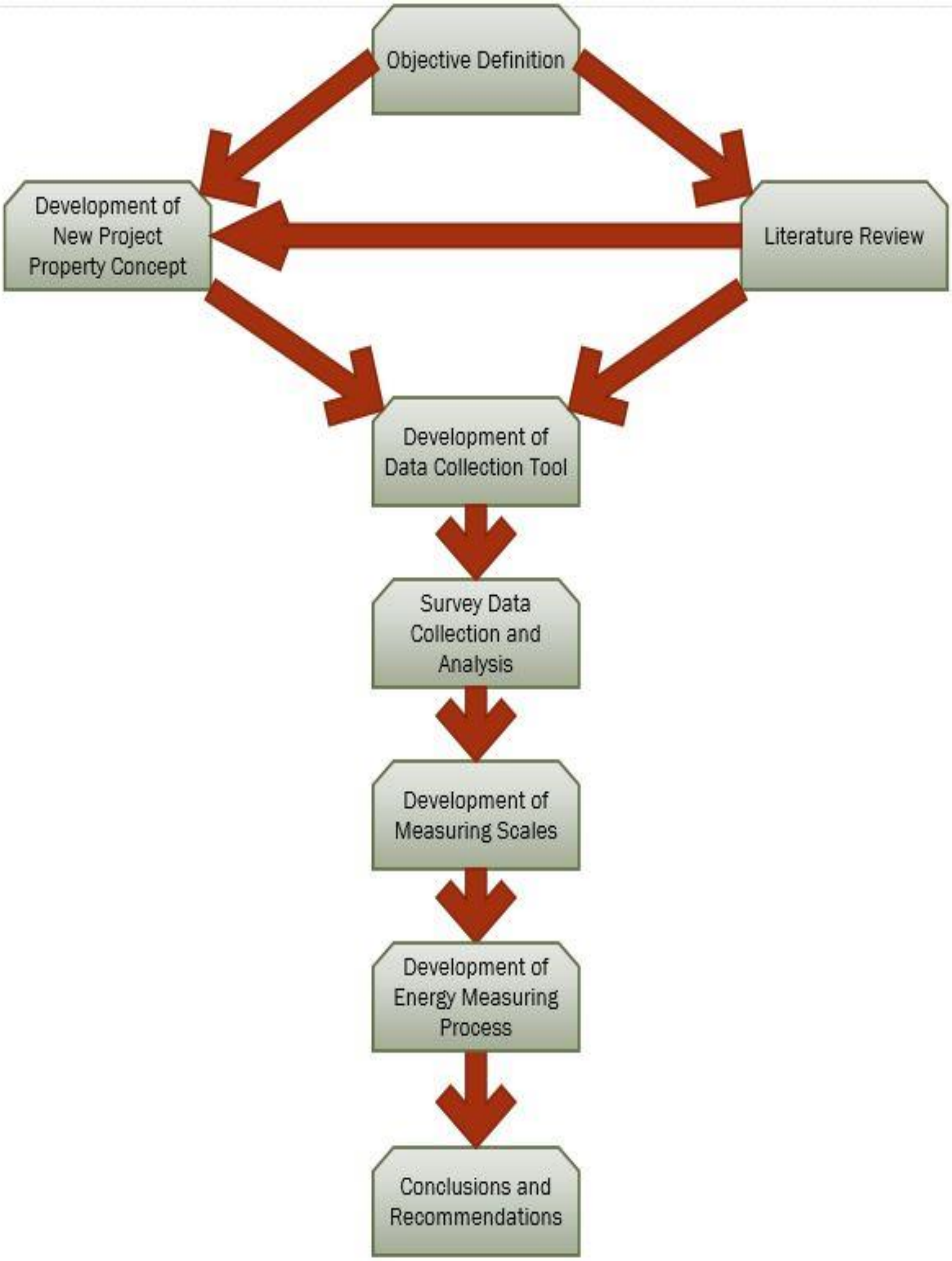


Figure 4.1: Research Process

4.3. GENERAL HYPOTHESIS

For this research, it is assumed that increase in energy level will correlate with a negative impact on work quality and worker safety. The null hypothesis of this study is that there is no change in impact on an employee's performance if energy is increased.

4.4. METHODOLOGY

To successfully achieve the research objectives, a mixed methodology with quantitative and qualitative properties was adopted. Although lacking in flexibility (Thomas 2003), a quantitative method of research is used in this thesis given the objectives of this study, the structure of the research, and the need to reduce the level of bias which improves the quality of the statistical analysis (Bryman 1984; Creswell 2013; Jick 1979). The procedures used for this study include:

I. Identifying variables that impact work quality and worker safety.

II. Developing an efficient survey to gather data.

III. Collecting quantitative data.

IV. Performing statistical analyses to develop metrics/scales for constituents of energy that impact potential and kinetic energy.

4.5. DATA COLLECTION AND ANALYSIS APPROACH

Establishing the presence of energy associated with a construction project operation is a primary task in this study. To achieve this goal, factors, conditions, and resources were identified by the research team after which a survey was created to confirm the presence of energy and its impact on worker performance. Figure 4.2 sums up the data collection and analysis processes.

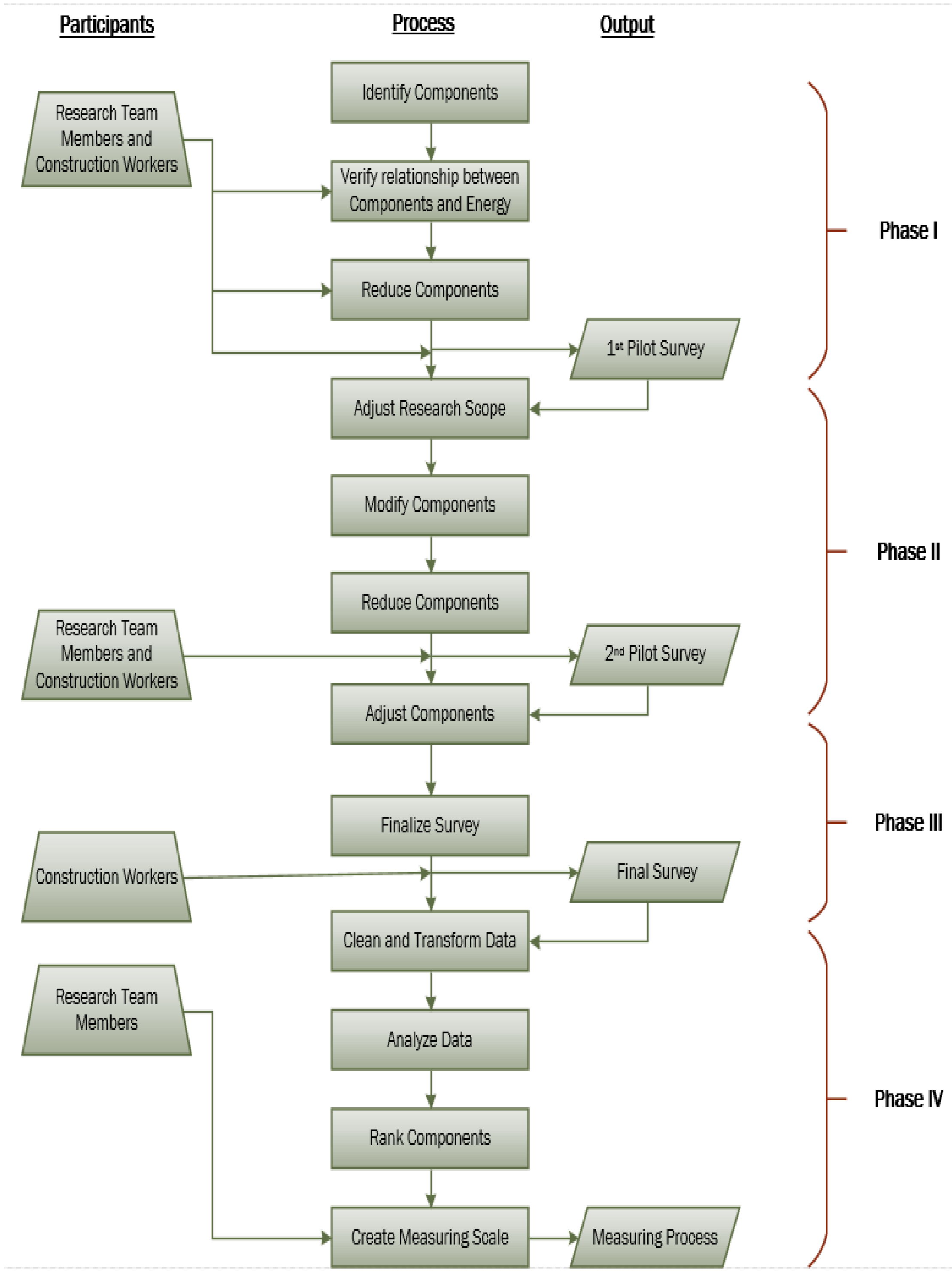


Figure 4.2: Data Collection and Analysis Process

As highlighted in Figure 4.2, the data collection and analysis process is divided into four phases. Each phase has a milestone attached to it to ensure the research progresses at a steady pace. The steps, techniques and methods that are used within each phase are succinctly explained within Sections 4.5.1 to 4.5.4.

4.5.1. PHASE I

To ascertain the presence of energy on a construction project, it is crucial to determine the components that make up energy. An extensive list of variables with considerable impact on workers was identified following in-depth literature review and discussions with construction professionals. As mentioned in Section 3.5, employee level was summarized into five categories which guided the investigation into performance impacting variables. This research study was initially designed to determine how the energy felt by construction workers, especially that of a field worker (non-supervisory role), impacts the performance of a construction project.

The initial scope of the study included productivity, cost, safety, schedule, and quality which influenced the number of identified factors. These project variables were discovered through extensive literature review and informal discussions with construction personnel. Journals and documents from the American Society of Civil Engineering's (ASCE), Safety Science, Science Direct, Research Direct, Construction Safety Management, American Society of Quality, Construction Industry Institute, and Project Management Institute formed the basis of data extraction. Alongside reviewing journals, master's theses and dissertations on topics related to construction project performance were scrutinized. A large amount of the variables used for the first pilot survey were extracted from studies conducted by the Construction Industry Institute (Dai et al. 2009).

After identifying the variables influencing worker performance, the research team determined the presence of a connection between these potential factors and the energy concept. To verify the existence of this connection, a relationship was established between the identified variables and the constituents of energy which consist of complexity and uniqueness of task, distractions and interruptions, resource availability, crowding, time available to complete task, pace, value of task, repetitiveness and predictability of task, and switching between activities. The relationships enabled the research team to successfully streamline the factors discovered during the literature search.

To evaluate the impact of the consolidated factors, a survey was conducted using questions based on the Likert scale. Various similar research studies in the past have made use of this scale to determine perception and opinions of the target population (Aksorn and Hadikusumo 2008; Dainty et al. 2005; Stewart 2007; Müller and Turner 2010; Ai Lin Teo and Yean Yng Ling 2006). Likert- type scales are a good means of collecting survey information that deals with opinions, emotions, and perception of people (Gliem and Gliem 2003). This scale was appropriate since a major component of the research was to determine the impact of various factors on construction employee performance. A 7-scale survey was adopted over a 5-scale survey due to its ability to depict a better picture of the true impact of factors on worker performance (Nunnally and Bernstein 1994).

To create an effective and efficient survey, the research team first split the compiled factors into different categories namely: company culture, project characteristics, project management, task scheduling and management, materials, tools and equipment, engineering and technology, and communication. To improve the accuracy of the factor impact evaluation process across all employee levels, the survey was divided into three sections;

I. Section 1: Demography
II. Section 2: Negative description of identified factors
III. Section 3: Positive description of identified factors

A general demographic section was created to delineate the distinct characteristics of the respondents and compiled information. Apart from providing "background" information (Tsui and O'reilly 1989; Salkind 2010), having a sense of the demographic distribution enabled the researchers to analyze relevant relationships that are significant to the research objectives (Wyse 2012). Questions involving the respondent's age, years of experience in the construction industry, level of education, position, trades involved in (if applicable), type of work experience, and type of company were enquired.

In establishing the effectiveness of the survey, the questionnaire was first distributed to seven people with different levels of experience in the construction industry. To ensure quick response and effective communication, personal contacts of employees actively involved in construction industry were selected to take part in the dry-run. Each employee level included within the scope of this research with the exception of superintendent were represented within the seven construction personnel involved in the first survey pilot test. Together with determining the effectiveness of the survey questionnaire, pilot testing helps improve target population comprehension of what is required of them thereby improving the quality of response data received at the end of the survey (Rea and Parker 1997).

Table 4.1 shows an example of Section 2 of the survey questionnaire which is characterized with a negative description of each energy component. Factors, similar to that in Table 4.1 are highlighted in Table 4.2. The factors in Table 4.2 are presented in a more positive description of components than in Table 4.1 which gives the research team a better understanding of the true significance of each factor to work quality and safety of a construction worker.

Table 4.1: Negative Description of Factors - Pilot Test 1

		Yourself							Construction Worker						
		Magnitude of impact							Magnitude of impact						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
3. Project Management															
3.1	Congested site (equipment, materials, and people)														
3.2	Many different crews/trades on site at the same time														
3.3	Extended work hours each day														
3.4	Night shifts														
3.5	In addition to weekdays, working on weekends and holidays														
3.6	Inexperienced (unqualified) supervisor														
3.7	Construction drawings not readily available														
3.8	No safety incentive														
3.9	Look-ahead (bi-weekly) schedule not available														
3.10	High number of project scope changes during construction														
3.11	Design-Bid-Build contract (hard-bid)														
3.12	Inexperienced crew														
3.13	Lack of personal protective equipment (PPE) and safety resources														
3.14	Low quality of instruction provided for work tasks														
3.15	High number of overlapping work activities for crew														
3.16	Many subcontractors on site at same time														
3.17	Many different tasks/activities being worked on by different crews at the same time														
	Other:														

Table 4.2: Positive Description of Factors - Pilot Test 1

		Yourself							**Construction Worker**						
		Magnitude of impact							Magnitude of impact						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
3. Project Management															
3.1	Non- Congested site (equipment, materials, and people)														
3.2	No or minimal overlapping of different crews/trades on site														
3.3	Regular work hours (40 hrs/week)														
3.4	Day shifts only														
3.5	Working on weekdays only (not on weekends and holidays)														
3.6	Experienced supervisor														
3.7	Construction drawings available when needed														
3.8	Project-based safety incentive														
3.9	Look-ahead (bi-weekly) schedule available														
3.10	Low number of project scope changes during construction														
3.11	Design-Build contract														
3.12	Experienced crew														
3.13	Excellent personal protective equipment (PPE) and safety resources available														
3.14	Acceptable quality of instruction provided for work tasks														
3.15	No overlapping work activities for crew														
3.16	Subcontractors not on-site at same time														
3.17	Few different tasks/activities being worked on by different crews at the same time														
	Other:														

Difficulty determining which project “performance factor” was being assessed (i.e., cost, safety, schedule, quality, etc.), lack of clarity with regards to which section should be filled in by the respondents, length of the survey, and time required to complete the survey were highlighted as concerns by the pilot test participants. These concerns led to re-evaluation of the project scope.

4.5.2. PHASE II

Feedback received from the first pilot test influenced the decision of the research team to adjust the scope of the study. This was aimed at tackling poor response rate and ultimately ensuring the quality of the data collected was of required standard. The project scope was reduced to focus on two project properties:

I. Safety
II. Quality

As mentioned earlier (see Section 2.4), the lack of an easy to use, system-based proactive safety and quality control tool in the construction industry informed the choice of these two project properties. Also, the research team was comprised of people with considerable experience and interest in construction safety and quality management. The survey was further reviewed to determine the possibility of combining or removing some factors. This evaluation led to the reduction of the questions from 64 to 57 which made the survey shorter thereby possibly reducing the time required to complete the survey. Finally, the formatting of the survey was adjusted to highlight some key information that would ensure respondents were properly guided as they complete the survey. As seen in Table 4.3, the possibility of comparing a supervisory employee’s perception of what factors impact a field worker considerably against the assessment of the actual worker was traded in for improved quality of data. As seen in Table 4.3, the revised questionnaire, focused on safety and quality. This revision also affected the factors with a more positive description as shown in Table 4.4

Table 4.3: Revised Survey with Negative Description of Factors

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
3. Project Management															
3.1	Congested site (equipment, materials, and people)														
3.2	Many different crews/trades on site at the same time														
3.3	Extended work hours each day														
3.4	Night shifts														
3.5	In addition to weekdays, working on weekends and holidays														
3.6	Inexperienced (unqualified) supervisor														
3.7	Construction drawings not readily available														
3.8	No safety incentive														
3.9	Look-ahead (bi-weekly) schedule not available														
3.10	High number of project scope changes during construction														
3.11	Design-Bid-Build contract (hard-bid)														
3.12	Inexperienced crew														
3.13	Lack of personal protective equipment (PPE) and safety resources														
3.14	Low quality of instruction provided for work tasks														
3.15	High number of overlapping work activities for crew														
3.16	Many subcontractors on site at same time														
3.17	Many different tasks/activities being worked on by different crews at the same time														
	Other:														

Table 4.4: Revised Survey with Positive Description of Components

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
3. Project Management															
3.1	Non-congested site (equipment, materials, and people)														
3.2	No or minimal overlapping of different crews/trades on site														
3.3	Regular work hours (40 hrs/week)														
3.4	Day shifts only														
3.5	Working on weekdays only (not on weekends and holidays)														
3.6	Experienced supervisor														
3.7	Construction drawings available when needed														
3.8	Project-based safety incentive														
3.9	Look-ahead (bi-weekly) schedule available														
3.10	Low number of project scope changes during construction														
3.11	Design-Build contract														
3.12	Experienced crew														
3.13	Excellent personal protective equipment (PPE) and safety resources available														
3.14	Acceptable quality of instruction provided for work tasks														
3.15	No overlapping work activities for crew														
3.16	Subcontractors not on-site at same time														
3.17	Few different tasks/activities being worked on by different crews at the same time														
	Other:														

Following the adjustments, the revised survey questionnaire was sent out for a second dry-run to verify the effect of the changes made during the review process on the target population's comprehension and the ability of the respondents to complete the survey. Generally, the participants of the second pilot tests had a better comprehension of what was required from them.

4.5.3. PHASE III

As a result of the feedback received after the second pilot test, only minor adjustments were made to the survey questionnaire. Once the survey iteration process was completed, a final copy of the document was sent to Oregon State University's Institutional Review Board (IRB) for final approval (Appendix A1). A copy of the approved survey questionnaire can be found in Appendix A2. The research team chose three methods for disseminating the survey questionnaires to ensure feedback was received from all employee levels targeted for this study. The methods were:

I. An online software program called Qualtrics.
II. Emailing an e-copy of survey questionnaires to participants.
III. In-person distribution or physical distribution.

Data was retrieved from each participant in accordance to the method of circulation.

4.5.3.1. IDENTIFICATION OF SAMPLE POPULATION

Considering the information required while creating this proposed model, the target population was determined to be contractors and client representatives in the construction industry. Due to location, financial, and time constraints, a convenience sample of construction workers was accepted to be a reasonable method of sampling the population (Sedgwick 2013). Three sources provided most of the data used for analysis. The sources are:

I. Construction workers involved in projects within the Oregon State University campus and environ.
II. Personal contacts within the construction industry.
III. A list of safety professionals within the state of Oregon

Participants involved in this research were not limited to the state of Oregon alone. Responses were received from different states within the Pacific Northwest, along with one from Texas and another from New York.

4.5.3.2. SURVEY DISTRIBUTION

An email was sent to 100 personal contacts within the construction industry in the United States. This email contained an electronic copy of the survey as well as a link to the Qualtrics online survey. Additionally, an email was sent to a list of 550 safety professionals affiliated with the Oregon chapter of Association of General Contractors (AGC). In total, 38 responses were received from the online survey within 30 days.

As seen in Table 4.5, three construction projects provided a total of 40 respondents consisting mainly of field workers, foremen, project engineers, and superintendents.

Project A is a new (ongoing) 30, 00-square-foot medical facility located in the Pacific Northwest.

Project B is a 116,000-square-foot $25 million remodeling project

Project C is a four-story, 130,000-square-foot, $65 million project

A total of 78 construction personnel took part in the survey from the on-line components, emails and targeted construction projects.

Table 4.5: Response from Projects

	Project	No. of Participants
1	Project A	7
2	Project B	13
3	Project C	20

Figure 4.3 highlights the response distribution according to source of dissemination. Information from the owner's representatives was entirely acquired between the electronic copies of the survey and Qualtrics software while that from field workers and foremen was gathered solely on-site. Responses from superintendents, project engineers, and safety professionals were received from all three distribution sources.

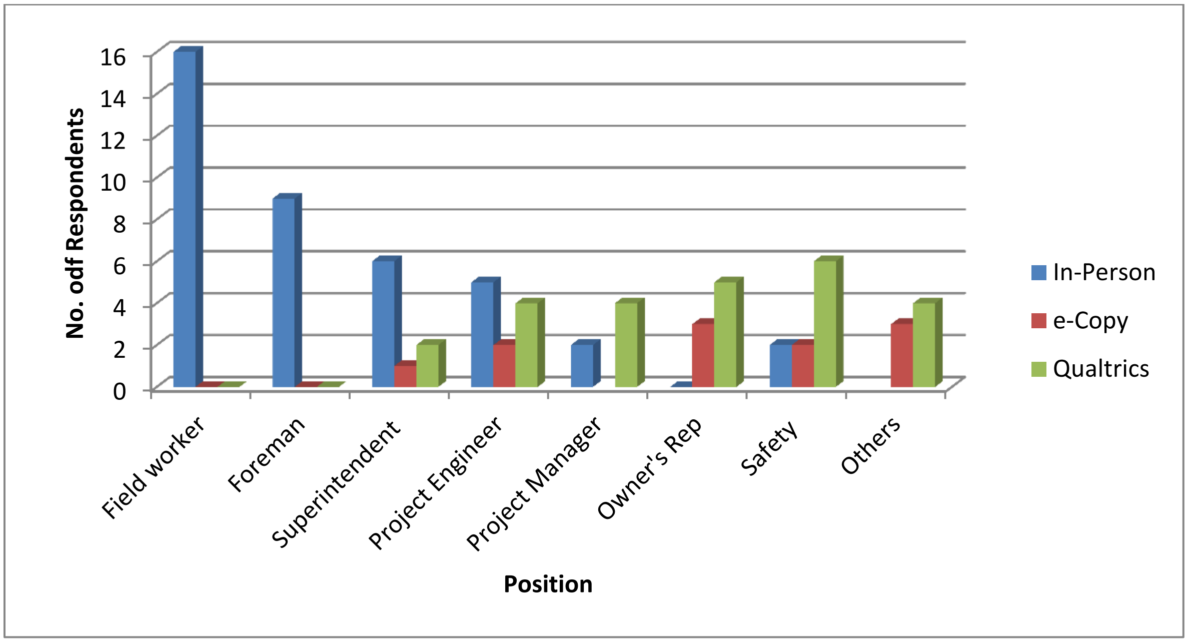


Figure 4.3: Response Distribution by Collection Source

4.5.4. PHASE IV

Before analysis of the data, it is important that the collected data be accurate and the degree of completeness accounted for. Not all retrieved survey questionnaires were used in the analysis. Some survey questionnaires were incomplete or/and lacked consistency. Listwise deletion was deemed necessary to ensure parameter estimates are unbiased thereby improving the quality of analysis (Outhwaite and Turner 2007). This data cleaning process reduced the sample size, making certain methods of analysis incompatible.

Nonparametric methods of data analysis were considered adequate for this research due to the limited sample size and presence of some variability. Descriptive statistics were carried out to determine central tendency and degree of distortion. To validate the use of non-parametric methods of analysis, a test for normality will also be carried out.

The following methods of analysis were used to interpret data and answer the research questions:

Relative Importance Index- To determine which energy components have a significant impact on work quality and the safety of construction employees, a method of ranking the responses received from respondents is required. Factor analysis and Principal Component Analysis are popular methods of reducing large numbers of variables into a smaller set by establishing underlying dimensions between measured variables and latent constructs. This methodology generates an output that identifies which variable or group of variables have considerable impact on the target population (Rao 1964; Suhr 2005). For principal component analysis to be carried out on a set of variables in a survey questionnaire, certain requirements have to be met. One major requirement is a sample size greater than 100 (Gorsuch 1983) which is almost double the sample size of this research study. Also, a ratio of at least five respondents to one variable (5:1) is required to have a good analysis. Bearing in mind the constraints associated with the PCA, an alternative method of ranking responses had to be considered.

Relative Impact Index (RII) is an analytical method widely used to rank responses from surveys (Johnson and Lebreton 2004; Kruskal 1984). Dai (2009), Kamings et al. (1998), and Muhwezi (2014) successfully used RII to create a hierarchal order of the factors that cause poor productivity and delay on construction projects. A number of similar formulas have been used in different studies to rank factors highlighted in the research. The current study adapted the formulas used by Dai (2009) and Muhwezi (2014) to suit the research structure. The formula for RII is given in Equation 4.1:

$$RII = \frac{\sum W}{A * N} * 100 \qquad \text{(Eqn. 4.1)}$$

Where:

W is the response of each participant ranging from -3 to 3, (significantly negative to significantly positive)

A is the highest possible value of the response (3 in this case) and,

N is the number of respondents.

Test for Normality and Equal Variance – A combination of plotting histograms of the data and a Shapiro-Wilk test for normality was carried out to determine is the responses are normally distributed within each work group and at the project level. To test for variance, descriptive analysis was performed.

Wilcoxon Signed-Rank Test – To determine if the identified factors impact safety and quality differently, a dependent t-test was conducted. Most quantitative research tends to apply a paired t-test to analyze the difference in means of dependent variables. This statistical analysis is hinged on certain assumptions. For a paired (dependent) t-test to be used in data analysis, the population sample is assumed to be normal. Given that our data violates this primary assumption, a similar test that can assess the difference in mean of two dependent variables and is robust to the normality assumption is needed. A Wilcoxon signed rank test is the nonparametric equivalent of a paired t-test used to analyze data that fail to meet one or more t-test assumptions.

Welch ANOVA/ Kruskal-Wallis one-way ANOVA - Previous research has demonstrated that factors impacting project performance differ along certain lines, which includes employee's designation. To determine if the impact of factors on work quality and safety of construction personnel across work level differ, an ANOVA is used to test the null hypothesis which states that there is no significant difference in mean between work groups. Whereas Welch ANOVA assumes the data is distributed normally, Kruskal-Wallis is robust to the normality assumption. Depending on the result of the test for normality, Welch ANOVA or Kruskal-Wallis one-way ANOVA will be used to ascertain if there is a difference between work groups

Spearman Correlation- This was used to measure the strength/ magnitude of similarity between different variables and work groups. As with Welch ANOVA, Spearman correlation is robust to the normality assumption thereby making it suitable for the current research.

5. CHAPTER 5 - RESULTS

5.1. INTRODUCTION

Descriptive analyses of the survey responses that were carried out are expounded within the text of this chapter. The analyses enabled the researchers to obtain fundamental information used to develop the framework for measuring energy on a construction project. The demography of the respondents is analyzed to determine the sample spread and presence or lack of any pattern/s. Secondly, Sections 2 and 3 of the survey questionnaires are statistically analyzed to determine distributions associated with each energy component. Finally, the methodology chosen for data analysis is introduced.

5.2. SUMMARY OF PARTICIPANT DEMOGRAPHICS

Section 1 of the survey questionnaire asked questions that were aimed at determining the demographic spread of the respondents. To this regard, the following information was requested from respondents: age, years of experience in the construction industry, level of education, position, trades involved in (if applicable), type of work experience, and type of company. These demographic questions were chosen due to the nature and objectives of the research. Given that there are different perspectives within the construction industry, each demographic question is connected to factors that may influence a worker's perception and understanding of the construction process. As an instance, knowing a respondent's position/title may elucidate why a component that was rated as relatively low-impact by one group of respondents was rated as somewhat high-impact by another group of respondents. As mentioned in Section 4.5.3.2, a total of 78 responses which consists of replies received from all three dissemination sources (see Table 4.5) were initially received. Incomplete/error-ridden surveys, which amounted to 22, were received from all three distribution sources, reducing the analyzable response by 28%. After removing incomplete responses and those with errors, analysis was carried out on 56 responses. Nevertheless, complete and analyzable information was received from all previously defined employee levels within the scope of construction operations. Position/title of respondent was the most vital demographic question on the survey given the research objectives. A summary of the employee level and distribution can be found in Figure 5.1.

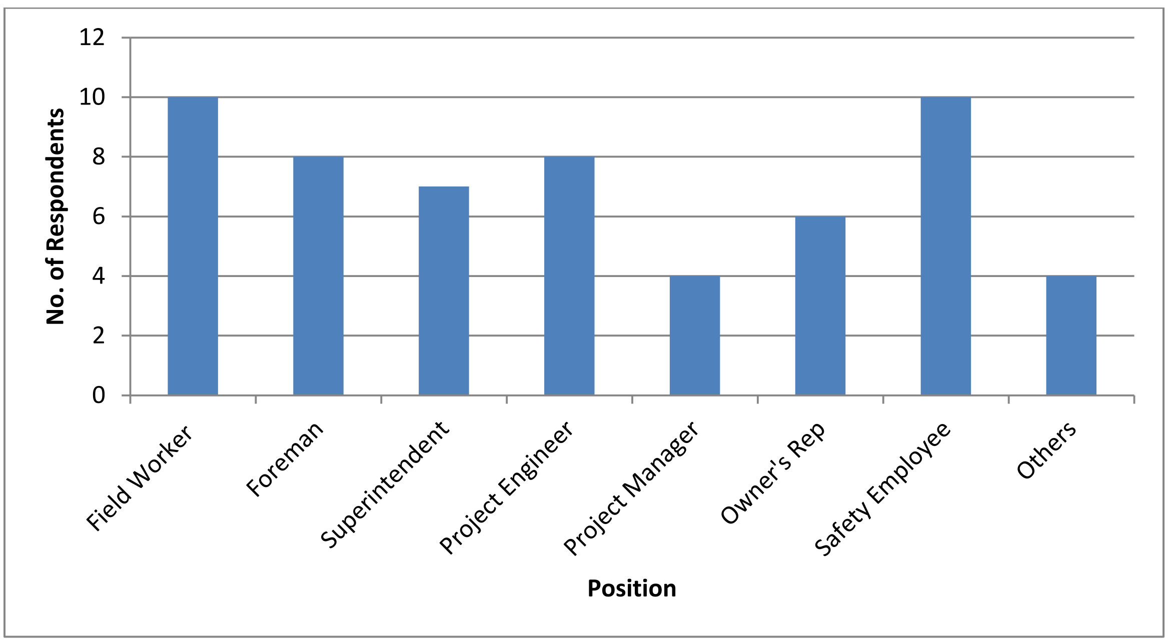


Figure 5.1: Position of Respondents (n= 56)

The criterion used to assign employee level was based on the current position of the respondents. It is important to note that some respondents, especially those in upper management, have had experiences within some other levels but responses were based on their current designation. Responses were also received from project engineers and safety professionals which were not part of the initial scope of study.

The graphical distribution of other demographic-based questions asked in Section 1 of the surveys can be found in Figures 5.2 to 5.7.

Figure 5.2 shows that 50% of the respondents fall within the age range of 25-34 years and 45-54 years while no respondent was below 21 or above 65 years old. The mean age range of the respondents was 35-44 years

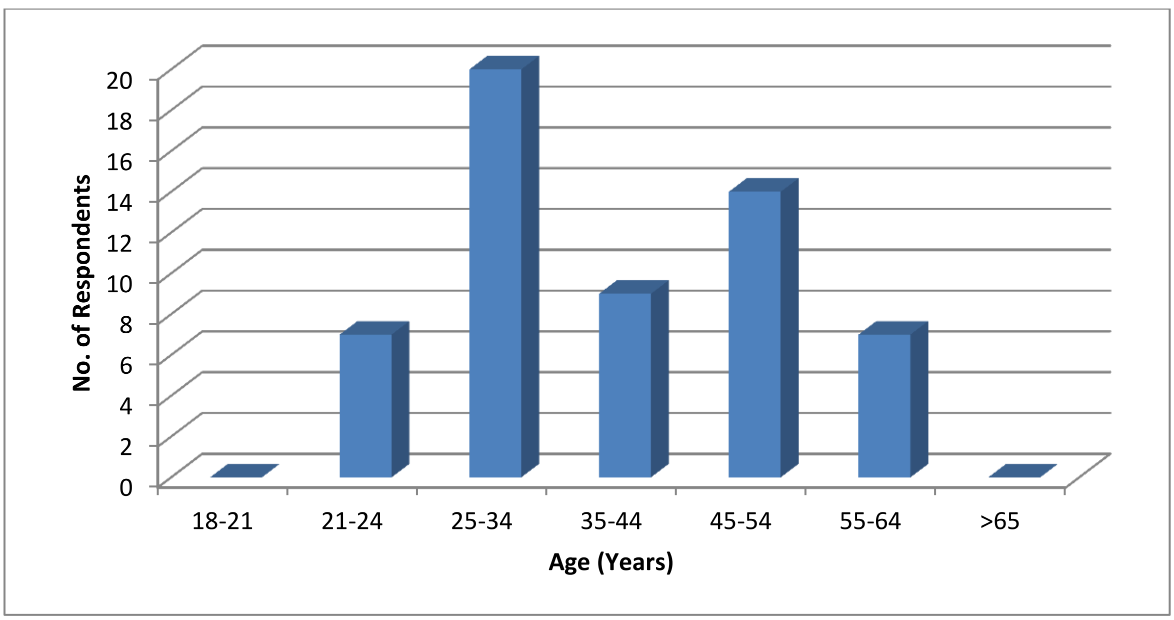


Figure 5.2: Distribution of survey participants by Age Range (n = 56)

Figure 5.3 shows that approximately 39% of the sampled respondents had more than 20 years of experience in the construction industry. The mean experience range of the respondents was 10- 20 years. As seen in Figure 5.4, about 85% of superintendents that took part in the research had above 20 years of experience.

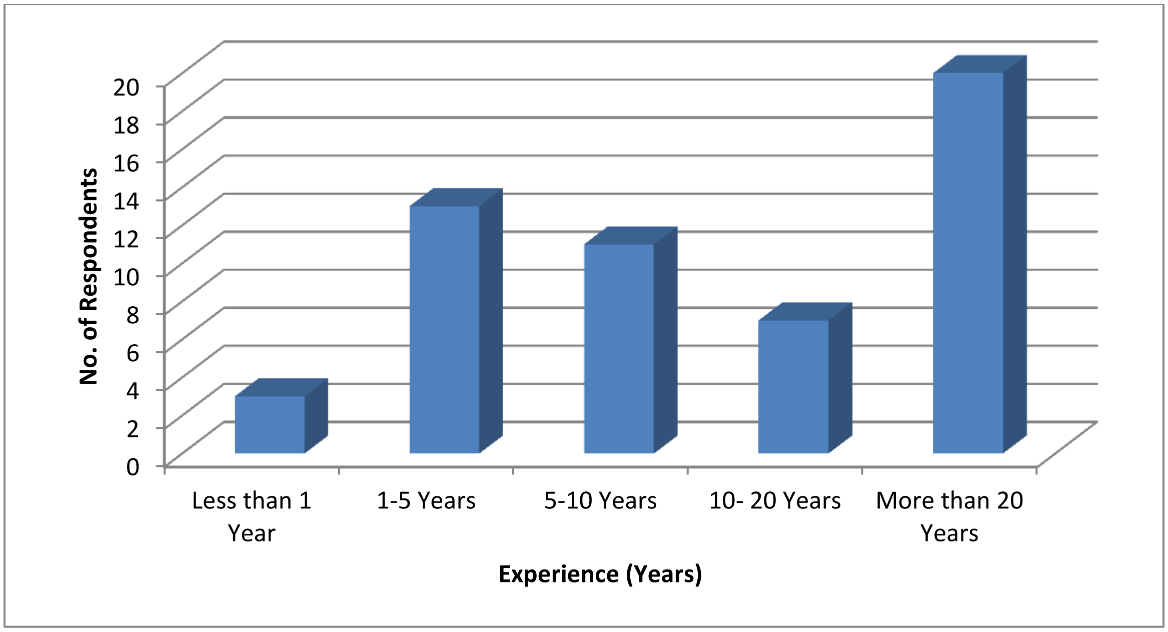


Figure 5.3: Distribution of Years of Experience in the Construction Industry (n =56)

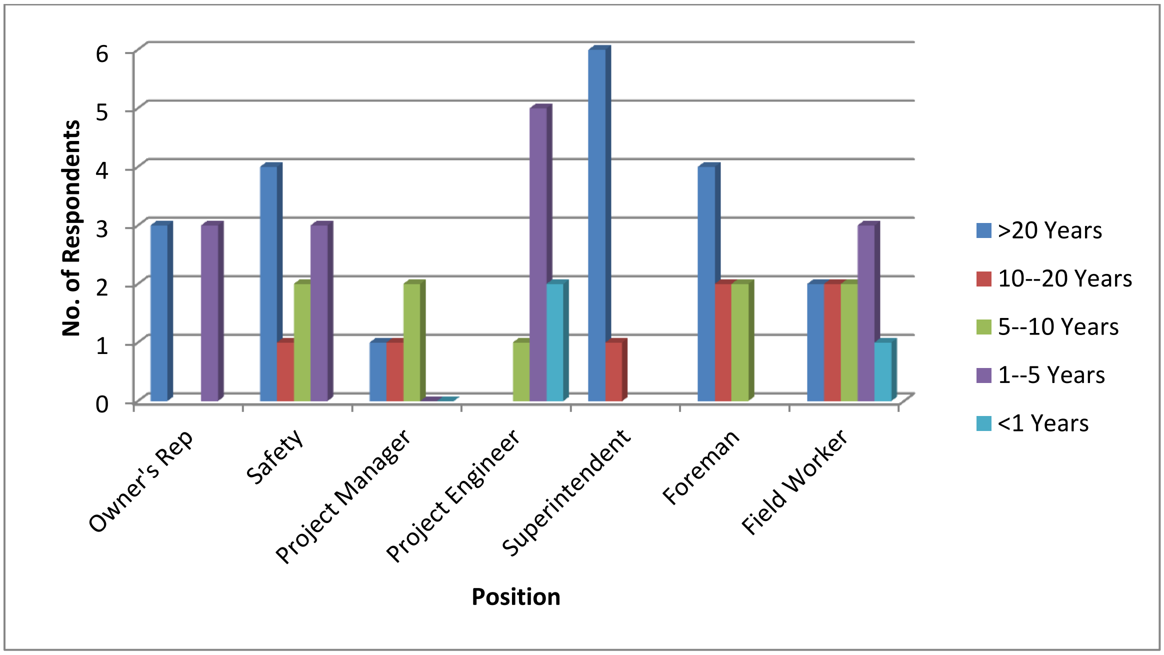


Figure 5.4: Distribution of Years of Experience by Worker Position (n = 56)

Respondents also provided information regarding the trades that they are currently involved in, or were part of in the past (see Figure 5.5). Information in Figure 5.5 is not limited to just field workers. Some foremen and superintendents also reported having an affiliation with a trade.

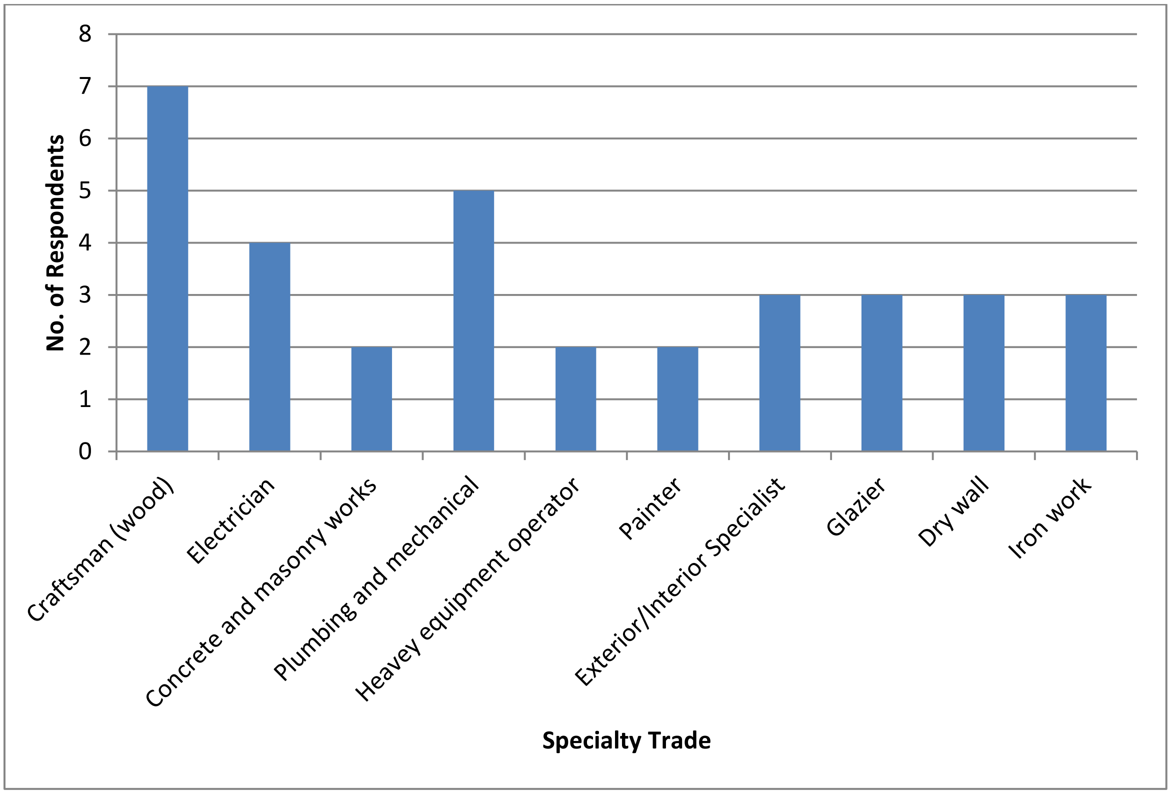


Figure 5.5: Distribution of Survey Participants' Specialty Trade (n = 56)

The information in Figure 5.6 shows that most respondents (92%) have some level of experience in commercial construction. 52% of the survey participants indicated that they have worked on at least two different types of construction projects.

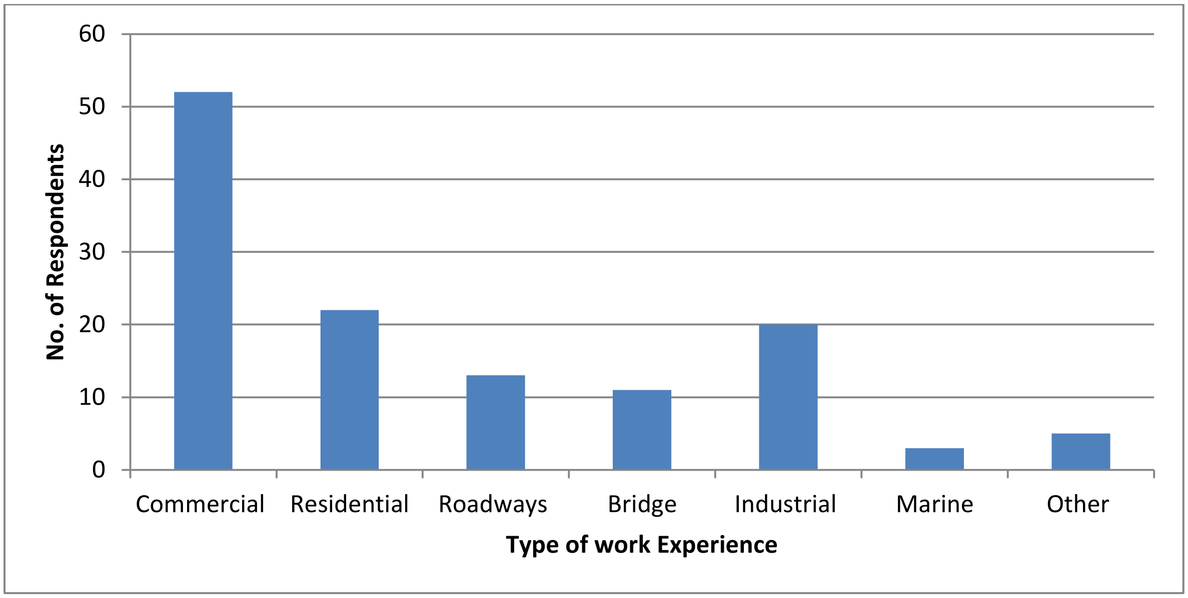


Figure 5.6: Distribution of Survey Participants' Type of Work Experience (n = 56)

Over 94% of the respondents either work for a general contractor or a sub-contractor. Figure 5.7 shows those participants' primarily worked in three different types of companies.

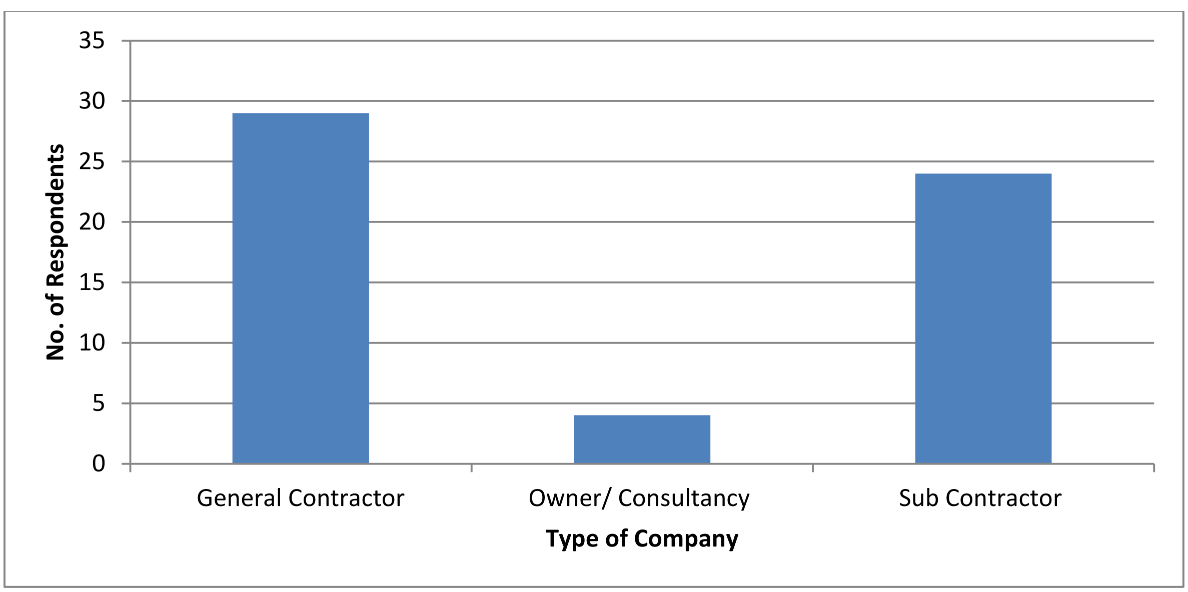


Figure 5.7: Distribution of survey Participants' Type of Company (n = 56)

5.3. ANALYSIS METHODOLOGY AND PROCESSING

Apart from requesting demographic information from participants, the survey also solicited responses on the impact of certain energy components on safety and quality. This section discusses the information extracted from the survey and the analysis method adopted for examining the different responses.

Each survey had 110 questions requiring two responses: one for magnitude of impact on worker's safety and one for magnitude of impact on work quality. In total, approximately 13,000 ratings were provided by the respondents across all personnel levels. To evaluate the effect of the identified components that make up energy, the participants were asked to rate the impact of each component on work quality and worker safety. Below are the different ratings provided to the participants using a Likert scale:

-3 = significant negative impact

-2 = moderate negative impact

-1 = minor negative impact

0 = no impact

1 = minor positive impact

2 = moderate positive impact

3 = significant positive impact

As shown in Table 5.1, the construction worker (Plaster foreman in this example) is of the opinion that within the project management category in Section 2, a congested site, inexperienced supervisor and crew, lack of PPE/safety resources, and low quality of instruction provided for work tasks are the most impactful components to a foreman's safety whereas type of contract, schedule type, and amount of change orders have the least impact on safety of the foreman. For quality, congestion of construction site, inexperienced supervisor and crew, unavailability of construction drawings, low quality of task-specific information, and a high number of overlapping work activities are identified as components that have the most severe impact on work quality of a foreman. Also, this response shows that energy components could have the same degree of impact on safety and quality.

Table 5.1: Sample of a Completed Survey with Negative Descriptions (filled in by a Plaster Foreman)

		Magnitude of impact on your SAFETY							**Magnitude of impact on the QUALITY of your work**						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
3. Project Management															
3.1	Congested site (equipment, materials, and people)	X							X						
3.2	Many different crews/trades on site at the same time			X						X					
3.3	Extended work hours each day		X							X					
3.4	Night shifts			X								X			
3.5	In addition to weekdays, working on weekends and holidays			X							X				
3.6	Inexperienced (unqualified) supervisor	X							X						
3.7	Construction drawings not readily available				X				X						
3.8	No safety incentive		X									X			
3.9	Look-ahead (bi-weekly) schedule not available				X					X					
3.10	High number of project scope changes during construction				X					X					
3.11	Design-Bid-Build contract (hard-bid)				X							X			
3.12	Inexperienced crew	X							X						
3.13	Lack of personal protective equipment (PPE) and safety resources	X										X			
3.14	Low quality of instruction provided for work tasks	X							X						
3.15	High number of overlapping work activities for crew		X						X						
3.16	Many subcontractors on site at same time		X									X			
3.17	Many different tasks/activities being worked on by different crews at the same time		X									X			
	Other:														

To verify if energy components have identical impact on workers when the components have different descriptions, the participants were asked to respond to the same questions, but with a more positive narrative. Table 5.2 illustrates the response of the same plaster foreman to the survey questions. Comparing Table 5.1 to Table 5.2, it is obvious that the foreman believes the impact that the energy components have on safety and work quality when the descriptions are positive is not the exact inverse of the impact of the same components with a negative description. This result validates the inclusion of a third section to this research study. Having a combination of both positive and negative descriptions of each energy component creates a better representation of the impact of an energy component on an employee.

Table 5.2: Sample of a Completed Survey with Positive Descriptions (filled by a Plaster Foreman)

		Magnitude of impact on your SAFETY							**Magnitude of impact on the QUALITY of your work**						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
3. Project Management															
3.1	Non-congested site (equipment, materials, and people)							X							X
3.2	No or minimal overlapping of different crews/trades on site							X							X
3.3	Regular work hours (40 hrs/week)						X							X	
3.4	Day shifts only				X							X			
3.5	Working on weekdays only (not on weekends and holidays)							X							X
3.6	Experienced supervisor							X							X
3.7	Construction drawings available when needed						X								X
3.8	Project-based safety incentive							X				X			
3.9	Look-ahead (bi-weekly) schedule available							X							X
3.10	Low number of project scope changes during construction					X								X	
3.11	Design-Build contract					X								X	
3.12	Experienced crew							X							X
3.13	Excellent personal protective equipment (PPE) and safety resources available							X				X			
3.14	Acceptable quality of instruction provided for work tasks							X							X
3.15	No overlapping work activities for crew							X							X
3.16	Subcontractors not on-site at same time						X							X	
3.17	Few different tasks/activities being worked on by different crews at the same time						X							X	
	Other:														

6. CHAPTER 6 - ANALYSIS AND DISCUSSION

6.1. OVERVIEW

Chapter 5 summarized the demographic information of the respondents that was extracted from the survey tool. In total, 56 construction employees across seven different job levels (including safety professionals and project engineers) within the construction industry provided useable feedback on factors that impact their safety and the quality of their work. Alongside identifying these factors, information on the degree of impact was also received from the respondents. The analysis of the data extracted from the survey questionnaire will be discussed within this section. The following research questions will be answered in this chapter:

I. What are the major factors that affect construction employee at different work levels?
II. Do identified factors have the same impact on safety and quality?
III. Do the factors when positive or negative, impact workers performance differently?
IV. How is energy measured?

To answer these research questions, statistical analysis was carried out on the responses received from the survey participants. Furthermore, the results of this analysis are compared to previous studies that highlighted factors that impact project performance. Lastly, a process for measuring energy on a construction project will be proposed.

6.2. STATISTICAL ANALYSIS AND DISCUSSION

As previously mentioned, data from 56 respondents were analyzed after going through a cleaning process. Statistical analyses were then performed on the data using Statistical Package for Social Sciences (SPSS) and Microsoft Excel in order to answer the research questions. To determine the type(s) of statistical analyses to perform on the data, it is important to verify if the data is normally distributed. Considering the sample size of the current research, a Shapiro-Wilk analysis was considered an appropriate test for normality. The result of this analysis showed that when looking at all 56 responses, most of the data did not show sign of normality as seen in Table 6.1 (see Appendix B for test of normality on all components). Nevertheless, when responses are separated into groups (work level), there seems to be a normal distribution in the pattern of responses received.

Table 6.1: Test for Normality of Data

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Many different tasks/activities being worked on by different crews at the same time	.179	55	.000	.902	55	.000
Task is highly repetitive	.166	55	.001	.932	55	.004
Task is long and continuous	.266	55	.000	.869	55	.000
Task involves high risk of injury-	.164	55	.001	.926	55	.002

Assigned task is very complex	.214	55	.000	.918	55	.001
Frequent switching between tasks required	.240	55	.000	.892	55	.000

a. Lilliefors Significance Correction

Since the value of Sig. is below 0.05 (p-value is <0.05), the null hypothesis which is "data is normally distributed" will be rejected on a project level. The outcome of the Shapiro-Wilk test for normality informs the decision to utilize non-parametric methods of data analysis on the responses received from the respondents. Table 6.2 provides insight on basic descriptive statistics of the data from the Company Culture category within Section 1 of the survey questionnaire. Table 6.2 highlights that there is little difference in variance. A descriptive summary of all the components can be found in Appendix B.

Table 6.2: Descriptive statistic of Response to Section 2 of Survey Questionnaire

Descriptive Statistics for Negative Description of Components							
	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Quality							
Poorly or non-defined organizational structure-	56	6.0	-3.0	3.0	-1.607	1.3305	1.770
Inability to retain skilled craftsmen	56	5.0	-3.0	2.0	-1.911	1.2399	1.537
Lack of regular performance reviews	56	6.0	-3.0	3.0	-.786	1.0568	1.117
Higher than typical productivity required	56	6.0	-3.0	3.0	-1.071	1.2039	1.449
Short project schedule	54	6.0	-3.0	3.0	-1.093	1.2173	1.482
Poor attitude towards safety	56	5.0	-3.0	2.0	-1.107	1.1705	1.370
Competing company priorities take precedence over safety	56	4.0	-3.0	1.0	-1.054	1.1973	1.433

High level of competition within company	56	6.0	-3.0	3.0	.393	1.4731	2.170
Safety							
Poorly or non-defined organizational structure	56	6.0	-3.0	3.0	-1.607	1.3167	1.734
Inability to retain skilled craftsmen	56	5.0	-3.0	2.0	-1.482	1.2209	1.491
Lack of regular performance reviews	55	6.0	-3.0	3.0	-.400	.9545	.911
Higher than typical level of productivity required	56	6.0	-3.0	3.0	-1.179	1.2520	1.568
Short project schedule	55	6.0	-3.0	3.0	-1.109	1.2122	1.469
Poor attitude towards safety	56	4.0	-3.0	1.0	-2.393	1.0562	1.116
Competing company priorities take precedence over safety	56	3.0	-3.0	.0	-1.946	1.0689	1.143
High level of competition within company	56	5.0	-3.0	2.0	-.196	1.0517	1.106
Valid N (listwise)	52						

Alongside looking at the descriptive data of the negative impact caused by the identified factors, the research team also looked into the descriptive data extracted from Section 3 of the survey questionnaire which had questions with a more positive description of factors. Table 6.3 shows the range, mean, standard deviation, and variance of the Company Culture category in Section 3 of the questionnaire.

Table 6.3: Descriptive statistic of Response to Section 3 of Survey Questionnaire

Descriptive Statistics for Positive Description of Components							
	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Safety							
Well-defined organizational structure	56	4.0	-1.0	3.0	1.554	1.0431	1.088

High retention rate of skilled craftsmen	56	3.0	.0	3.0	2.000	.9145	.836
Regular performance reviews	56	3.0	.0	3.0	1.071	.9507	.904
Lower than typical productivity required	56	5.0	-2.0	3.0	.482	1.2209	1.491
More time allowed in project schedule than typical	56	4.0	-1.0	3.0	1.000	1.0954	1.200
Good attitude towards safety	56	3.0	.0	3.0	2.304	1.0076	1.015
Safety takes precedence over other companies priorities	56	3.0	.0	3.0	2.125	1.0965	1.202
Relaxed atmosphere within company	56	4.0	-1.0	3.0	1.000	1.2649	1.600
Well-defined organizational structure	56	3.0	.0	3.0	1.768	.7860	.618
High retention rate of skilled craftsmen	56	3.0	.0	3.0	2.214	.8679	.753
Regular performance reviews	56	3.0	.0	3.0	1.232	.9722	.945
Lower than typical productivity required	56	5.0	-2.0	3.0	.696	1.2638	1.597
More time allowed in project schedule than typical	56	5.0	-2.0	3.0	1.179	1.2226	1.495
Good attitude towards safety	56	3.0	.0	3.0	1.304	1.1743	1.379
Safety takes precedence over other companies priorities	56	4.0	-1.0	3.0	1.161	1.2472	1.556
Relaxed atmosphere within company	56	6.0	-3.0	3.0	.893	1.3971	1.952
Valid N (listwise)	56						

Careful assessment of Tables 6.2 and 6.3 show that certain questions such as what is the impact of a poorly or well defined organization on a workers safety and work quality showed an upper and lower limit of 3 and -3 respectively. Logically speaking, the response to this questioned should be skewed one direction. As seen in Figures 6.1 and 6.2, although a small fraction of respondents selected that a poorly defined organizational structure has a major positive impact on the quality of their work, the presence of the hypothesized skew is present.

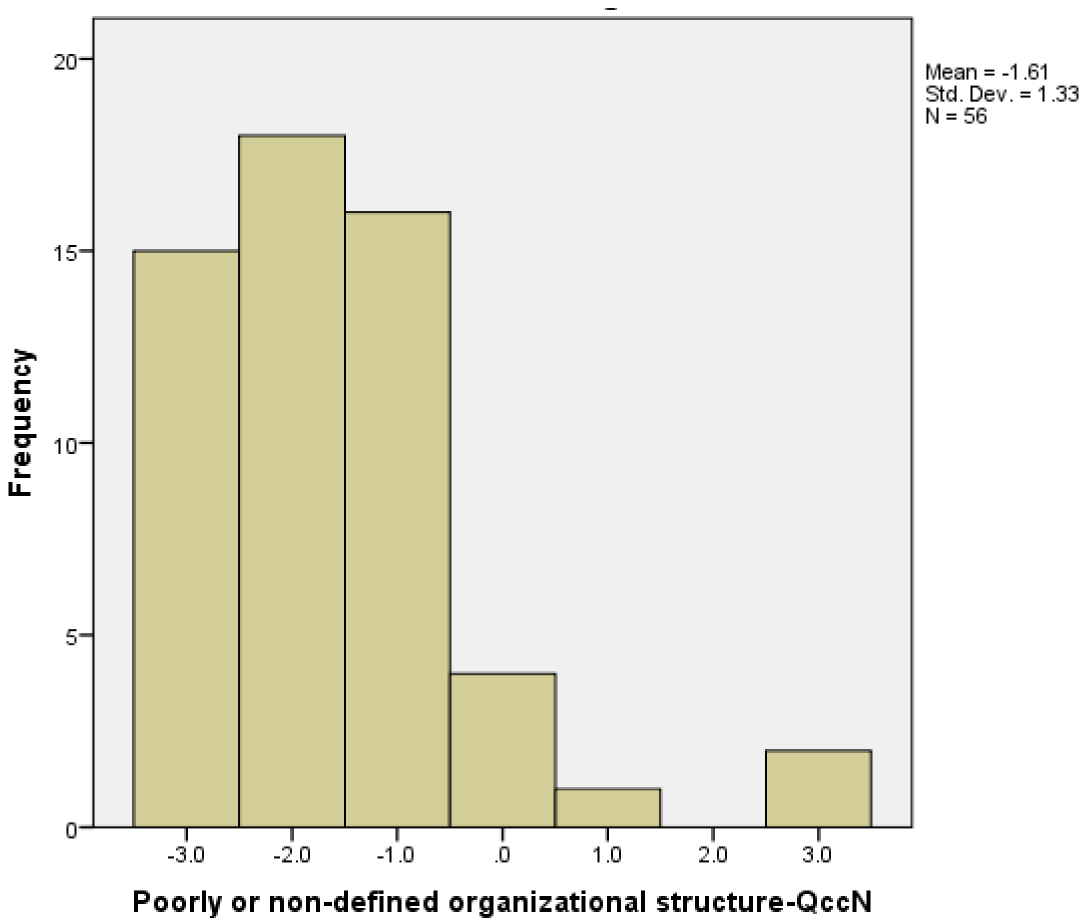


Figure 6.1: Response distribution to Poorly or non-defined organizational structure

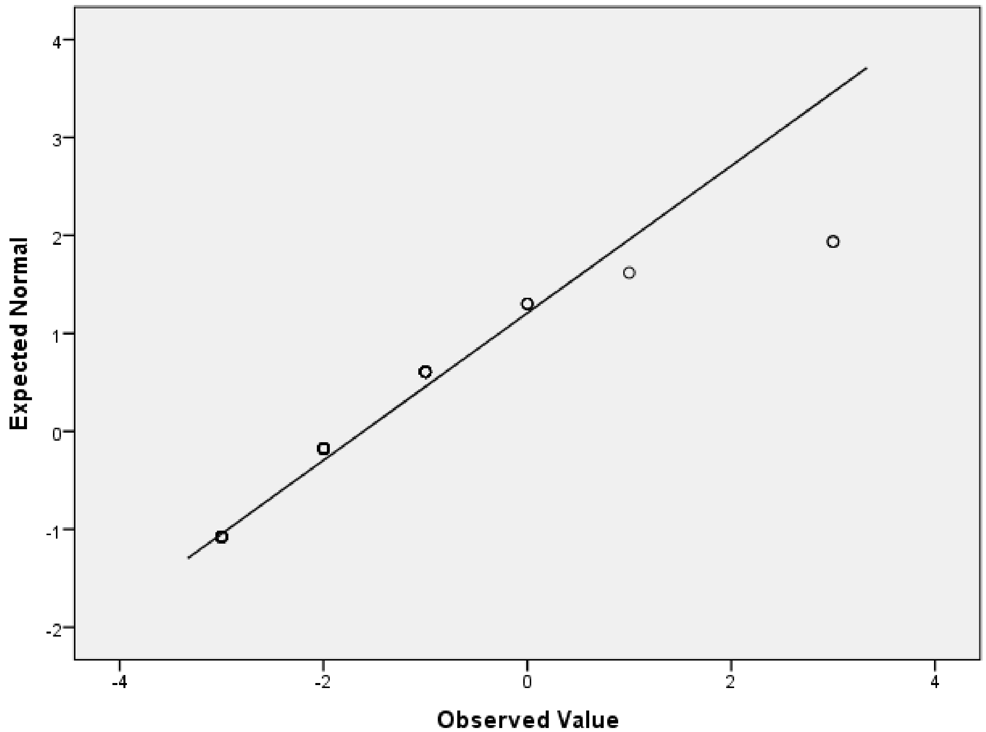


Figure 6.2: Normal Q-Q Plot of impact of Poor or non-defined organizational structure on work quality

Data populated from the SPSS software also provided information on the percentage distribution of response to each question. As seen in Table 6.4, 30.4% of the respondents said that a congested site has a minor negative impact on their safety while Table 6.5 shows that 35.7% of respondents believe that congestion has a minor negative impact on the quality of their work. The response frequency of each factor can be found in Appendix D.

Table 6.4: Distribution of Response to Congested Site with respect to Safety

Congested Construction Site- Safety					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	16	28.6	28.6	28.6
	moderate negative impact	15	26.8	26.8	55.4

	minor negative impact	17	30.4	30.4	85.7
	no impact	5	8.9	8.9	94.6
	minor positive impact	2	3.6	3.6	98.2
	moderate positive impact	1	1.8	1.8	100.0
	Total	56	100.0	100.0	

Table 6.5: Distribution of Response to Congested Site with respect to Quality

Congested Construction Site- Quality					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	8	14.3	14.3	14.3
	moderate negative impact	11	19.6	19.6	33.9
	minor negative impact	20	35.7	35.7	69.6
	no impact	15	26.8	26.8	96.4
	moderate positive impact	2	3.6	3.6	100.0
	Total	56	100.0	100.0	

6.3. PROJECT LEVEL ANALYSIS

As discussed in Section 4.5.4, the impact of each factor on a participant's performance was determined by calculating the Relative Impact Index (RII). Table 6.6 lists the top 10 factors that impair a construction employee's performance. A complete list of the ranking based on the impact of factors on workers safety and work quality can be found in Appendix E.

Table 6.6: Top 10 Factors that Impact Worker Negatively

Negative Description				
Ranking	**Worker Safety**	**RII**	**Quality of Work**	**RII**

	Most Impactful Components		Most Impactful Components	
1	Workers Poor attitude towards safety	-79.77	Poor quality materials	-68.46
2	Lack of personal protective equipment (PPE) and safety resources	-72.62	Inability to retain skilled craftsmen-	-63.70
3	Competing company priorities take precedence over safety	-64.88	Poor quality of equipment and tools	-62.5
4	Lack of familiarity with equipment	-64.29	Poor quality of pre-fabrication	-61.91
5	Inexperienced (unqualified) supervisor	-62.5	Poor working relationships and cohesiveness with co-workers	-57.74
6	Inexperienced crew	-61.91	Inexperienced (unqualified) supervisor	-57.15
7	Poor working relationships and cohesiveness with co-workers	-58.33	Slow response to Requests for Information (RFIs)	-57.15
8	Poor quality of equipment and tools	-57.15	Low quality of detailed design drawings	-56.55
9	Poor material, tools, and equipment storage	-55.95	Unpredictability of the work tasks due to unknown information	-55.36
10	Congested site	-54.17	Lack of adequate communication within site management	-55.36

Of the top five components that impact quality of work of a construction employee, three factors are components within the material, equipment, and tool management category of the survey (See Appendix A2). This result shows that respondents consider the effective management of supplies paramount to the quality of work. An in-depth study carried out by Dai et al. (2009) identified tool and consumable management as key factors that impact productivity of foremen and field workers. As regards to safety of personnel, a poor attitude towards safety was identified as the factor with the highest impact on safety performance of a worker. This assertion displays some level of correlation with the Accident-Proneness theory which alludes that "a personal idiosyncrasy predisposes the individual who possesses it in a marked degree to a relatively high accident rate" (Chambers 1929). Furthermore, it is noted that a high accident rate is associated with people with "innate propensity for accident" (Shaw and Sichel 1971). Lack of safety resources, which include PPE, was identified as a problem with considerable impact on worker safety. Different researchers such as Sawacha (1999), Tam et al. (2004), and Haslam (2005) support the assertion that lack of adequate safety equipment and resources has a considerable impact on safety performance. A close observation of Table 6.6 shows that factors that have considerable impact on safety do not necessarily have the same impact on quality. Nevertheless, three out of the ten listed factors are identified as having significant impact on safety and quality. Relationship with co-workers, experience of supervisor, and poor quality of equipment and tools are considered to have a substantial impact on both the safety of the worker and the quality of their output.

Table 6.7 highlights the factors that improve workers safety and work quality performance. The major factors that improve the safety of construction personnel are attitude towards safety, availability of safety resources, and a company that emphasizes on safety. Compared to those shown in Table 6.6, these top three components mirror the ranking of factors that impede safety of construction personnel. On the other hand, the top three factors that have the most positive impact on quality output of construction employee differ considerably.

Table 6.7: Top 10 Factors that Impact Worker Positively

Positive Description				
Ranking	Worker Safety Most Impactful Components	RII	Quality of work Most Impactful Components	RII
1	Good attitude towards safety	76.79	High retention rate of skilled craftsmen	73.81
2	Excellent personal protective equipment (PPE) and safety resources available	72.62	Experienced crew	72.62
3	Safety takes precedence over other companies priorities	70.83	Experienced supervisor	72.02
4	Experienced crew	69.64	Materials are of good quality	70.24
5	Experienced supervisor	67.86	Excellent working relationships and cohesiveness with co-workers	70.24
6	High retention rate of skilled craftsmen	66.67	Construction drawings available when needed	69.05
7	Familiar with equipment used for task	66.07	Pre-fabrication is of good quality	66.07
8	Excellent working relationships and cohesiveness with co-workers	63.69	Good communication within site management	66.07
9	Good communication within site management	61.31	Equipment and tools are of good quality	65.48
10	Non-congested site	60.71	High quality of detailed design drawings	65.48

Tables 6.6 and 6.7 describe factors that have the most impact on work quality and worker safety. To determine if this difference is statistically significant, a null hypothesis was developed stating that there is "no significant difference" in the mean of workers safety and work quality resulting from the impact of energy components. To test the null hypothesis, a Wilcoxon Signed Rank Test was conducted on the mean score of each factor. A Wilcoxon rank test was deemed appropriate since it is resistant to the assumption of normality and a small sample size (Shieh et al. 2007; Zaiontz 2015). As

shown in Table 6.8, the result of the Wilcox rank sum test showed that there is no significant difference between the impact of the assessed factors on workers safety and work quality.

Table 6.8: Test of difference in Median between quality and Safety

	Null Hypothesis	**Test**	**Sig./p-value**	**Decision**
1	The median differences between the impact of identified factors on Safety and Quality equals 0	Related-samples Wilcoxon Signed Rank Test	0.217	Retain the null hypothesis

Significance level is 0.05.

There is some validation of this finding amongst academic research. Wanberg et al. (2013) discovered that there was a positive correlation between recordable injury rate on a project and rework. The nature of rework activities (demolition, unstable work process, and schedule pressure) was highlighted as the major reason for the correlation. Also, Hoonakker (2010) stated that improved safety is one of the benefits associated with implementing a quality management system. To maximize resource efficiency, Pheng and Shiua (2003) proposed a framework that incorporated both safety and quality management systems. This integration was considered possible due to similarity between quality and safety management.

Further analysis will be carried out on each work group to determine if the discovery of a lack of statistically significant difference between safety of worker and work quality resulting from the impact of energy components on a project level is a reoccurring phenomenon across all work levels.

The RII scores were derived using the average rating of each respondent not minding the current position, experience, and trade of the respondent. According to Dai et al. (2009), the performance of construction employees is affected by different components. In most cases, these components are connected to their job function. To verify if the impact of factors on the work quality and safety of workers on different work levels differ significantly, an ANOVA was used to compare the average of each work level group. A Welch's Test method of performing an ANOVA analysis was used given that the sample size within each group was unequal and the homogeneity of variances assumption was not met. The default null hypothesis which states that there is "no significant difference in mean between each work level" was retained. Table 6.9 depicts the result of a Welch's Test on the difference in mean of the safety section of the survey. The ANOVA analysis shows that there is a significant difference between the field worker category and all other work groups which leads to the rejection of the null hypothesis. This means that the impact of identified factors on field worker safety differs from other identified work groups. A statistical test on the impact of factors on the quality of work done by workers at different levels was also carried out. In Table 6.9, a p-value below 0.05 was reported in all five cases. The p-value (sig.) in Table 6.10 denotes the presence of a significant difference between the mean impact rating of energy components on the quality of work carried out by a superintendent compared to other work groups. The result of this analysis shows that workers at different work levels perceive the impact of factors on their performance differently.

Table 6.9: Comparing Field worker against other Work Levels

Welch ANOVA on Safety- Field worker						
		Sum of Squares	df	Mean Square	F	Sig.
Safety Professional	Between Groups	27.577	28	.985	4.025	.000
	Within Groups	6.852	28	.245		
	Total	34.429	56			
Owner's Rep	Between Groups	19.192	28	.685	4.336	.000
	Within Groups	4.426	28	.158		
	Total	23.618	56			
Project Manger	Between Groups	28.519	28	1.019	2.359	.013
	Within Groups	12.089	28	.432		
	Total	40.607	56			
Project Engineer	Between Groups	30.909	28	1.104	5.290	.000
	Within Groups	5.843	28	.209		
	Total	36.752	56			
Superintendent	Between Groups	33.467	28	1.195	5.070	.000
	Within Groups	6.601	28	.236		
	Total	40.068	56			
Foreman	Between Groups	26.762	28	.956	3.442	.001
	Within Groups	7.775	28	.278		
	Total	34.537	56			

Table 6.10: Comparing Superintendent against other Work Levels

Welch ANOVA on Quality- Superintendent						
		Sum of Squares	df	Mean Square	F	Sig.
Field worker	Between Groups	27.577	28	.985	4.025	.000
	Within Groups	6.852	28	.245		
	Total	34.429	56			
Foreman	Between Groups	19.192	28	.685	4.336	.000
	Within Groups	4.426	28	.158		
	Total	23.618	56			
Project Engineer	Between Groups	28.519	28	1.019	2.359	.013
	Within Groups	12.089	28	.432		
	Total	40.607	56			
Project Manager	Between Groups	30.909	28	1.104	5.290	.000
	Within Groups	5.843	28	.209		
	Total	36.752	56			
Owner's Rep	Between Groups	33.467	28	1.195	5.070	.000
	Within Groups	6.601	28	.236		
	Total	40.068	56			
Safety	Between Groups	26.762	28	.956	3.442	.001

Professional	Within Groups	7.775	28	.278		
	Total	34.537	56			

Tables showing the analysis on the difference in mean across each group can be found in Appendix G.

6.4. STATISTICAL ANALYSIS BY WORK LEVEL

The analysis of variance test showed that the degree of impact caused by each factor differs across the seven work groups. This difference was witnessed both in the quality of work and the safety of workers at each personnel level. From the result of the ANOVA test, it could be implied that each group would be impacted differently by components of energy. To verify the assumption that energy components affect employees in different work level antithetically, the RII of each work group was calculated and the factors ranked. This restructuring of ranking was carried out for both safety/quality and positive/negative description.

6.4.1. FIELD WORKER

Table 6.11 lists the factors with the most significant impact on the safety of a field worker. Lack of safety resources was identified as the major factor that could lead to an incident. Fast pace of a project was identified as the least impactful factor for field worker safety while on the job. Zohar (1980; 2000) highlighted that requiring workers to work at a higher pace is “potentially hazardous” and has a negative impact on the safety culture of a company. Certain factors were identified by respondents as components that could improve working conditions. These factors include: familiarity with equipment, good quality material, and availability of safety resources. A list of the five most and least five impactful components that have a positive impact on field worker safety is found in Table 6.12.

Table 6.11: Least and Most Negatively Impacting Factors on Field workers (FW)

Negative Description - (FW)				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Lack of personal protective equipment (PPE) and safety resources	-66.67	Very high quality of work required	36.67
2	Poor attitude towards safety	-60.00	Large project (physical size)	26.67
3	Lack of familiarity with equipment	-60.00	High cost project	23.33
4	Poor working relationships and cohesiveness with co-workers	-56.67	Use of advanced technologies	16.67
5	Competing company priorities take precedence over safety	-53.33	Fast pace of work	10.00

Table 6.12: Least and Most Positively Impacting Factors on Field workers (FW)

Positive Description- FW				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Excellent personal protective equipment (PPE) and safety resources available	73.33	Low quality of work required	3.33
2	Familiar with equipment used for task	73.33	Low amount of paperwork involved	16.67
3	Materials are of good quality	73.33	Low cost project	20.00
4	Experienced crew	70.00	Remote project - location	23.33
5	Easy-to-use equipment (requires only basic skills)	70.00	Worker tasks are not long and monotonous (dull)	23.33

6.4.2. FOREMAN

Analysis of the responses received from the survey participants showed that foremen perceive the impact of factors on their performance differently from the field workers. A Spearman correlation was run to determine the relationship between foreman and field worker (on impact of factors on safety and quality of work). There was a very strong monotonic correlation between the impact of factors on safety of a foreman and that of a field worker ($r_s = 0.803$, $p < 0.001$) as seen in Table 6.13. Also, Table 6.14 shows that a strong monotonic correlation was recorded between foreman and field worker when analysis the impact of factors on quality ($r_s = 0.797$, $p < 0.001$). Results from both correlation tests indicate that factors tend to affect the performance of a fieldworker and foreman in a similar manner.

Table 6.13: Correlation between Foreman and Field worker with respect to Safety

Correlations- Safety				
			Field Worker	Foreman
Spearman's rho	Field Worker	Correlation Coefficient	1.000	.803**
		Sig. (2-tailed)	.	.000
		N	57	57
	Foreman	Correlation Coefficient	.803**	1.000
		Sig. (2-tailed)	.000	.
		N	57	57

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

Table 6.14: Correlation between Foreman and Field worker with respect to Quality

Correlations- Quality				
			Field Worker	Foreman
Spearman's rho	Field Worker	Correlation Coefficient	1.000	.797**
		Sig. (2-tailed)	.	.000
		N	57	57
	Foreman	Correlation Coefficient	.797**	1.000
		Sig. (2-tailed)	.000	.
		N	57	57

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

Notwithstanding the presence of correlations in the current study, past research shows that although the presence of similarities may be observed between foremen and field workers, their perception on what factors impact their performance differs (Dai et al. 2009). In the current research, foremen stated that the poor quality of equipment and poor attitude towards safety were the biggest factors that could impact their safety on the job. The five most and least impacting factors on safety of a Foreman are listed in Table 6.15.

Table 6.15: Least and Most Negatively Impacting Factors on Foremen with respect to Quality

Negative Description- F				
Ranking	**Most Impactful**	**RII**	**Least Impactful**	**RII**
1	Poor quality of equipment and tools	-87.5	Use of advanced technologies	25.00
2	Poor attitude towards safety	-75	Very high quality of work required	16.67
3	Competing company priorities take precedence over safety	-75	High amount of paperwork involved	8.33

4	Lack of personal protective equipment (PPE) and safety resources	-75	Assigned task is very complex	4.17
5	Congested site	-70.83	High cost project	0.00

The perception that a factor has a significant impact on worker safety and work quality could be skewed by several factors, including experience on the job. Previous academic research has shown a positive correlation between work experience and safety (Siu et al. 2003). Figure 6.3 shows the construction experience distribution of foremen who were surveyed as part of this study.

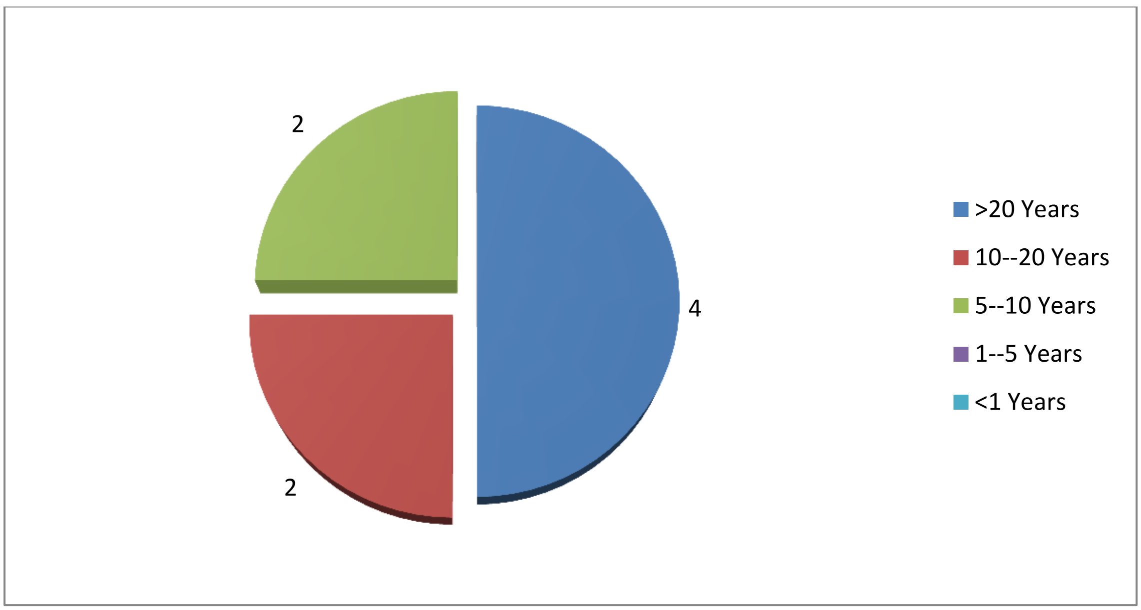


Figure 6.3: Foreman Experience distribution

To analyze the impact of experience on the responses received from the foremen, two categories were created: foremen with experience above 20 years and those with experience below 20 years. Table 6.16 shows that all respondents with less than 20 years of construction experience believe that lack of personnel protective equipment is the most significant factor that could lead to an incident on a construction site. Foremen with more than 20 years of experience believe that a congested site is the main factor that could cause the highest impact on worker safety.

Table 6.16: Most Impactful Factors based on Foreman Experience with respect to Safety

Worker Safety- Foreman				
<20 Years of Experience			**>20 Years of Experience**	
Ranking	**Most Impactful Components**	**RII**	**Most Impactful Components**	**RII**
1	Lack of personal protective equipment (PPE) and safety resources	-100	Congested site	-91.67
2	Poor quality of equipment and tools	-91.67	Inexperienced (unqualified) supervisor	-91.67
3	Poor attitude towards safety	-83.33	Poor quality of equipment and tools	-83.33
4	Competing company priorities take precedence over safety	-83.33	Lack of personal protective equipment (PPE) and safety resources	-75.00
5	Lack of familiarity with equipment	-83.33	Inexperienced crew	-75.00

This variance in perception related to experience is also recorded when determining factors that impact quality of work carried out by a foreman as highlighted in Table 6.17. Respondents with more than 20 years are of the opinion that poor quality of tools and equipment is the most impactful factor on quality of work whereas data from foremen with less experience suggests that the inability to retain skilled craftsmen is the most vital factor that could impede quality of work.

Table 6.17: Most Impactful Factors based on Foreman Experience- Quality

Quality of Work- Foreman

<20 Years of Experience			>20 Years of Experience	
Ranking	Most Impactful Components	RII	Most Impactful Components	RII
1	Inability to retain skilled craftsmen	-83.33	Poor quality of equipment and tools	-83.33
2	Construction drawings not readily available	-75.00	Low quality of instruction provided for work tasks	-83.33
3	Unpredictability of the work tasks due to unknown information	-75.00	Poor quality materials	-83.33
4	Poor quality of equipment and tools	-75.00	Poor quality of pre-fabrication	-83.33
5	Low quality of detailed design drawings	-75.00	Inexperienced crew	-66.67

6.4.3. SUPERINTENDENT AND SAFETY PROFESSIONALS

Safety engineers are tasked with developing systems and programs to prevent and decrease the possibility of human error that leads to accidents on a construction project. Although the current research did not include safety professionals within the construction work levels targeted initially, gaining input from safety professionals was deemed necessary due to the scope of this study. While on the job, it is important to note that certain factors impact a safety professional's ability to perform. The current study highlights the factors that impact both safety on the job and the quality of his/her work. These factors are attached in Appendix F.

Table 6.18 shows a comparison of the factors that impact the safety of superintendents to those that impact construction safety professionals. Although both groups believe that having the wrong attitude towards safety is the most impactful factor to their work, safety professionals, unlike superintendents, identified a poorly defined organizational structure as a major source of concern. Superintendents noted that having a multilingual workforce has a negative impact on safety performance. This observation by the superintendents is consistent with a recent research study conducted by Alsmadani et al. (2013). The researchers stated that unilingual work crews have a safety performance that is 51% better than multilingual crews.

Table 6.18: Factors that Impact Superintendent and Safety Professional Safety

Negative Description				
	Superintendent		Safety Professional	
Ranking	**Most Impactful**	**RII**	**Most Impactful**	**RII**
1	Poor attitude towards safety	-95.84	Poor attitude towards safety	-83.33
2	Lack of personal protective equipment (PPE) and safety resources	-83.33	Competing company priorities take precedence over safety	-75
3	More than one language spoken on construction site	-79.17	Inexperienced (unqualified) supervisor	-75
4	Lack of adequate communication within site management	-70.84	Congested site	-66.67
5	Lack of familiarity with equipment	-70.83	Poorly or non-defined organizational structure	-66.67

6.4.4. PROJECT ENGINEER AND PROJECT MANAGER

Looking at the age distribution in Figure 6.4, the project engineers in the sample primarily have experience ranging from 1-10 years which is lower than that of the project managers. This could be as a result of a typical construction career path that requires a project engineer to transition into a project manager or superintendent after a period of time (ASCE 2015). As seen in Table 6.19, project engineers believe that experience is a vital factor that impacts safety performance.

Figure 6.4: Project Engineer and Project Manager Construction Experience

Table 6.19: Factors that Impact Project Engineers and Project Manager- Safety

Negative Description				
	Project Engineer		**Project Manager**	
Ranking	**Most Impactful**	**RII**	**Most Impactful**	**RII**
1	Poor attitude towards safety	-95.84	Poor attitude towards safety	-83.33
2	Inexperienced crew	-83.33	Competing company priorities take precedence over safety	-75
3	Lack of personal protective equipment (PPE) and safety resources	-79.17	Lack of personal protective equipment (PPE) and safety resources	-75

4	Inexperienced (unqualified) supervisor	-70.84	Inability to retain skilled craftsmen	-66.67
5	Lack of familiarity with equipment	-70.83	Night shifts	-66.67

In view of the analysis conducted on the factors that impact safety among all work groups, it is observed that having a poor safety attitude is a major concern. This is asserted by its ranking as the number one impacting factor at the project level. Siu et al. (2003) carried out a research study that investigated the relationship between age difference and safety attitude. It was discovered that while there is no significant relationship between age and accident rate, there is a significant relationship between safety attitudes and experience in the construction industry. Experienced workers tend to report more incidents and are more risk averse. This is consistent with the finding of the current study which listed inexperience of both supervisor and crew and poor safety attitude as major safety concerns. To statistically test this observation, a Welch test was carried out on the responses associated with poor safety attitude and inexperienced supervisors and crews to determine if the difference in response was significant. The Welch test result shown in Table 6.20 reveals that there is a statistically significant difference between group means (p-value <0.05).

Table 6.20: Welch ANOVA on Poor Attitude and Inexperience

Welch ANOVA- Poor Safety Attitude						
		Sum of Squares	df	Mean Square	F	Sig.
Inexperienced (unqualified) supervisor-	Between Groups	15.369	4	3.842	3.452	.014
	Within Groups	56.756	51	1.113		

	Total	72.125	55			
Inexperienced crew -	Between Groups	22.350	4	5.587	9.635	.000
	Within Groups	28.996	50	.580		
	Total	51.345	54			

Although not statistically proven within the parameters of this study, it is important to note experience has an impact on safety (Sawacha et al. 1999).

6.4.5. OWNER'S REPRESENTATIVE, PROJECT MANAGER, AND SUPERINTENDENT

Construction management consultancy firms are becoming more popular in the United States. This change could be linked to the growth in alternative contracting methods in the construction industry (Gordon 1994; Gransberg and Shane 2010). In most cases, the project owner gives authority to an experienced individual (or consulting firm) to represent owner's interest. While carrying out delegated duty/ies, certain factors could impede the quality of work of the consultant. The result may be reduced effectiveness and efficiency which translates to the client not getting optimum value for money spent. The current study made an attempt to identify the impact of certain factors on safety and work quality of a consulting construction manager. Table 6.21 compares the top five factors that impact the work quality of an owner's representative, project manager, and a superintendent. Project managers and superintendents believe that inability to retain skilled craftsmen has the highest impact on work quality on a construction project. Also, poor quality of material was rated as the third most significant factor that could cause considerable impact on work quality of project managers and superintendents.

Conversely, the list of the top five factors that impact the owner's representative has little in common with the other two groups. Availability of construction drawings was highlighted as having the potential to cause a severe impact on work quality.

Although not extensively discussed within the text of Chapter 6, the current study also identified factors that had a considerable positive impact on both safety and quality. These tables can be found in Appendix E.

Table 6.21: Factors that Impact Owner’s Representative, Project Manager and Superintendent- Quality

Negative Description						
	Owner’s Rep		**Project Manager**		**Superintendent**	
Ranking	**Most Impactful Components**	**RII**	**Most Impactful Components**	**RII**	**Most Impactful Components**	**RII**
1	Construction drawings not readily available	-77.78	Inability to retain skilled craftsmen	-75	Inability to retain skilled craftsmen	-90.48
2	Poor working relationships and cohesiveness with co-workers	-72.22	Inexperienced (unqualified) supervisor	-75	Poor material, tools, and equipment storage	-80.95
3	Frequent interruption/interferences	-66.67	Poor quality materials	-75	Poor quality materials	-80.96
4	Unpredictability of the work tasks due to unknown information	-61.11	Inexperienced crew	-66.67	Poor quality of equipment and tools	-76.20
5	Lack of adequate communication within site management	-61.11	Construction drawings not readily available	-58.33	More than one language spoken on construction site	-76.20

In summary, the factors that cause the most impact on worker safety and work quality as identified by the survey participants are poor attitude towards safety and poor quality of material, respectively. Table 6.22 show that 69% of respondents mentioned that a poor attitude towards safety has a significant impact on the safety of construction personnel. As shown in Table 6.23, 73% of participants stated that having to work with material of poor quality has moderate to significant impact on the quality of their work.

Table 6.22: Response Frequency to most Impactful Factor- Safety

Poor attitude towards safety					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	39	23.2	69.6	69.6
	moderate negative impact	6	3.6	10.7	80.4
	minor negative impact	6	3.6	10.7	91.1
	no impact	4	2.4	7.1	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Table 6.22: Response Frequency to most Impactful Factor- Quality

Poor quality materials					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	23	13.7	41.1	41.1
	moderate negative impact	18	10.7	32.1	73.2
	minor negative impact	10	6.0	17.9	91.1
	no impact	5	3.0	8.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

6.5. PROPOSED METHOD FOR MEASURING ENERGY

The last objective of this research is to propose a method of measuring energy on a construction project. To develop a measuring process for the energy concept, input from the data analyzed in Section 6.4 is required. Prior to data analysis, the energy concept was defined and explained in detail in Section 3. Equations for calculating kinetic and potential energy were derived from literature review. To quantify energy on an individual and project level, the following steps were taken:

I. Determine if the assumptions made when selecting the components that make up the energy formula synchronizes with the findings of the data analysis.
II. Determine the magnitude of impact of energy constituent.
III. Develop scales to measure each constituent.
IV. Quantify energy at the work and project levels

6.5.1. VERIFICATION OF ASSUMPTIONS

The Equations in Chapter 3 were derived from literature review and logical construction operation processes. Applying logic required the research team to make certain assumptions prior to data collection and analysis. To determine if the Equations remain functional, data on degree of impact of each factor assessed in the survey was extracted from and assigned to the following energy constituents: Complexity, Uniqueness, Predictability, Repetitiveness, Availability of needed resources, Crowding, Interruptions, switching between task, and Distractions. Table 6.23 shows a combination of measured factors separated into different energy constituents.

Most factors assessed in the survey questionnaire were assigned to an energy constituent on the basis of relevance and similarity to the constituent.

Table 6.23: Distribution of Energy Components into Energy Constituents

Variables of PE & KE	Energy Constituents		Impacting Components								
Nature of Task (NT)	Constituents of NT	**Complexity**	Large project	Task involves high risk of injury	Assigned task is very complex	High number of sub-tasks within one task					
		Uniqueness	Very unique work								
		Predictability	Unpredictability of the work tasks due to unknown information								
		Repetitiveness	Task is highly repetitive	Task is long and continuous							
		Availability of needed resources	Inability to retain skilled craftsmen	Poor material, tools, and equipment storage	Using complex equipment (requires advanced skills)	Lack of familiarity with equipment	Material, tools, and equipment not readily available	Poor quality of equipment and tools	Poor quality of pre-fabrication	Poor quality materials	
Execution of All Tasks (EAT)	Constituents of EAT	**Crowding**	Congested site	Many different crews/trades on site at the same time	Many subcontractors on site at same time	Many different tasks/activities being worked on by different crews at the same time	High amount of paperwork involved				

		Interruptions	Inexperienced crew	Construction drawings not readily available	Low quality of instruction provided for work tasks	High number of overlapping work activities for crew	Frequent interruption/interferences	Slow response to RFI			
		Distractions **Internal**	Poor attitude towards safety	More than one language spoken on construction site	Lack of adequate communication within site management	Night shifts	Inexperienced supervisor	Lack of deserved positive feedback (compliments)	No safety incentive	Poor working relationships and cohesiveness with co-workers	Unorthodox method of Foreman's supervision
		External	Project located in urban area	Adverse weather condition	Low quality of detailed design drawings	Lack of PPE	High number of project scope changes during construction	Use of advanced technologies			
		Switching	Frequent switching between tasks required	You are given new tasks very frequently	.						

* Constituents required to calculate potential energy (value of task, time allowed to complete tasks, and duration factor) are project specific. N/A is used in Tables 6.24 - 6.32 to represent values that are derived from project documents.

The grouping of factors as seen in Table 6.23 provides the researchers an opportunity to assign a figure to the constituents of energy. Since the equations where formulated before the data was compiled, it is paramount that equations be compared to the findings to ensure that the equations remain true representations of the impact felt by construction employees sampled. Tables 6.24, 6.25, 6.26, and 6.27 depict a summary of the values extracted from the questionnaire survey which will be used to determine the validity of the equations. Each table is described below.

6.5.2. VALUE OF ENERGY CONSTITUENTS.

The following listed elements are the constituents of energy as defined by the current research. The mean value of each constituent is derived by calculating the average of the value for safety, and for quality, across all work groups.

Complexity

As seen in tables 6.24 and 6.25, the average ratings of complexity of the task on safety and work quality across all identified work groups are -0.5 and -1.13, respectively. Although the impact of complexity on safety is on the low side when averaged, its impact on quality is significant. Also, complexity has some degree of impact on safety at certain work levels. Results from the survey show that project engineers think complexity has a minor impact on safety of their work.

Uniqueness

A value of -0.024 was calculated as the average impact score of project uniqueness on the safety of construction personnel. In terms of its impact on work quality, an average impact score of 0.4 was calculated, showing it has more of a positive impact than a negative impact. These values indicate that, notwithstanding the uniqueness of a project, uniqueness of task will have little or no negative impact on worker's safety and quality of work. The research team is of the opinion that although there is some merit in this finding, uniqueness could impact other project performance indicators such as productivity, schedule, and cost. Therefore, uniqueness will remain a fundamental constituent of energy which could be negligent depending on the scope of the research that applies the energy concept.

Predictability

Predictability of work/ task was identified as a key factor that impact task performance in construction. Work predictability is one of the foundations of the lean construction concept. High predictability is recognized as a key factor that improves work flow (Alarcon 1997). Since predictability is a denominator in the energy equation (see Equation 3.3 in Sections 3.2.1 and 6.5.4.1), the mean scores, when the factors have positive descriptions will be used. The scores of impacts when the descriptions of identified factors are positive can be found in Tables 6.26 and 6.27. Average impact scores of 1.36 and 1.71 are the calculated scores associated with workers safety and quality of work, respectively. This result shows that work which is more predictable could improve the safety and quality performance of construction personnel.

Repetitiveness

As with predictability, repetitiveness is deemed to have a positive impact on a worker as a result of the presence of a learning curve. A task that is more repetitive will result in learning and lower stress on worker. The values from Tables 6.26 and 6.27 were used to determine if repetitiveness of a task has any impact to work quality and worker safety. For safety of personnel, an average impact value of 0.86 was calculated while 1.15 was estimated as the impact of a task that involves repetition on quality of work.

Availability of resources

All work tiers indicated that availability of resources to carry out assigned tasks has a significant impact on both quality of work and worker safety. Better availability of needed resources will result to better work performance. The average impact scores across the identified work levels for quality of work and worker safety are 2.19 and 2.28, correspondingly. The results from the data analysis show that availability of resources has the most impact on the quality of a foreman's work and the least on that of the owner's representative. Again, the values used for availability of resources are scores extracted from the positive description component section because this constituent of energy is an "enabler" and denominator in the Equation for "nature of task".

Crowding

A worksite that is overly crowded can negatively impact work performance. The average values of the impact of crowding on safety and quality across work categories are -1.6

and -1.14, respectively. It is also important to note that certain work group such as foremen and superintendents, indicate that crowding has a significant impact on safety. Crowding is considered one of the vital components that impact safety and quality of work and therefore retains its place in the energy Equation.

Table 6.24: Summary Values of Energy Constituent when Descriptions are Negative- Safety

Group	Nature of Task					Demand to Complete all Tasks			Execution of All Tasks				
	Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources	Value of all tasks	Time to complete all tasks	Duration / Preceding time	Pace	Crowding	Interruptions	Distractions	Switching
Field Worker	-0.6	-0.1	-1.1	0	-1.8	n/a	n/a	n/a	n/a	-1	-1.4	-2.62	-0.4
Foreman	-875	-0.25	-1.5	-0.375	-2.63	n/a	n/a	n/a	n/a	-2.13	-2.13	-2.76	-0.9
Superintendent	-0.75	0.15	-1.4	-1.43	-2.43	n/a	n/a	n/a	n/a	-2	-2.2	-2.5	-0.57
Project Engineer	-1	-0.5	-1.75	-0.375	-2.12	n/a	n/a	n/a	n/a	-1.5	-2.5	-2.13	-1.13
Project Manager	0.25	1	-0.75	-0.25	-1.75	n/a	n/a	n/a	n/a	-1	-1.75	-2.4	-1
Safety Professional	-0.3	-0.3	-1.4	-1.2	-1.9	n/a	n/a	n/a	n/a	-2.1	-1.6	-2.72	-1.2
Owner's Rep	-0.17	-0.17	-1.17	-0.8	-1.83	n/a	n/a	n/a	n/a	-1.5	-1.3	-2.33	-1

Table 6.25: Summary Values of Energy Constituent when Descriptions are Negative- Quality

Group	Nature of Task					Demand to Complete all Tasks			Execution of All Tasks				
	Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources	Value of all tasks	Time to complete all tasks	Duration/ Preceding time	Pace	Crowding	Interruptions	Distractions	Switching
Field Worker	-0.9	0.1	-1.6	0.9	-1.9	n/a	n/a	n/a	n/a	-0.6	-1.6	-2.3	-1.1
Foreman	-1.25	0.63	-2	1.3	-2.4	n/a	n/a	n/a	n/a	-1.5	-2.13	-2.75	-0.75
Superintendent	-1.4	-0.3	-1.85	0.43	-2.72	n/a	n/a	n/a	n/a	-1.43	-1.86	-2.78	-0.57
Project Engineer	-1.13	0.25	-1.88	0.36	-2.38	n/a	n/a	n/a	n/a	-1	-2.13	-2.65	-1.38
Project Manager	-1	1.75	-0.25	0.75	-2.25	n/a	n/a	n/a	n/a	-0.75	-1.75	-2.56	-0.5
Safety Professional	-1.2	-0.3	-1.4	0.1	-2.1	n/a	n/a	n/a	n/a	-1.5	-1.6	-2.1	-1
Owner's Rep	-1	0.67	-1.83	0.17	-1.67	n/a	n/a	n/a	n/a	-1.3	-2.3	-2.2	-1.67

Interruption

Findings from the current research discovered that interrupting a worker extensively while on duty could lead to significant impact on the workers safety and work quality. Based on the respondents, the average impact values of interruption on safety and quality of work across work categories are -1.84 and -1.91, respectively. It is also important to note that foremen and superintendents consider interruption as a major cause of concern with a score of -2.13 for safety and -2.2 for quality.

Distraction

This is a vital constituent of energy which creates hazards that could lead to an incident and mistakes that construe to poor quality of work. Hinze's Distraction theory (2006, pg. 199) argues that distraction has a significant impact on worker safety performance. Findings from the current research supports the Distraction theory, given that participants highlighted components within the distraction constituent as having significant impact on their safety and quality of work. Poor safety attitude of the worker, which is an example of internal distraction, was assessed as having the most impact on workers safety. The average ratings of the impact of distraction (both internal and external) on worker safety and work quality are -2.5 and -2.48, accordingly.

Switching between tasks

Depending on the nature of task scheduling implemented by a supervisor, some activities may require a worker to switch between tasks often. Past research into task switching has proven that performance is reduced when a worker is required to alternate between tasks often (Pashler et al. 2000). The results from data sampling in the current research show that switching between tasks has some degree of impact on both safety of worker and work quality with scores of -0.89 and -1, correspondingly.

Table 6.26: Summary Values of Energy Constituent when Descriptions are Positive- Safety

Group	Nature of Task					Demand to Complete all Tasks			Execution of All Tasks				
	Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources	Value of all tasks	Time to complete all tasks	Duration/ Preceding time	Pace	Crowding	Interruptions	Distractions	Switching
Field Worker	0.9	0.8	1.2	1.2	2.2	n/a	n/a	n/a	n/a	1.7	2.1	2.4	1.7
Foreman	1.85	1.125	2	0.75	2.25	n/a	n/a	n/a	n/a	1.85	1.63	2.71	1.88
Superintendent	1.833	1.14	1.067	1.17	2.33	n/a	n/a	n/a	n/a	2.14	2.4	2.55	1.67
Project Engineer	1.125	2.25	1.625	0.5	2.5	n/a	n/a	n/a	n/a	2.13	2.75	2.62	1.13
Project Manager	0.5	-0.25	0.25	0.75	2.25	n/a	n/a	n/a	n/a	1	1.5	2.72	0.75
Safety Professional	1.4	1.2	1.8	1	2.1	n/a	n/a	n/a	n/a	2.2	1.8	2.82	1.4
Owner's Rep	0.6	0	1	0.67	1.67	n/a	n/a	n/a	n/a	1.16	1.16	2.3	0.83

Table 6.27: Summary Values of Energy Constituent when Descriptions are Positive- Quality

Group	**Nature of Task**					**Demand to Complete all Tasks**			**Execution of All Tasks**				
	Compl exity	Unique ness	Predicta bility	Repetiti veness	Availability of needed resources	Value of all tasks	Time to complete all tasks	Duration/ Preceding time	Pace	Crowd ing	Interrupt ions	Distract ions	Switchi ng
Field Worker	1.67	1.1	2	1.4	2.4	n/a	n/a	n/a	n/a	1.7	2.5	2.51	2.1
Foreman	1.75	1	2.38	1.25	2.63	n/a	n/a	n/a	n/a	1.75	2.38	2.68	1.88
Superintende nt	2	1	2.17	1.34	2.57	n/a	n/a	n/a	n/a	2	2.43	2.75	1.83
Project Engineer	1.38	1	1.75	1.13	2.25	n/a	n/a	n/a	n/a	1.5	2.38	2.31	1.25
Project Manager	0.25	0.25	0.25	0.75	2.25	n/a	n/a	n/a	n/a	1	1.25	2.55	0.75
Safety Professional	1.4	1.2	1.8	1	2.2	n/a	n/a	n/a	n/a	1.8	1.9	2.1	1.5
Owner's Rep	0.67	0.3	1.67	1.17	1.67	n/a	n/a	n/a	n/a	1.17	1.17	2.78	0.83

6.5.3. IMPACT MEASURING SCALE

As highlighted in Table 6.23, different components make up the constituents of energy. These components were identified through literature review and their impact on workers performance was determined through the responses received from the survey questionnaire. Extensive search into past literature did not highlight a particular means or method for estimating the constituents that make up energy. The current research study proposes a method of measuring the constituents of energy. This will be done by using the responses gotten from the research survey questionnaire. The responses showed that different constituents of energy have different impact on construction personnel. Results from the data analysis show that the factors within a constituent also showed signs of variability in means as is witnessed in Tables 6.24 - 6.27. To determine the impact of individual energy constituents on the energy (KE or PE) felt by construction personnel, a stand-alone number has to be determined for each constituent.

Due to limited time and resources, the current research is focused on measuring the maximum possible impact of identified constituents on energy and lay the foundation for a scaled (gradient) measurement.

Given that the current research is focused on the **maximum negative** impact that could be caused by a component on quality and safety, the maximum value of the components that make-up the various energy constituents was selected as the factor to create a scale. Table 6.28 shows the summary of the impact of components on the quality of work being performed by a field worker and the safety of the field worker. The values in Table 6.28 highlight the average impact of each component on a fieldworker. By consolidating energy components related to each energy constituent, the maximum possible value of a component within a constituent is established and included in the measuring scale. The mean value of the components within each constituent could be represented by adjusting the value on the scale to reflect the average. Tables 6.29 - 6.32 highlight the scaled value for each constituent of energy.

Table 6.28: Impact of Energy Components on a Field worker

Energy Constituent	Component	SAFETY		Quality	
		-ve Impact	+ve Impact	-ve Impact	+ve Impact
Uniqueness	Work is Unique	-0.1	0.8	0.1	1.1
Predictability	Task predictability	-1.1	1.2	-1.6	2
Repetitiveness	Task is Highly repetitive.	0.3	1.2	1	1.2
	Task is long and continuous	0	0.7	0.8	1.4
Complexity	Large Project	0.8	0.9	0.7	1.4
	High risk of injury.	-0.11	1.7	-0.9	1.5
	Complex task.	0.5	1.3	-0.4	1.4
	High number of sub task within 1 task.	-0.6	1.7	-0.1	1.67
Availability of needed resources	Inability to retain skilled men.	-1	1.7	-1.1	1.8
	Poor material and tool storage.	-1.5	2	-1.5	2
	Complex equipment.	-0.6	2.1	-0.3	2
	Lack of familiarity with tools.	-1.8	2.2	-1.3	2.3
	Tools not readily available.	-0.9	2	-1.6	2.1

	Poor quality of tools and equipment.	-1.4	2.1	-1.6	2.4
	Poor quality of pre-fabs.	-1.4	1.9	-1.9	2.3
	Poor quality of material.	-1.4	2.2	-1.7	2.4

The highlighted values in Table 6.28 are the most impactful (negatively or positively) within each constituent. As seen in Figures 6.5 and 6.6, constituents with fewer components may show some degree of bias when selecting the value for the scale. Future research should look into balancing the amount of components within each constituent to reduce the severity of any possible bias associated with having uneven amount of components.

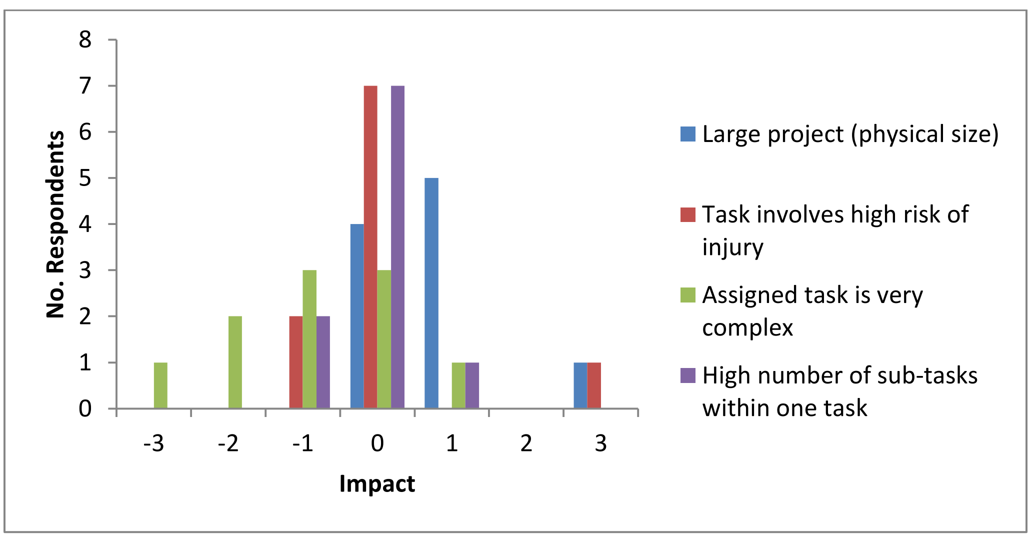


Figure 6.5: Distribution of Fieldworker responses associated with Complexity

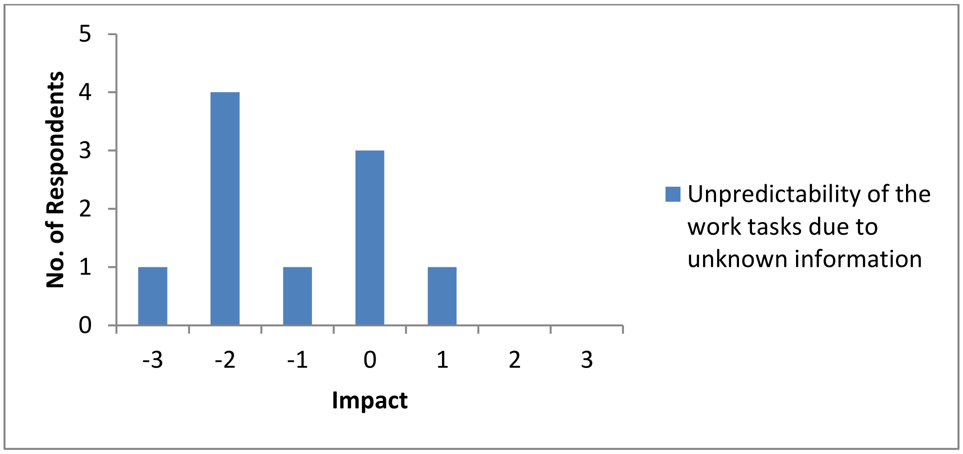


Figure 6.6: Distribution of Fieldworker responses associated with Predictability

To determine if independent scales should be created for each work level and each energy constituent, results from the Welch's ANOVA were checked. Given that there is a statistically significant difference between each work group and energy constituent, the research team decided to create a scale for each constituent of energy at each work level to illustrate the true impact of each constituent on each employee level.

The figures shown in Tables 6.29 - 6.32 are upper-limits of the measuring scale. The scales go from 1 to the number shown in the tables mentioned below.

Table 6.29: Scale for Energy Constituents when Description is Negative - Safety

Group	Nature of Task					Demand to Complete all Tasks			Execution of All Tasks				
	Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources	Value of all tasks	Time to complete all tasks	Duration/ Preceding time	Pace	Crowding	Interruptions	Distractions	Switching
Field Worker	2	1	4	1	7	n/a	n/a	n/a	n/a	4	6	10	2
Foreman	4	1	6	2	11	n/a	n/a	n/a	n/a	9	9	11	4
Superintendent	3	1	6	6	10	n/a	n/a	n/a	n/a	8	9	10	2
Project Engineer	4	2	7	2	8	n/a	n/a	n/a	n/a	6	10	9	5
Project Manager	1	1	3	1	7	n/a	n/a	n/a	n/a	4	7	10	4
Safety Professional	1	1	6	5	8	n/a	n/a	n/a	n/a	8	6	11	5
Owner's Rep	1	1	5	3	7	n/a	n/a	n/a	n/a	6	5	9	4

Table 6.30: Scale for Energy Constituents when Description is Negative - Quality

Group	**Nature of Task**					**Demand to Complete all Tasks**			**Execution of All Tasks**				
	Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources	Value of all tasks	Time to complete all tasks	Duration/ Preceding time	Pace	Crowding	Interruptions	Distractions	Switching
Field Worker	4	1	6	1	8	n/a	n/a	n/a	n/a	2	6	9	4
Foreman	5	1	8	1	10	n/a	n/a	n/a	n/a	6	9	11	3
Superintendent	6	1	7	1	11	n/a	n/a	n/a	n/a	6	7	11	2
Project Engineer	5	1	8	1	10	n/a	n/a	n/a	n/a	4	9	11	6
Project Manager	4	1	1	1	9	n/a	n/a	n/a	n/a	3	7	10	2
Safety Professional	5	1	6	1	8	n/a	n/a	n/a	n/a	6	6	8	4
Owner’s Rep	4	1	7	1	7	n/a	n/a	n/a	n/a	5	9	9	7

Table 6.31: Scale for Energy Constituents when Description is Positive - Quality

Group	Nature of Task					Demand to Complete all Tasks			Execution of All Tasks				
	Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources	Value of all tasks	Time to complete all tasks	Duration/ Preceding time	Pace	Crowding	Interruptions	Distractions	Switching
Field Worker	7	4	8	6	10	n/a	n/a	n/a	n/a	7	10	10	8
Foreman	7	4	10	5	11	n/a	n/a	n/a	n/a	7	10	11	8
Superintendent	8	4	9	5	10	n/a	n/a	n/a	n/a	8	10	10	7
Project Engineer	6	4	7	5	9	n/a	n/a	n/a	n/a	6	10	10	5
Project Manager	1	1	1	3	9	n/a	n/a	n/a	n/a	4	5	11	3
Safety Professional	6	5	7	4	9	n/a	n/a	n/a	n/a	7	8	11	6
Owner's Rep	3	1	7	5	7	n/a	n/a	n/a	n/a	5	5	9	3

Table 6.32: Scale for Energy Constituents when Description is Positive - Safety

Group	Nature of Task					Demand to Complete all Tasks			Execution of All Tasks				
	Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources	Value of all tasks	Time to complete all tasks	Duration/ Preceding time	Pace	Crowding	Interruptions	Distractions	Switching
Field Worker	4	3	5	5	9	n/a	n/a	n/a	n/a	7	8	10	7
Foreman	7	5	8	3	9	n/a	n/a	n/a	n/a	7	7	11	8
Superintendent	7	5	7	5	9	n/a	n/a	n/a	n/a	9	10	11	7
Project Engineer	5	9	7	2	10	n/a	n/a	n/a	n/a	9	11	9	5
Project Manager	2	1	1	3	9	n/a	n/a	n/a	n/a	4	6	10	3
Safety Professional	6	5	7	4	8	n/a	n/a	n/a	n/a	9	7	8	6
Owner's Rep	2	1	4	3	7	n/a	n/a	n/a	n/a	5	5	11	3

6.5.4. QUANTIFICATION OF ENERGY ON WORKER AND PROJECT LEVEL

One of the key objectives of the current study is to propose a framework for quantifying the energy felt by a worker at each work level and determining the interaction of energy across different work tiers. The scale proposed in Section 6.5.3 is used to estimate the value of variables such as the nature of task and execution of all tasks needed to quantify energy. The scale uses the values in Tables 6.29 – 6.32 as the upper-limit of the possible impact of that constituent on energy.

The proposed scale provides the capacity to have different impact gradients without losing the ratio of impact between the energy constituents. Although this capacity is not used in the current study, having the ability to alter the impact magnitude of given constituents of energy will be exploited in future research. As seen in Table 6.29, the effect caused by "complexity" of a task on the safety of a foreman has a maximum impact value of 4 on NT. This value is lower than the maximum impact caused by "availability of needed resources" on the safety of a foreman as highlighted in Table 6.29. The proposed scale provides the ability to measure the impact of energy constituents on an even platform without sacrificing the true impact as identified by respondents.

The process for quantifying the impact of energy on worker safety and work quality are similar. The only difference is in changing the values of the energy constituents using the scale developed for the impact of energy on quality. The energy associated with a construction operation can be measured from four different perspectives as described below.

6.5.4.1. ONE CONSTRUCTION EMPLOYEE, ONE ACTIVITY

To calculate the energy associated with one construction employee, the values that make up kinetic and potential energy are first calculated. The calculation below assumes that a field worker is carrying out a single activity. Certain factors that will be used in the calculation of energy are derived directly from the targeted project's construction operation documents. Information on pace of work, duration, and cost assigned to a task, value of a task, and the deadline to complete a preceding activity are all extracted from the project specific project management plan. Tables 6.33 – 6.36 are extracted measuring scales for the impact of an assigned task on the quality of work and safety of a field worker. The tables below also reflect combination of values extracted from Tables 6.29 – 6.32.

Safety

Table 6.33: Scaled impact of Energy Constituents for Nature of task- Field worker (Safety)

Nature of Task				
Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources
1-2	1	1-5	1-5	1-9

Table 6.34: Scaled impact of Energy Constituents for Execution of all tasks- Field workers (Safety)

Execution of All Tasks			
Crowding	Interruptions	Distractions	Switching
1-4	1-6	1-10	1-2

Quality

Table 6.35: Scaled impact of Energy Constituents for Nature of task- Field worker (Quality)

Nature of Task				
Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources
1-4	1	1-8	1-6	1-10

Table 6.36: Scaled impact of Energy Constituents for Execution of all tasks- Field workers (Quality)

Execution of All Tasks			
Crowding	Interruptions	Distractions	switching
1- 2	1- 6	1- 9	1-4

For the sake of brevity, illustration of the process for measuring energy will focus on just safety. To measure energy associated with quality, a process, similar to the examples below is followed with the only difference being the values that go into NT and ET. Below is an example of calculations for the impact of energy on the safety of a field worker:

*As mentioned in Section 3.2.3, the current study proposes the use of $/hr as the unit of energy.

$$NT = \frac{(\text{Complexity})(\text{Uniqueness})}{(\text{Predictability})(\text{Repetitiveness})(\text{Availability of needed resources})}$$

Since the project property to be evaluated is worker safety, values for the constituent of NT are extracted from Table 6.33. As mentioned in Section 6.5.3, the current study is focused on the maximum negative impact of energy on a worker. Therefore, the maximum values on the measuring scales will be used to calculate the constituents of energy.

$NT = \frac{(2)(1)}{(5)(5)(9)}$ = 0.0089

To determine if a task with an NT value of 0.0089 is considered a "High Threat" task, NT_{min} and NT_{max} are calculated using Equations 3.4 and 3.5.

$$NT_{max} = \frac{(\text{Complexity}_{\text{max}})(\text{Uniqueness}_{\text{max}})}{(\text{Predictability}_{\text{min}})(\text{Repetitiveness}_{\text{min}})(\text{Availability of needed resources}_{\text{min}})} \quad \text{(Eqn. 3.4)}$$

$$NT_{min} = \frac{(\text{Complexity}_{\text{min}})(\text{Uniqueness}_{\text{min}})}{(\text{Predictability}_{\text{max}})(\text{Repetitiveness}_{\text{max}})(\text{Availability of needed resources}_{\text{max}})} \quad \text{(Eqn. 3.5)}$$

$NT_{max} = \frac{(2)(1)}{(1)(1)(1)}$ = 2.0

$NT_{min} = \frac{(1)(1)}{(5)(5)(9)}$ = 0.0044

The value of 0.0088 could be assumed to be within the ambit of a "low threat" task. It should be noted that the current study did not collect empirical data to have the capacity to determine “safe” threat level of an activity. This limitation also applies to all energy constituents.

$$ET = (pace)[(crowding)(interrruptions)(distractions)(switching\ between\ tasks\ )]$$

Values selected for ET are extracted from Table 6.34.

$ET = (Pace)[(4)(6)(10)(2)]$ = 480 (Pace)

The value of ET is equivalent to ET_{max} as a result of using the maximum values on the measuring scale in Table 6.34.

$ET_{min} = (Pace)[(1)(1)(1)(1\ )]$= 1 (Pace)

As mentioned in Section 6.5.1, the value for pace of work is derived from the project plan. Information on cost of activity and schedule are needed to estimate the required pace of work:

$$DCT = \left[\frac{\text{Value of tasks}}{\text{Time to complete all tasks}}\right](DF)$$

Computation of the value of “demand to complete all tasks” (DCT) is project specific. Project information such as duration of task, value of task, cost of activity, and deadline dates are required to calculate the value of DCT.

A hypothetical example of how to derive DCT is given below:

> In a highly sensitive government industrial project worth $1 billion, a field worker is assigned to complete a task that involves installing a 1500 ft long pipe.

The duration assigned to this task is seven work days and it will cost $4,760 to install. Due to the fast paced nature of the project and this activity being on the critical path, the value of the task is approximately $10,000 given the cost associated with impending activities and the lack of float. When this task is finished, the pipe fitter is expected to immediately move to a different station within the construction site and install a similar pipe system, but this time at an elevation of 15ft above the ground. It is estimated that this installation activity will take approximately ten days to complete. The pipe fitter is paid $85 an hour.

Energy, as in, physics is calculated based on a given point in time. To calculate the implication of the DCT and DF on the field worker, the following calculation is carried out:

For calculating DCT, the dollar amount associated with the activity is the value of the activity and not necessarily the activity cost. The duration of the activity is seven work days which translates to 56 work hours. The value of DF is derived from the values associated with the impending activity.

$DCT = \left[\frac{10,000}{56}\right](1 + (\frac{80}{136}))$= 283.61

$PE = [\sum_{i=1}^{n}(Nature\ of\ task)](Demand\ to\ complete\ all\ tasks)$

$PE = [\sum_{i=1}^{n}(0.0088)](283.61)$ = 2.49 $/hr

$KE = [\sum_{i=1}^{n}(Nature\ of\ task)](Execution\ of\ the\ task)$

$KE = [\sum_{i=1}^{n}(0.0088)]\{480(pace)\}$

The pace of an activity can be either calculated in terms of feet per hour or dollars per hour. The pace associated with the activity can be calculated in terms of ft/hr as shown below:

1500ft/56hrs = 26.79 ft/hr.

Since the current study recommends that the unit for energy be in $/hr, the pace of work will have to be in $/hr. Since the cost of the entire activity is $4,760, the cost at a given time (hour) is shown below:

$4,760/56hrs = 85 $/hr

Therefore, the pace of the activity = 85 $/hr

Following the derivation of pace of work, the kinetic energy of the field worker is

0.0088*]{480(85)} = 359.04 $/hr

Given that total energy is KE + PE, the value of the impact of work conditions, factors and resources on a field worker is given below:

359.04 + 2.49 = 361.53 $/hr

This proposed method conforms to the physical process of determining constant energy as shown in Equation 6.1.

Mechanical total energy = KE +PE (Boundless 2014) (Eqn. 6.1)

To estimate the energy felt by other construction employees, a similar calculation is carried out with the values of the constituents of NT and ET in accordance to the developed scales. Iterations can be made using the measuring scales to recognize the difference in impact associated with each constituent.

6.5.4.2. ONE WORKER, MULTIPLE ACTIVITIES

In some cases, the construction schedule requires that more than one activity is undertaken by a single worker simultaneously. To determine the energy felt by a worker carrying out multiple tasks, the nature of task (NT) of each activity is calculated, and then the NT's for all activities are summed. This sum is then multiplied by the derived value of ET. Although not empirically proven, it is implied that the energy level of a personnel increases with every added activity which could lead to heightened risk of a quality or safety related problem occurring.

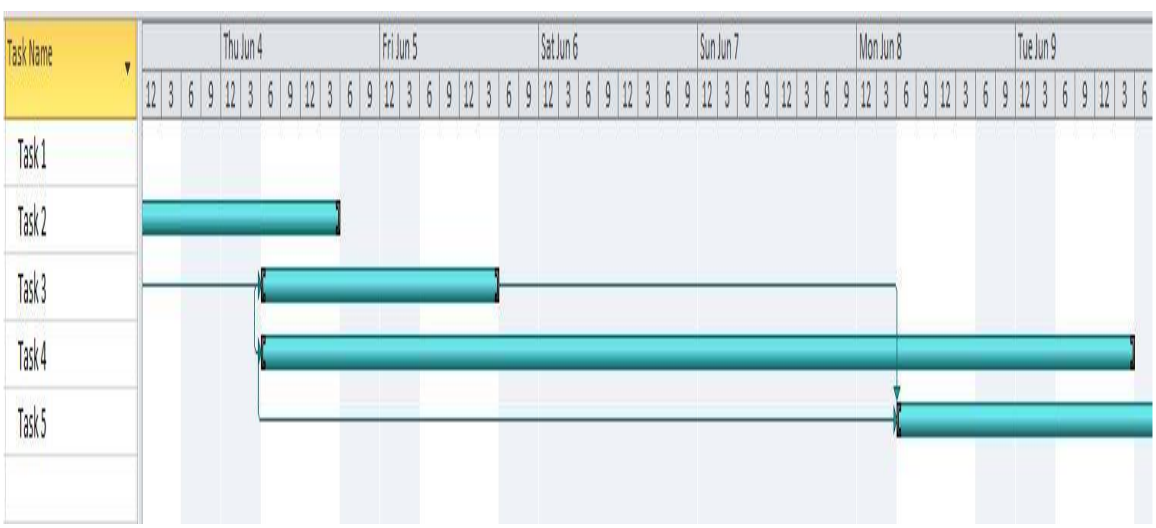


Figure 6.7: Work schedule showing multiple activities

Figure 6.7 depicts a scenario were a field worker is required to carry out two and three activities simultaneously. Logically, these activities could be sequenced to take place one after the other but in some situations, they have to be carried out at the same time. If the energy is being evaluated at the exact point when all three activities are being carried out, the following calculations will apply:

Value for the constituent of energy is extracted from Table 6.33. Previously, the maximum values for each constituent was used to determine the degree of influence the nature of task had on the safety of a worker. Since multiple activities are being considered, the values of the constituent will be adjusted to represent the possibility of carrying out different activities simultaneously.

Activity 1- $NT = \frac{(4*1)}{(6*1*8)}$ = 0.0088

Activity 2- $NT = \frac{(3*1)}{(6*1*7)}$ = 0.0071

Activity 3- $NT = \frac{(2*1)}{(4*1*8)}$ = 0.0063

The example above assumes that all three tasks have different values for the nature of tasks. It should be noted that this research did not capture data for the magnitude of impact associated with specific tasks such as wall framing, steel installation, equipment planning, change order management, etc. To this effect one recommendation of the current study is the generation of quantifiable data on the impact of specific tasks on worker performance.

The total energy felt by the field worker is then calculated using Equations 6.2 and 6.3.

$\sum_{i=1}^{n} PE$=$[\sum_{i=1}^{n}(0.0088 + 0.0071 + 0.0063)](283.61)$ = 6.3 \$/hr (Eqn. 6.2)

$\sum_{i=1}^{n} KE$ = $KE_1 + KE_2 + KE_3$ (Eqn. 6.3)

Where,

$KE_1 = [\sum_{i=1}^{n}(0.0088)]\{ET(pace)\}$ Activity 1

$KE_1 = [\sum_{i=1}^{n}(0.0071)]\{ET(pace)\}$ Activity 2

$KE_3 = [\sum_{i=1}^{n}(0.0063)]\{ET(pace)\}$ Activity 3

The kinetic energy, which is the sum energy felt by the worker when undertaking a task, will be derived by summing the value of all KE. Since the activities (tasks) will be done simultaneously, it is assumed that the impact when combining activities will be less than the sum of carrying them out individually. Future research could look into the magnitude of impact associated with the additional activities.

Assuming the values of ET for the three activities are 470, 500, and 375 respectively and that of pace are 89 \$/hr, 85 \$/hr, and 90 \$/hr accordingly, the total energy can be derived as seen below:

$KE_1 = [\sum_{i=1}^{n}(0.0088)]\{470(89)\}$ = 368.1

$KE_2 = [\sum_{i=1}^{n}(0.0071)]\{500(85)\}$ = 301.75

$KE_3 = \ [\sum_{i=1}^{n}(0.0063)]\{375(90)\}$ = 212.63

KE = 882.48 $/hr

Total energy = KE +PE = 882.48 + 6.3 = 888.78 $/hr

6.5.4.3. MULTIPLE WORKERS WITHIN A GROUP

It is expected that at any given time, a construction project will involve multiple workers with a certain amount of energy at different work levels. The total energy felt by workers identified within a work tier could be independently calculated. This capability becomes important when attempting to evaluate the entire energy felt on a project at a given time. An example of this structure is illustrated Figure 6.8:

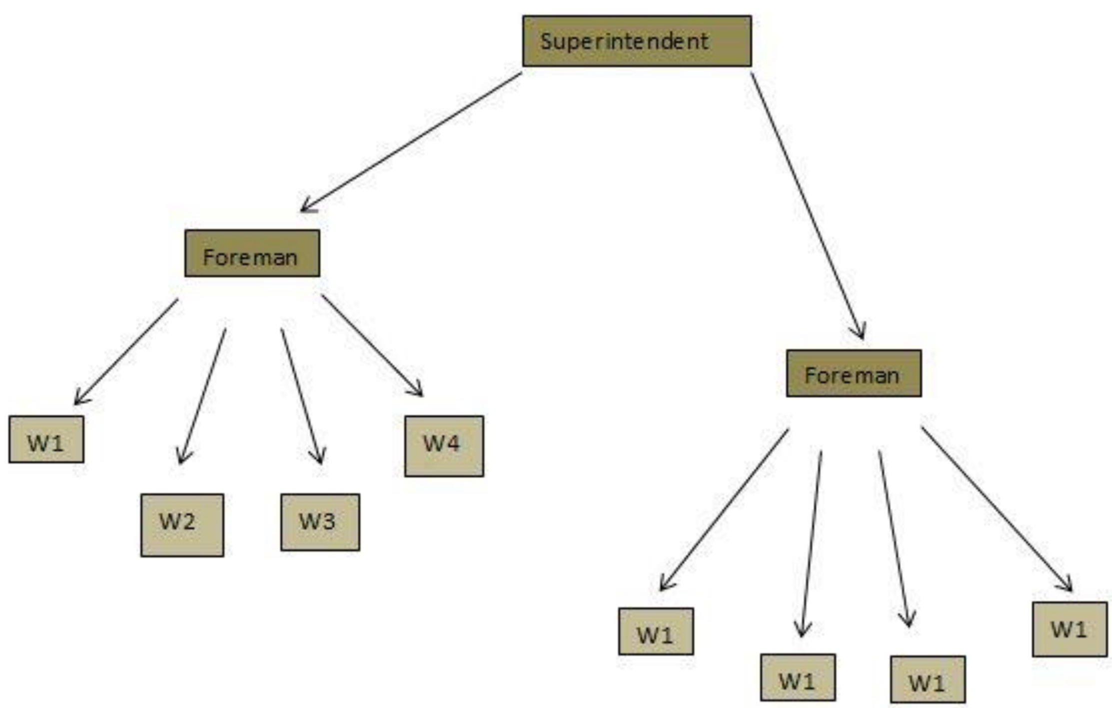


Figure 6.8: Multiple Workers Within a work group

As observed in the construction industry, it is normal to see a foreman running a crew of a group of field workers. To determine the energy of the group or groups (multiple foremen), the energy of each field worker is first calculated and the summed up for all field workers. The energy created by a group of workers can be calculated using Equation 6.3.

$$[\sum_{i=1}^{n}(Field\ worker\ energy)] \qquad \text{(Eqn. 6.3)}$$

Equation 6.3 translates to the following:

Worker 1- KE + PE = 435

Worker 2- KE + PE = 525

Worker 3- KE + PE = 612

Worker 4- KE + PE = 347

Therefore the level of energy within the hypothetical group is 1919 $/hr.

6.5.4.4. PROJECT LEVEL PERSPECTIVE

As stated in Section 2.4, the construction industry lacks a predictive and proactive process of determining the impact of construction operations, associated conditions, and processes on construction employees. Furthermore, the built industry lacks an empirically proven intuitive process of determining how to modify work process to ensure improved safety and quality performance.

To determine the total energy of a construction project, the energy felt by each worker within a work group is first estimated on an individual level followed by calculation based on worker level. This estimation is carried out across all work levels to create a matrix of energy levels which enables the possibility of determining an estimate for a project level energy. The energy at each level is then summed up to create the total energy felt on a project at a given time. Figure 6.9 depicts a hypothetical structure of how energy is summed up on a project.

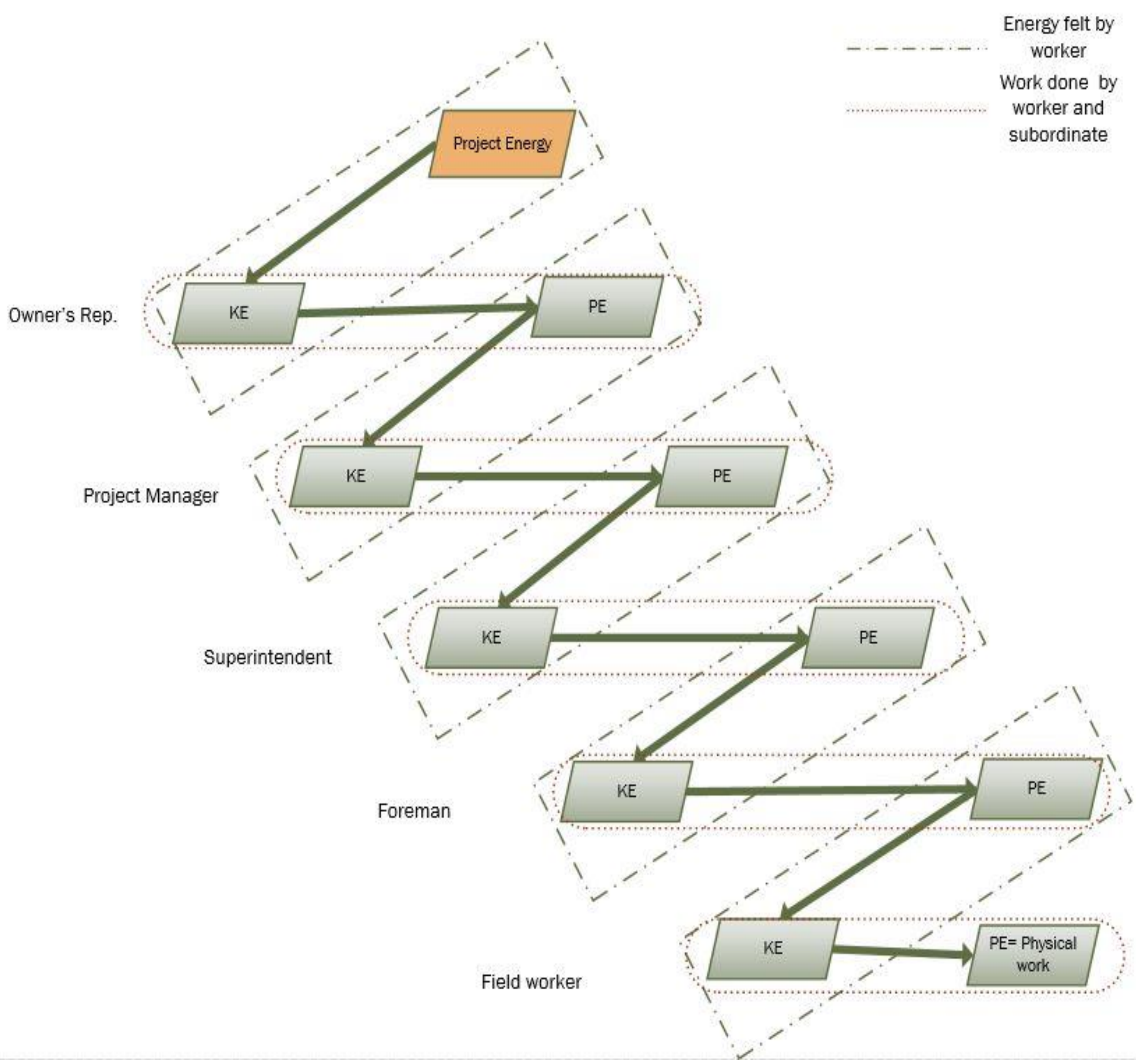


Figure 6.9: Example of Project Level

Estimating Project Level Energy

The calculations below are based on theoretical values. For simplicity, the values of pace and DCT will be arbitrary picked just to show how energy could be evaluated. Ideally, the values will be extracted from the contract documents and project plans. Values for NT and ET will be extracted from the measuring scale tables.

Owner's Representative

$NT = \frac{(1)(1)}{(4)(3)(7)}$ = 0.012

$ET = (Pace)[(6)(5)(9)(4\ )]$ = 1080 (pace)

$KE = \ [\sum_{i=1}^{n}(0.012)]\{1080(140)\}$ = 1,814.4 $/hr

$PE = \ [\sum_{i=1}^{n}(0.012)](1057)$ = 12.69 $/hr

Project Manager

$NT = \frac{(1)(4)}{(1)(3)(9)}$ = 0.148

$ET = (Pace)[(4)(10)(7)(4\ )]$ = 1120 (pace)

$KE = \ [\sum_{i=1}^{n}(0.148)]\{1120(135)\}$ = 22,377.6 $/hr

$PE = \ [\sum_{i=1}^{n}(0.148)](1054.1)$ 156.2 $/hr

Superintendent

$NT = \frac{(3)(1)}{(7)(5)(9)}$ = 0.0095

$ET = (Pace)[(8)(9)(10)(2\ )]$ = 1440 (pace)

$KE = \ [\sum_{i=1}^{n}(0.0095)]\{1440(120)\}$ = 1,641.6 $/hr

$PE = \ [\sum_{i=1}^{n}(0.0095)](1210.5)$ = 11.5 $/hr

Foreman

$NT = \frac{(4)(1)}{(8)(3)(9)}$ = 0.0185

$ET = (Pace)[(9)(9)(11)(4\ )]$ = 3564 (pace)

$KE = \ [\sum_{i=1}^{n}(0.0185)]\{3564(89)\}$ = 5,868.13 $/hr

$PE = \ [\sum_{i=1}^{n}(0.0185)](2221.6)$ = 41.1 $/hr

Field Worker

$NT = \frac{(2)(1)}{(5)(5)(9)}$ = 0.0088

$ET = (Pace)[(4)(6)(10)(2)]$ = 480 (Pace)

$KE = \ [\sum_{i=1}^{n}(0.0088)]\{480(85)\}$ = 359.04 $/hr

$PE = \ [\sum_{i=1}^{n}(0.0088)](283.61)$ = 2.49 $/hr

Figure 6.8 shows a hypothetical example of how project level energy can be derived. Following the statistical analysis result on the mean difference between the impact of energy components on safety and quality within worker levels, it is recommended that independent evaluation of energy level be carried out for assessing worker safety and work quality. Assessing the energy level of a typical project with multiple field workers and foremen, the energy felt by each worker is first calculated then summed at the worker level. This is followed by adding the values derived in each work group to create an estimate of a project level energy value.

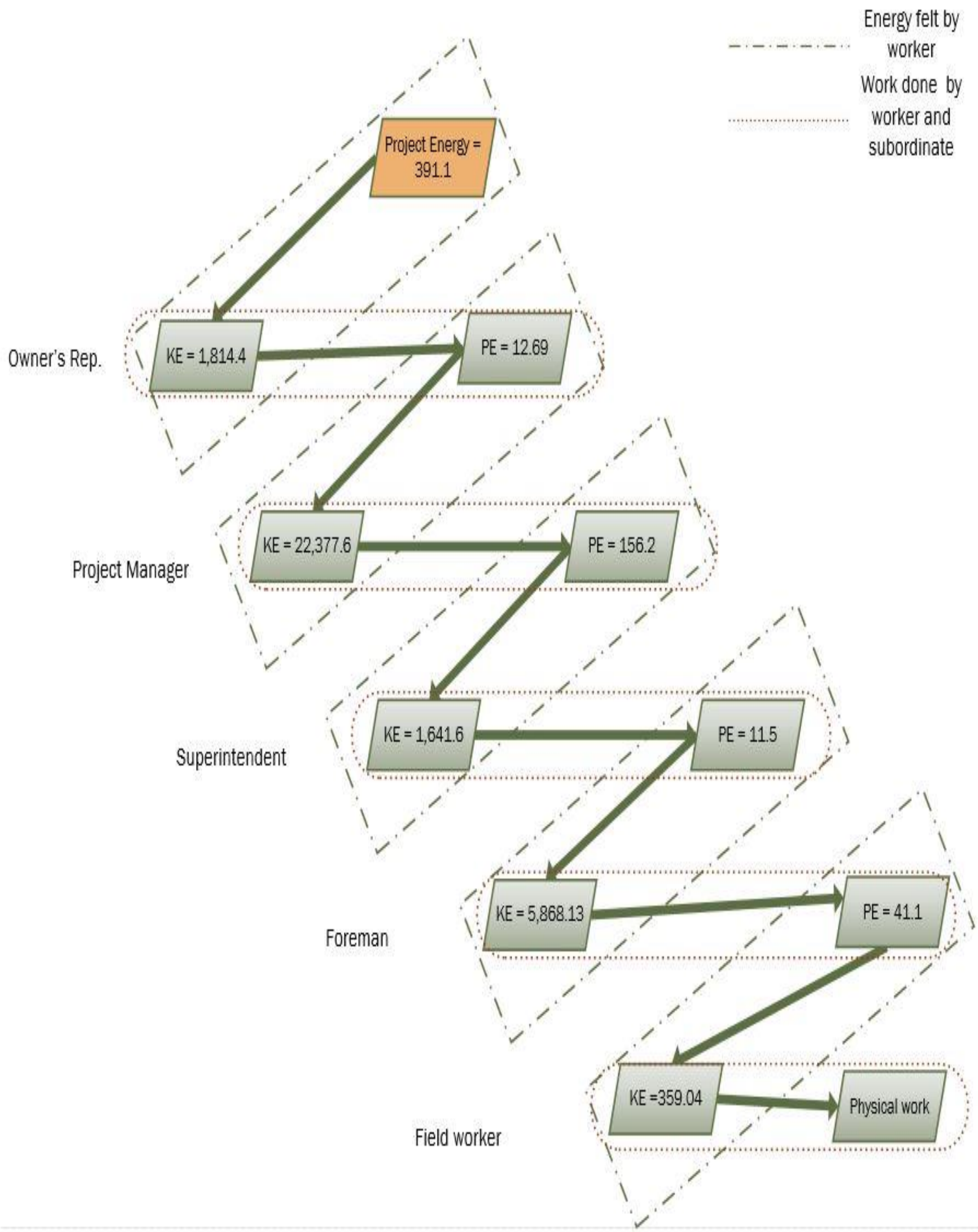


Figure 6.10: Example of Project Energy Tree (all values in $/hr)

6.6. ESTIMATING PROJECT PRESSURE

The concept of pressure in the construction industry was introduced in Section 3.6 of the thesis. Pressure in the context of construction operations was defined as the interaction between physical limitations associated with a project and resources assigned to a project. This can be seen as the effect that the location of a construction, its size, associated equipment, and type has on construction personnel. In physics, pressure is denoted as seen in Equation 3.12.

$$Pressure = \frac{\text{Force}}{\text{Area}} \qquad \text{(Eqn. 3.12)}$$

A proposed method for estimating pressure associated with a construction project is represented in Equation 6.4.

$$Pressure = \frac{\text{Nature of task} * \text{Pace}}{External\ factor} \qquad \text{(Eqn. 6.4)}$$

Nature of task takes into consideration the peculiarities of that task such as its complexity, uniqueness, predictability, and repetitiveness. Similar to force in the pressure equation, nature of a given task could remain relatively constant which accounts for the mass of an object. Pace of work is considered an equivalent of acceleration in the equation for force (Force= mass* acceleration). The area could play a significant role in determining the impact felt by a construction worker. To determine the representative of area within a construction operation process, the research team determined factors that could construe external impact on the way a task impacts a worker. Environmental (external) factors (EF) such as congested site, location, weather condition, experience of supervisor, type of shift, and activity schedule were determined to have an adverse impact on a construction worker. Equation 6.5 represents the mathematical expression of EF.

$$EF = \text{Crowding} * \text{Distraction} \qquad \text{(Eqn. 6.5)}$$

Crowding, as highlighted in Section 3.2.1, is the result of having a considerable amount of different trades and crews on the same project within a stipulated timeframe. This occurrence will definitely have an impact on the pressure felt by workers.

Distractions could either be external or internal. For the purposes of developing the EF, only factors associated with external distraction will be used. Factors such as adverse weather conditions, safety attitude/culture of company or crew, location of project, excessive demand, poor working relationship with co-workers, poor communication, work schedule, etc. are considered to be constituents of external distraction of a construction worker.

As seen in equation 3.12, if a force remains constant, pressure increases with the reduction in area. In a construction operation, poor performance is associated with an increased value of Environmental Factor.

To account for this, the value used to determine pressure is based on when the environmental factors have no negative impact on the performance of workers. When the environmental (external) factors changes to an undesirable condition, the value of pressure increases. The effect of EF on quality of work and worker safety can be calculated using values from Tables 6.37 – 6.40.

It should be noted that at this time, the values used for external distractions are similar to that used for distraction (external and internal). This will be updated subsequently.

Below is a practical example of how pressure can be calculated:

Going by the example highlighted in Section 6.5.4.1, the calculation of a value for the impact of nature of task on a fieldworker safety was 0.0088.

Pace of work associated with the task was calculated as 85 $/hr

EF= 4*10= 40

As seen in Equation 6.4, an increase in EF is associated with a reduction in pressure. In construction operations, increase in environmental factors is actually linked to an increase in pressure of a worker. To account for this, the value used for EF is the value when constituents have the most positive impact on a worker. As the constituents lose their positive impact, the construction employee feels more pressure. These values are found in Table 6.40.

$Pressure = \frac{0.0088 * 85}{70}$ = 0.011

One of the objectives of this thesis is to propose a new procedure for measuring pressure felt by a worker on a construction project. Future research will determine the threshold of pressure on a construction project.

Table 6.37: Modified Scale for Energy Constituents of External Factors when Description is Negative - Safety

Group	Nature of Task					Pace	External Factors	
	Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources	Pace	Crowding	Distractions
Field Worker	2	1	4	1	7	n/a	4	10
Foreman	4	1	6	2	11	n/a	9	11
Superintendent	3	1	6	6	10	n/a	8	10
Project Engineer	4	2	7	2	8	n/a	6	9
Project Manager	1	1	3	1	7	n/a	4	10
Safety Professional	1	1	6	5	8	n/a	8	11
Owner's Rep	1	1	5	3	7	n/a	6	9

Table 2.38: Modified Scale for Energy Constituents of External Factors when Description is Negative - Quality

Group	Nature of Task					Pace	External Factors	
	Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources	Pace	Crowding	Distractions
Field Worker	4	1	6	1	8	n/a	2	9
Foreman	5	1	8	1	10	n/a	6	11
Superintendent	6	1	7	1	11	n/a	6	11
Project Engineer	5	1	8	1	10	n/a	4	11
Project Manager	4	1	1	1	9	n/a	3	10
Safety Professional	5	1	6	1	8	n/a	6	8
Owner's Rep	4	1	7	1	7	n/a	5	9

Table 6.39: Modified Scale for Energy Constituents of External Factors when Description is Positive - Quality

Group	Nature of Task					Pace	External Factors	
	Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources	Pace	Crowding	Distractions
Field Worker	7	4	8	6	10	n/a	7	10
Foreman	7	4	10	5	11	n/a	7	11
Superintendent	8	4	9	5	10	n/a	8	10
Project Engineer	6	4	7	5	9	n/a	6	10
Project Manager	1	1	1	3	9	n/a	4	11
Safety Professional	6	5	7	4	9	n/a	7	11
Owner's Rep	3	1	7	5	7	n/a	5	9

Table 6.40: Modified Scale for Energy Constituents of External Factors when Description is Positive - Safety

Group	Nature of Task					Pace	External Factors	
	Complexity	Uniqueness	Predictability	Repetitiveness	Availability of needed resources	Pace	Crowding	Distractions
Field Worker	4	3	5	5	9	n/a	7	10
Foreman	7	5	8	3	9	n/a	7	11
Superintendent	7	5	7	5	9	n/a	9	11
Project Engineer	5	9	7	2	10	n/a	9	9
Project Manager	2	-1	1	3	9	n/a	4	10
Safety Professional	6	5	7	4	8	n/a	9	8
Owner's Rep	2	1	4	3	7	n/a	5	11

6.7. ESTIMATING PROJECT POWER

Section 3.7 introduced the application of the properties of power, another derivative on energy, to construction operations. As defined earlier, power in a construction operation is the change in work being done by construction personnel relative to time. Prior to this section, energy of a worker was calculated for a given moment in time by summing the potential and kinetic energy. This was done without consideration given to time and evaluation of the amount of change. Power is considered an important component of energy in the current research given its capacity to evaluate the degree of change with respect to time. It is envisaged that a steep change in energy will result in sudden increase in power which could lead to performance concerns. Power can be calculated using Equation 6.6

$$Power_{avg} = \frac{\Delta \text{ Worker Energy}}{\Delta \text{Time}} \qquad \text{(Eqn. 6.6)}$$

Going by the example used in Section 6.5.4.1, a fieldworker was determined to have a total energy of 359.1 $/hr. If the value changes from 359.1 $/hr to 450 $/hr within two hours, the power felt by the worker as a result of the activities being carried out can be calculated using Equation 6.6 as seen in Equation 6.7.

$$Power_{avg} = \frac{450-359.1}{2} = 88.9 \text{ \$/hr} \qquad \text{(Eqn. 6.7)}$$

Future research will determine the maximum value of allowable power for each work level.

Figure 3.4 in Section 3.6 shows the energy level of a project over a 12 month period. For better understanding of the effect of power on a worker, Figure 6.9 depicts a hypothetical hourly energy level of a fieldworker over a period of a week. Figure 6.11 shows some sharp changes in energy level which translates to a high degree of power connected to the task schedule that is required of the fieldworker. The energy level, which is a sum of kinetic and potential energy has some level of impact on the worker's performance and deduced from the survey carried out.

An example of an improved energy level is shown is Figure 6.12. Assuming an acceptable level of energy for a field worker is 250 $/hr, Figure 6.5 clearly shows that at certain periods, the fieldworker is required to carry out activities that demand much more that the set limit. The current research did not determine the level of energy that is deemed appropriate for each work level. This will be carried out in subsequent research.

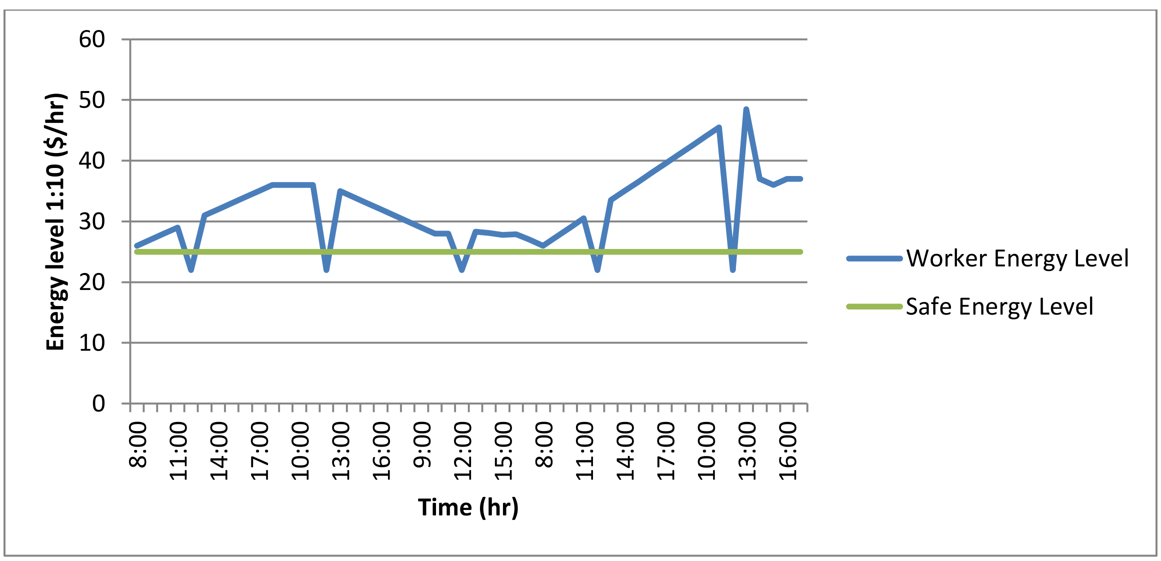


Figure 6.11: Energy Level relative to Time

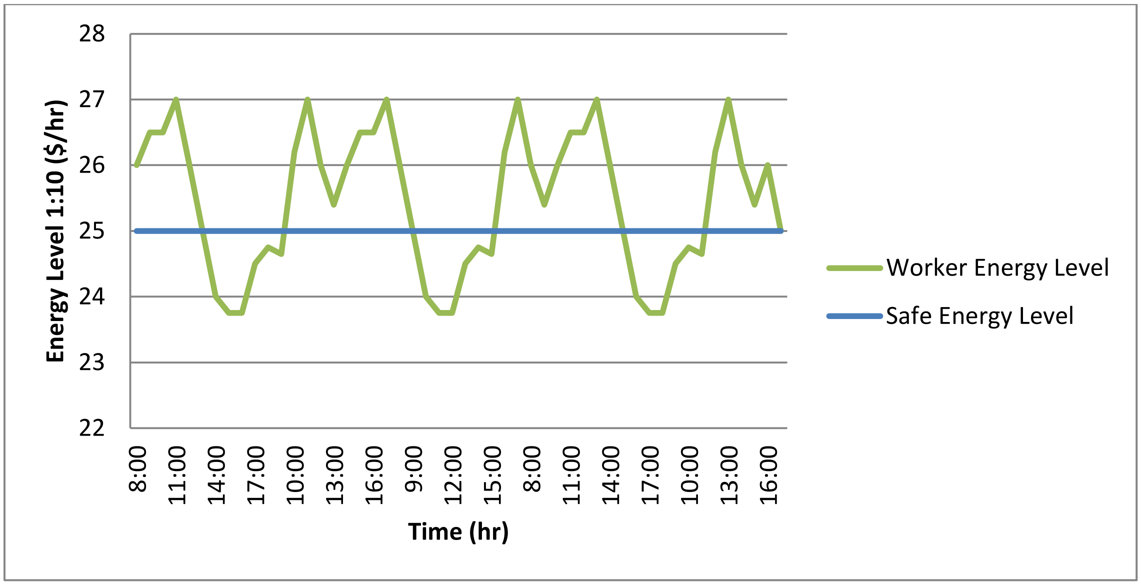


Figure 6.12: Improved Energy Oscillation

7. CHAPTER 7- RESEARCH SUMMARY

7.1. CONCLUSIONS

The primary goal of this research was to introduce a novel approach for measuring, forecasting, and controlling safety and quality performance on a project. To achieve this goal, secondary objectives where formulated to ensure that the proposed methodology had efficacy, was robust, and has some relevance in the construction industry. This section summarizes the findings of the current study as it concerns the research objectives lined out in Chapter 1.

Objective #1

The first objective of the study was to identify factors that have an impact on work quality and worker safety on a project. To achieve this, an extensive literature review was undertaken by the research team. Alongside an in-depth search of literature, input from employees within the construction industry was solicited. This effort led to the compilation of a list of 65 components that have an impact on safety and quality performance of construction employees.

Objective #2

The second objective was to determine which factors impair or aid work quality and worker safety on a project. This was objective was met using three steps:

I. A survey questionnaire was created using the factors that were identified as a result of achieving the first objective. The factors were streamlined to ensure the survey was as concise as possible. To determine the factors that impair as well as those that aid work quality and worker safety, the factors were put forward in both positive and negative descriptions.

II. The survey was then applied to two phases of pilot testing to ensure the target population had sufficient understanding of what is required of the participants. Following a successful dry-run, the questionnaire was distributed to construction employees.

III. The responses from the participants were evaluated to determine which factors were more of an impediment and which factors enhanced participant performance.

Objective #3

The third objective was to determine the degree of impact of each identified factor on work quality and worker safety on a project. The degree of impact of each component on work quality and worker safety was quantified and evaluated on a work tier and project level using the responses received from the survey. Analysis of the feedback shows that while each work level ranked the components differently, attitude of worker to safety and the use of poor quality materials were ranked as the most impactful factors to safety and quality of work on a project level, respectively. Further analysis showed that there was no statistically significant difference when comparing the mean of the impact of all identified factors on safety and quality on a project level. The project-level-based finding did not hold when evaluated on a worker group level. There was a statistically significant difference between impact of factors on work quality and worker safety at all seven work levels.

Objective #4

The fourth objective was to introduce a concept termed "energy" and its relevance to construction operations. Chapter 3 of this thesis was dedicated to expounding on the concept of energy. Extensive discussion, illustration of the adaptability of its mechanical properties to construction operations, Equations derived from basic principles of energy and thermodynamics, and process maps were handled within the text of Chapter 3.

Objective #5

For the proposed theory to be useful, a process for measuring energy on a construction project has to be developed. This was achieved using Equations derived in Chapter 3 and an Energy Constituent Magnitude Scale (ECMS) developed in Chapter 6. The scale was developed using values developed from statistical analysis of the responses to the survey questionnaire.

The overriding objective of this research was to propose a new easy-to-use leading methodology for evaluating safety and quality. This concept has the potential to be a project control tool that could be used by construction project planners to identify possible flashpoints on a construction schedule that could lead to quality and safety concerns prior to the commencement of a project. It could also be used on an active project as an assessment tool to ensure that changes made real-time do not impact worker safety and work quality. The researchers are of the opinion that this concept could be used in both micro and macro management of work process as it relates to construction personnel.

7.2. LIMITATIONS

This research study was constrained by a number of challenges that limits its accuracy and ability to generalize the results to a wider population. They include:

I. The population in this research study was sampled by convenience. In-person distribution of survey questionnaires was limited to Northwest Oregon while the responses received on-line were substantially from the Pacific Northwest. Thus, the result of this study must be treated with caution and cannot be statistically extrapolated across the entire construction industry.

II. The sample size of the population was small and not evenly distributed across the work categories that the research study focused on.

III. The survey questionnaire required approximately 20 minutes to complete which led to a low response rate and incomplete information. Participants may have not spent considerable time on certain sections or questions which could affect the quality of the data.

IV. The values used to develop the measuring scale were derived from the perception of the sampled population. The rating could depend on a number of personal factors such as experience, safety awareness/ knowledge of respondent, and prevailing state of mind.

V. As a result of a lack of available resources, the Relative Impact Index was developed by modifying Equations used in past research. This modification might influence the rating of factors that impact the performance of construction employees.

VI. The relationship between energy constituents (complexity, uniqueness, repetitiveness, etc.) and characteristics of specific activities (e.g., pouring of concrete, installation of partition walls, etc.) was not quantified in this study.

7.3. RECOMMENDATION FOR FURTHER STUDY

As highlighted in the Conclusions section of Chapter 7, the current research study successfully answered the key research questions. The current study laid the foundation for creating a new project property termed energy. As is associated with most novel ideas, there is room for further exploration. Below are possible ways to improve and substantiate the proposed concept:

I. More extensive data sampling

The current research study successfully introduced the energy concept and how it applies to construction. Nevertheless, the measurement process was derived using limited data which could limit the effectiveness and accuracy of the process. It is recommended that a second phase of survey be conducted using a larger population. The result of the current research finding regarding which factors affect worker safety and quality of work of different work levels could guide the process of creating a new survey questionnaire. A shorter, more concise survey questionnaire will improve the response rate, thereby reducing bias and increasing confidence.

II. Assess impact of factors on certain tasks

For a wider application of this concept, assessing the impact of key activities across work levels is important. For example, the complexity associated with carrying out different tasks within a work level differs. To account for this difference, research into the major activities each work level undertakes should be looked into. Findings from this research should be included in the next phase of survey questionnaire. At the field worker level, surveys questionnaires should be distributed according to trades to improve the quality of response.

III. Capacity to have different gradients on measuring scale

The current research developed a scale for each constituent of energy but used a fixed value (maximum) for the estimation of energy. To improve the quality of measurement and assessment, qualitative data on degree of severity should be collected. This could be achieved by asking respondents questions on severity of impact and frequency of occurrence of each component that makes up the energy constituent.

IV. Develop and validate a measurement tool

The current investigation suggested a method that could be used to quantify the energy level on a project at a given time. It is recommended that a tool that incorporates the measuring process set forth in this research study be created. A case study should be used to show how the tool could be used on a construction project. Furthermore, the tool should be validated on an active project as to determine the soundness of the instrument.

V. **Determining appropriate level of energy**

Following validation of the tool, it is research worthy to determine what the appropriate level of energy for each work group should be. This will enable project planners to determine if a project schedule or resource planning should be adjusted, or if more safety and quality control measures should be put in place to counter the effects of a high level of energy.

VI. **Application of Energy to other project properties e.g., cost, productivity, scheduling, etc.**

As highlighted in the literature review, project performance could be measured using different indicators. This research focused on evaluating just two project performance indicators: quality and safety. Future research could look into how energy could be used to improve productivity, reduce cost, optimize schedule, enhance social sustainability of employees, etc.

This research study only scratched the surface of the potential of the energy concept. The energy concept is a widely applicable approach that shows how the interaction between different work levels has an impact on a project. The combination of the micro detailed approach to a system level assessment creates a better understanding of how work relationships and interactions within construction operations affect the performance of a project. This relationship shows that improving the performance of workers at just one level does not necessarily assure improved performance at the project level since the root cause of the problem could be from a different level. Past studies highlighted the need for a system-based approach as a means of improving project performance. Hopefully, the energy concept will spur more intellectual discussion that will lead to the creation of a sustainable model which will have a positive impact on construction projects.

Bibliography

Adebayo Akanbi Oladapo, Oyedolapo Ogunbiyi. 2014. “An Empirical Study of the Impact of Lean Construction Techniques on Sustainable Construction in the UK.” *Construction Innovation* 14 (1): 88. doi:10.1108/CI-08-2012-0045.

Ai Lin Teo, Evelyn, and Florence Yean Yng Ling. 2006. “Developing a Model to Measure the Effectiveness of Safety Management Systems of Construction Sites.” *Building and Environment* 41 (11): 1584–92. doi:10.1016/j.buildenv.2005.06.005.

Aksorn, Thanet, and B. H. W. Hadikusumo. 2008. “Critical Success Factors Influencing Safety Program Performance in Thai Construction Projects.” *Safety Science*, Construction Safety, 46 (4): 709–27. doi:10.1016/j.ssci.2007.06.006.

Alarcon, Luis. 1997. *Lean Construction*. Taylor & Francis.

Alhazmi, T, and R McCaffer. 2000. “Project Procurement System Selection Model.” *Journal of Construction Engineering and Management* 126 (3): 176–84. doi:10.1061/(ASCE)0733-9364(2000)126:3(176).

Ali, Azlan S., and Ismail Rahmat. 2010. “The Performance Measurement of Construction Projects Managed by ISO-certified Contractors in Malaysia.” *Journal of Retail & Leisure Property* 9 (1): 25–35. doi:10.1057/rlp.2009.20.

Ali, Hany Abd Elshakour M., Ibrahim A. Al-Sulaihi, and Khalid S. Al-Gahtani. 2013. “Indicators for Measuring Performance of Building Construction Companies in Kingdom of Saudi Arabia.” *Journal of King Saud University - Engineering Sciences* 25 (2): 125–34. doi:10.1016/j.jksues.2012.03.002.

Alsamadani, Rayyan, and Matthew R. Hallowell. 2013. "Relationships Among Language Proficiency, Communication Patterns, and Safety Performance in Small Work Crews in the United States." *Journal of Construction Engineering and Management* 139 (9): 1125–34. doi:10.1061/(ASCE)CO.1943-7862.0000724.

Alzahrani, Jaman I., and Margaret W. Emsley. 2013. "The Impact of Contractors' Attributes on Construction Project Success: A Post Construction Evaluation." *International Journal of Project Management* 31 (2): 313–22. doi:10.1016/j.ijproman.2012.06.006.

Ankrah, Nii Amponsah. 2007. "An Investigation into the Impact of Culture on Construction Project Performance". University of Wolverhampton. http://wlv.openrepository.com/wlv/handle/2436/14403.

Anna Dubois, and Lars-Erik Gadde. 2002. "The Construction Industry as a Loosely Coupled System: Implications for Productivity and Innovation." *Construction Management & Economics* 20 (7): 621. doi:10.1080/01440190210163543.

Arditi, David, Ahmed Elhassan, and Cengiz Toklu. 2002. "Constructability Analysis in the Design Firm." *Journal of Construction Engineering and Management* 128 (2): 117–26. doi:10.1061/(ASCE)0733-9364(2002)128:2(117).

Arditi, David, and H. Murat Gunaydin. 1998. "Factors That Affect Process Quality in the Life Cycle of Building Projects." *Journal of Construction Engineering and Management* 124 (3): 194–203. doi:10.1061/(ASCE)0733-9364(1998)124:3(194).

Aziz, Remon Fayek, and Sherif Mohamed Hafez. 2013. “Applying Lean Thinking in Construction and Performance Improvement.” *Alexandria Engineering Journal* 52 (4): 679–95. doi:10.1016/j.aej.2013.04.008.

Baker, Bruce N., David C. Murphy, and Dalmar Fisher. 1997. “Factors Affecting Project Success.” In *Project Management Handbook*, edited by David I. Clelandessor and William R. Kingessor Fellow, 902–19. John Wiley & Sons, Inc. http://onlinelibrary.wiley.com/doi/10.1002/9780470172353.ch35/summary.

BLS. 2015. “Industries at a Glance: Construction: NAICS 23.” http://www.bls.gov/iag/tgs/iag23.htm.

Boukamp, Frank, and Burcu Akinci. 2004. “Towards Automated Defect Detection: Object-oriented Modeling of Construction Specifications.”

Boundless. 2014. “Conservation of Mechanical Energy.” *Boundless*, November. https://www.boundless.com/physics/textbooks/boundless-physics-textbook/work-and-energy-6/potential-energy-and-conservation-of-energy-64/conservation-of-mechanical-energy-283-5219/.

Bryman, Alan. 1984. “The Debate About Quantitative and Qualitative Research: A Question of Method or Epistemology?” *The British Journal of Sociology* 35 (1): 75–92. doi:10.2307/590553.

Burati, James L., Jodi Farrington, and William B. Ledbetter. 1992. “Causes of Quality Deviations in Design and Construction.” *Journal of Construction Engineering and Management* 118 (1): 34–49. doi:10.1061/(ASCE)0733-9364(1992)118:1(34).

Business Roundtable, and Construction Industry Cost Effectiveness Task Force. 1982. *Contractual arrangements: a construction industry cost effectiveness project report.* New York, N.Y.: Business Roundtable.

Chan, Albert PC, David Scot, and Ada Chan. 2004. “Factors Affecting the Success of a Construction Project.” *Journal of Construction Engineering and Management* 130 (1): 153–55. doi:10.1061/(ASCE)0733-9364(2004)130:1(153).

Cheung, Sai On, Henry C. H. Suen, and Kevin K. W. Cheung. 2004. “PPMS: a Web-based Construction Project Performance Monitoring System.” *Automation in Construction* 13 (3): 361–76. doi:10.1016/j.autcon.2003.12.001.

Coffey, Vaughan. 2008. “Measuring Quality : How Does This Improve Construction Performance?” In *CIB International Conference on Building Education and Research : Building Resilience*, edited by Richard Haigh and Dilanthi Amaratunga. Heritance, Kandalama, Sri Lanka: School of the Built Environment, University of Salford, UK. http://www.bear2008.org/.

Cooke-Davies, Terry. 2002. “The ‘real’ Success Factors on Projects.” *International Journal of Project Management* 20 (3): 185–90. doi:10.1016/S0263-7863(01)00067-9.

Cox, Robert, Raja Issa, and Dar Ahrens. 2003. “Management’s Perception of Key Performance Indicators for Construction.” *Journal of Construction Engineering and Management* 129 (2): 142–51. doi:10.1061/(ASCE)0733-9364(2003)129:2(142).

Creswell, John W. 2013. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications.

Cristobal, Jose Ramon. 2009. “Time, Cost, and Quality in a Road Building Project.” *Journal of Construction Engineering and Management* 135 (11): 1271–74. doi:10.1061/(ASCE)CO.1943-7862.0000094.

Cutnell, John. 2012. *e-Study Guide for: Physics*. Cram101 Textbook Reviews.

D I Ikediashi, A. Mendie. 2012. “Key Performance Indicators of Design and Build Projects in Nigeria.” *Journal of Human Ecology* 37: 37–46.

Dai, Jiukun, Paul M. Goodrum, and William F. Maloney. 2009. “Construction Craft Workers’ Perceptions of the Factors Affecting Their Productivity.” *Journal of Construction Engineering and Management* 135 (3): 217–26.

Dainty, Andrew RJ, Mei-I. Cheng, and David R. Moore. 2005. “Competency-based Model for Predicting Construction Project Managers’ Performance.” *Journal of Management in Engineering* 21 (1): 2–9.

Davey, Caroline L., John McDonald, David Lowe, Roy Duff, James A. Powell, and Jennifer E. Powell. 2006. “Defects Liability Management by Design.” *Building Research & Information* 34 (2): 145–53. doi:10.1080/09613210500492991.

Deffenbaugh, Ronald L. 1993. “Total Quality Management at Construction Jobsites.” *Journal of Management in Engineering* 9 (4): 382–89. doi:10.1061/(ASCE)9742-597X(1993)9:4(382).

Dharmapalan, Vineeth. 2011. “Risk factor quantification of design elements for multistory commercial office buildings”, June. http://ir.library.oregonstate.edu/xmlui/handle/1957/21805.

Donaghy, Rita. 2010. *The Government Response to the Rita Donaghy Report*. The Stationery Office.

El- Mashaleh, Mohammad, Edward Minchin, and William O'Brian. 2007. "Management of Construction Firm Performance Using Benchmarking." *Journal of Management in Engineering* 23 (1): 10–17. doi:10.1061/(ASCE)0742-597X(2007)23:1(10).

El- Mashaleh, Mohammad, William O'Brian, and Edward Minchin. 2006. "Firm Performance and Information Technology Utilization in the Construction Industry." *Journal of Construction Engineering and Management* 132 (5): 499–507. doi:10.1061/(ASCE)0733-9364(2006)132:5(499).

Enshassi, Adnan, Sherif Mohamed, and Saleh Abushaban. 2009. "Factors Affecting the Performance of Construction Projects in the Gaza Strip." *Journal of Civil Engineering and Management* 15 (3): 269–80.

Everett, John G, and Peter B. Frank. 1996. "Costs of Accidents and Injuries to the Construction Industry." *Journal of Construction Engineering and Management* 122 (2): 158–64. doi:10.1061/(ASCE)0733-9364(1996)122:2(158).

Froese, Thomas M. 2015. "Impact of Emerging Information Technology on Information Management." In *Computing in Civil Engineering (2005)*, 1–10. American Society of Civil Engineers. Accessed April 22. http://ascelibrary.org/doi/abs/10.1061/40794%28179%29162.

Gambatese, John A. 1998. "Liability in Designing for Construction Worker Safety." *Journal of Architectural Engineering* 4 (3): 107–12. doi:10.1061/(ASCE)1076-0431(1998)4:3(107).

———. 2000a. “Owner Involvement in Construction Site Safety.” In *Construction Congress VI*, 661–70. American Society of Civil Engineers. http://ascelibrary.org/doi/abs/10.1061/40475%28278%2971.

———. 2000b. “Safety Constructability: Designer Involvement in Construction Site Safety.” In *Construction Congress VI*, 650–60. American Society of Civil Engineers. http://ascelibrary.org/doi/abs/10.1061/40475%28278%2970.

Gambatese, John A., Michael Behm, and Jimmy Hinze. 2005. “Viability of Designing for Construction Worker Safety.” *Journal of Construction Engineering and Management* 131 (9): 1029–36. doi:10.1061/(ASCE)0733-9364(2005)131:9(1029).

Gambatese, John A., Jimmy Hinze, and Carl Haas. 1997. “Tool to Design for Construction Worker Safety.” *Journal of Architectural Engineering* 3 (1): 32–41. doi:10.1061/(ASCE)1076-0431(1997)3:1(32).

Garza, Jesus M. de la, Donn E. Hancher, and Lisa Decker. 1998. “Analysis of Safety Indicators in Construction.” *Journal of Construction Engineering and Management* 124 (4): 312–14. doi:10.1061/(ASCE)0733-9364(1998)124:4(312).

Ghaderi, Roozbeh, and Mohammad Kasirossafar. 2015. “Construction Safety in Design Process.” In *AEI 2011*, 464–71. American Society of Civil Engineers. Accessed April 21. http://ascelibrary.org/doi/abs/10.1061/41168%28399%2954.

Giel, B., and Raja Issa. 2014. “Framework for Evaluating the BIM Competencies of Building Owners.” In *Computing in Civil and Building Engineering (2014)*, 552–59.

American Society of Civil Engineers. http://ascelibrary.org/doi/abs/10.1061/9780784413616.069.

Glen, Ballard, and Gregory Howell. 1998. “Shielding Production: Essential Step in Production Control.” *Journal of Construction Engineering and Management* 124 (1): 11–17. doi:10.1061/(ASCE)0733-9364(1998)124:1(11).

Gliem, Joseph A., and Rosemary R. Gliem. 2003. “Calculating, Interpreting, And Reporting Cronbach’s Alpha Reliability Coefficient For Likert-Type Scales.” https://scholarworks.iupui.edu/handle/1805/344.

Gordon, Christopher. 1994. “Choosing Appropriate Construction Contracting Method.” *Journal of Construction Engineering and Management* 120 (1): 196–210. doi:10.1061/(ASCE)0733-9364(1994)120:1(196).

Gorsuch, Richard L. 1983. *Factor Analysis*. L. Erlbaum Associates.

Gransberg, Douglas D., and Jennifer Sue Shane. 2010. *Construction Manager-at-risk Project Delivery for Highway Programs*. Transportation Research Board.

Graves, Ray. 1993. “Total Quality—Does It Work in Engineering Management?” *Journal of Management in Engineering* 9 (4): 444–55. doi:10.1061/(ASCE)9742-597X(1993)9:4(444).

Hadikusumo, B, and Steve Rowlinson. 2004. “Capturing Safety Knowledge Using Design-for-Safety-Process Tool.” *Journal of Construction Engineering and Management* 130 (2): 281–89. doi:10.1061/(ASCE)0733-9364(2004)130:2(281).

Halliday, David, Robert Resnick, and Jearl Walker. 2013. *Fundamentals of Physics Extended*. 10th Edition Binder Ready Version ed. S.l.: Wiley.

Hallowell, and John A. Gambatese. 2009. “Construction Safety Risk Mitigation.” *Journal of Construction Engineering and Management* 135 (12): 1316–23.

Hallowell, Matthew. 2010. “Cost-effectiveness of Construction Safety Programme Elements.” *Construction Management and Economics* 28 (1): 25–34.

Harvey, Danny. 2013. *Energy and the New Reality 1 - Energy Efficiency and the Demand for Energy Services*. Routledge.

Hasan, S, Mohamed Al- Hussein, U Hermann, and Hassan Safouhi. 2015. “Integrated Module for Mobile Crane Dynamic Instability Analysis and Supporting System Design.” In *Construction Research Congress 2009*, 386–95. American Society of Civil Engineers. Accessed April 22. http://ascelibrary.org/doi/abs/10.1061/41020%28339%2940.

Haslam, R. A., S. A. Hide, A. G. F. Gibb, D. E. Gyi, T. Pavitt, S. Atkinson, and A. R. Duff. 2005. “Contributing Factors in Construction Accidents.” *Applied Ergonomics*, Ergonomics in Building and Construction, 36 (4): 401–15. doi:10.1016/j.apergo.2004.12.002.

Hayne, Graham, Bimal Kumar, and Billy Hare. 2014. “The Development of a Framework for a Design for Safety BIM Tool.” In *Computing in Civil and Building Engineering (2014)*, 49–56. American Society of Civil Engineers. http://ascelibrary.org/doi/abs/10.1061/9780784413616.007.

Hinze, Jimmie. 2006. *Construction Safety Second Edition*. 2nd. ed. Gainesville, FL: Pearson Education, Inc. as Pre.

Hinze, Jimmy, and Paul Raboud. 1989. “Closure to ‘Safety on Large Building Construction Projects’ by Jimmie Hinze and Paul Raboud (June, 1988, Vol. 114, No. 2).” *Journal of Construction Engineering and Management* 115 (4): 644–45. doi:10.1061/(ASCE)0733-9364(1989)115:4(644).

Hinze, Jimmy, and Gary Wilson. 2000. “Moving Toward a Zero Injury Objective.” *Journal of Construction Engineering and Management* 126 (5): 399–403. doi:10.1061/(ASCE)0733-9364(2000)126:5(399).

Holmes, Noni, Helen Lingard, Zeynep Yesilyurt, and Fred De Munk. 1999. “An Exploratory Study of Meanings of Risk Control for Long Term and Acute Effect Occupational Health and Safety Risks in Small Business Construction Firms.” *Journal of Safety Research* 30 (4): 251–61. doi:10.1016/S0022-4375(99)00020-1.

Hoonakker, Peter, Pascale Carayon, and Todd Loushine. 2010. “Barriers and Benefits of Quality Management in the Construction Industry: An Empirical Study.” *Total Quality Management & Business Excellence* 21 (9): 953–69. doi:10.1080/14783363.2010.487673.

Hoonakker, Peter, Pascale Carayona, and Todd Loushine. 2011. “Barriers and Benefits of Quality Management in the Construction Industry: An Empirical Study.” *Quality Control and Applied Statistics* 56 (5): 475–77.

Howes, Rodney. 2000. “Improving the Performance of Earned Value Analysis as a Construction Project Management Tool.” *Engineering Construction and Architectural Management* 7 (4): 399–411. doi:10.1111/j.1365-232X.2000.00171.pp.x.

Huang, Xinyu, and Jimmy Hinze. 2006. “Owner’s Role in Construction Safety.” *Journal of Construction Engineering and Management* 132 (2): 164–73. doi:10.1061/(ASCE)0733-9364(2006)132:2(164).

Hwang, Bon-Gang, Stephen R. Thomas, Carl Haas, and Carlos H. Caldas. 2009. “Measuring the Impact of Rework on Construction Cost Performance.” *Journal of Construction Engineering and Management* 135 (3): 187–98. doi:10.1061/(ASCE)0733-9364(2009)135:3(187).

Ikpe, Elias, Felix Hammon, and David Oloke. 2012. “Cost-Benefit Analysis for Accident Prevention in Construction Projects.” *Journal of Construction Engineering and Management* 138 (8): 991–98. doi:10.1061/(ASCE)CO.1943-7862.0000496.

Isabelina Nahmens, Laura H. Ikuma. 2009. “An Empirical Examination of the Relationship Between Lean Construction and Safety in the Industrialized Housing Industry.”

Jang, Won-Suk, and Mirosław J. Skibniewski. 2009. “Cost-Benefit Analysis of Embedded Sensor System for Construction Materials Tracking.” *Journal of Construction Engineering and Management* 135 (5): 378–86. doi:10.1061/(ASCE)0733-9364(2009)135:5(378).

Jaselskis, Edward, Stuart Anderson, and Jeffrey S. Russell. 1996. “Strategies for Achieving Excellence in Construction Safety Performance.” *Journal of Construction Engineering and Management* 122 (1): 61–70. doi:10.1061/(ASCE)0733-9364(1996)122:1(61).

Jastaniah, Yasir R. 1997. “Performance Evaluation and Benchmarking of Construction Industry Projects Using Data Envelopment Analysis /.”

Jessica, Tega. 2010. “Define Entropy.” *Universe Today*. http://www.universetoday.com/51887/define-entropy/.

Jick, Todd D. 1979. “Mixing Qualitative and Quantitative Methods: Triangulation in Action.” *Administrative Science Quarterly* 24 (4): 602–11. doi:10.2307/2392366.

Johnson, Jeff W., and James M. Lebreton. 2004. “History and Use of Relative Importance Indices in Organizational Research.” *ORGANIZATIONAL RESEARCH METHODS*, no. 3: 2004.

Josephson, P. -E, and Y Hammarlund. 1999. “The Causes and Costs of Defects in Construction: A Study of Seven Building Projects.” *Automation in Construction* 8 (6): 681–87. doi:10.1016/S0926-5805(98)00114-9.

Juran, Joseph M., and Frank M. Gryna. 1993. *Quality Planning and Analysis: From Product Development Through Use*. McGraw-Hill.

Kaming, Peter F., Paul O. Olomolaiye, Gary D. Holt, and Frank C. Harris. 1998. “What Motivates Construction Craftsmen in Developing Countries? A Case Study of Indonesia.” *Building and Environment* 33 (2–3): 131–41. doi:10.1016/S0360-1323(97)00041-3.

Kang, Youngcheol, William O’Brian, Stephen R. Thomas, and Robert E. Chapman. 2008. “Impact of Information Technologies on Performance: Cross Study Comparison.” *Journal of Construction Engineering and Management* 134 (11): 852–63. doi:10.1061/(ASCE)0733-9364(2008)134:11(852).

Kangari, Roozbeh. 1988. “Business Failure in Construction Industry.” *Journal of Construction Engineering and Management* 114 (2): 172–90. doi:10.1061/(ASCE)0733-9364(1988)114:2(172).

Kaplan, Robert S., and avid P. Norton. 2005. “The Balanced Scorecard: Measures That Drive Performance.” *Harvard Business Review*. https://hbr.org/2005/07/the-balanced-scorecard-measures-that-drive-performance.

Kartam, Nabil A. 1997. “Integrating Safety and Health Performance into Construction CPM.” *Journal of Construction Engineering and Management* 123 (2): 121–26. doi:10.1061/(ASCE)0733-9364(1997)123:2(121).

Kasirossafar, Mohammad, and Farzad Shahbodaghlou. 2012a. “Application of Visualization Technologies to the Design for Safety Concept.” In *Forensic Engineering 2012*, 370–77. American Society of Civil Engineers. http://ascelibrary.org/doi/abs/10.1061/9780784412640.040.

———. 2012b. “Building Information Modeling or Construction Safety Planning.” In *ICSDEC 2012@ sDeveloping the Frontier of Sustainable Design, Engineering, and Construction*, 1017–24. ASCE. http://ascelibrary.org/doi/abs/10.1061/9780784412688.120.

Kim, Byung-Cheol, and Kenneth F. Reinschmidt. 2011. “Combination of Project Cost Forecasts in Earned Value Management.” *Journal of Construction Engineering and Management* 137 (11): 958–66.

Kruskal, William. 1984. “Concepts of Relative Importance.” *Questiió: Quaderns d’Estadística, Sistemes, Informatica i Investigació Operativa* 8 (1): 39–45.

KWAK, YOUNG H., and C. WILLIAM IBBS. 31. "Calculating project management's return on investment." *PROJECT MANAGEMENT JOURNAL*, no. 2: 2000.

Lam, E, D Chan, and A Chan. 2008. "Determinants of Successful Design-Build Projects." *Journal of Construction Engineering and Management* 134 (5): 333–41. doi:10.1061/(ASCE)0733-9364(2008)134:5(333).

Lester, Ronald H., Norbert L. Enrick, and Harry E. Mottley Jr. 1992. *Quality Control for Profit: Gaining the Competitive Edge, Third Edition,*. CRC Press.

Leung, Mei- yung, Yee-Shan Chan, and Paul Olomolaiye. 2008. "Impact of Stress on the Performance of Construction Project Managers." *Journal of Construction Engineering and Management* 134 (8): 644–52. doi:10.1061/(ASCE)0733-9364(2008)134:8(644).

Leung, Mei- yung, Qi Liang, and Paul Olomolaiye. 2015. "Impact of Job Stressors and Stress on the Safety Behavior and Accidents of Construction Workers." *Journal of Management in Engineering* 0 (0): 04015019. doi:10.1061/(ASCE)ME.1943-5479.0000373.

Lopez, Robert, and Peter Love. 2012. "Design Error Costs in Construction Projects." *Journal of Construction Engineering and Management* 138 (5): 585–93. doi:10.1061/(ASCE)CO.1943-7862.0000454.

Love, Peter, David Edwards, Hunna Watson, and Peter Davis. 2010. "Rework in Civil Infrastructure Projects: Determination of Cost Predictors." *Journal of Construction Engineering and Management* 136 (3): 275–82. doi:10.1061/(ASCE)CO.1943-7862.0000136.

Love, Peter, and Jim Smith. 2003. "Benchmarking, Benchaction, and Benchlearning: Rework Mitigation in Projects." *Journal of Management in Engineering* 19 (4): 147–59. doi:10.1061/(ASCE)0742-597X(2003)19:4(147).

Luis F Alarcón, Alejandro Grillo. 2001. "Learning from Collaborative Benchmarking in the Construction Industry."

Luis F. Alarcón, Sven Diethelm. 2014. "Assessing the Impacts of Implementing Lean Construction Evaluando Los Impactos De La Implementación De Lean Construction."

Makulsawatudom, Arun, and Margaret Emsley. 2003. "Factors Affecting the Productivity of the Construction Industry in Thailand: The Foremen's Perception." *Bridges* 10 (40671): 6.

McGeorge, John. 1988. "Design Productivity: A Quality Problem." *Journal of Management in Engineering* 4 (4): 350–62. doi:10.1061/(ASCE)9742-597X(1988)4:4(350).

Memon, Aftab Hameed, Ismail Abdul Rahman, and Ade Asmi Abdul Azis. 2012. "Time and Cost Performance in Construction Projects in Southern and Central Regions of Peninsular Malaysia." *International Journal of Advances in Applied Sciences* 1 (1): 45–52. doi:10.11591/ijaas.v1i1.537.

Morris, P. W. G., and G. H. Hough. 1987. "The Anatomy of Major Projects: a Study of the Reality of Project Management." http://inis.iaea.org/Search/search.aspx?orig_q=RN:21028774.

Müller, Ralf, and Rodney Turner. 2010. “Leadership Competency Profiles of Successful Project Managers.” *International Journal of Project Management* 28 (5): 437–48. doi:10.1016/j.ijproman.2009.09.003.

Nepal, Madhav, Moonseo Park, and Bosik Son. 2006. “Effects of Schedule Pressure on Construction Performance.” *Journal of Construction Engineering and Management* 132 (2): 182–88. doi:10.1061/(ASCE)0733-9364(2006)132:2(182).

Nudurupati, Sai, Tanweer Arshad, and Trevor Turner. 2007. “Performance Measurement in the Construction Industry: An Action Case Investigating Manufacturing Methodologies.” *Computers in Industry*, Performance Measurement Special Issue, 58 (7): 667–76. doi:10.1016/j.compind.2007.05.005.

Nunnally, Jum C., and Ira H. Bernstein. 1994. *Psychometric Theory*. 3rd ed. New York: McGraw-Hill.

Odeh, Abdalla M, and Hussien T Battaineh. 2002. “Causes of Construction Delay: Traditional Contracts.” *International Journal of Project Management* 20 (1): 67–73. doi:10.1016/S0263-7863(00)00037-5.

Outhwaite, William, and Stephen Turner. 2007. *The SAGE Handbook of Social Science Methodology*. SAGE.

Pashler, Harold, Pierre Jolicœur, Roberto Dell’Acqua, Jacquelyn Crebolder, Thomas Goschke, Ritske De Jong, Nachshon Meiran, Richard B. Ivry, and Eliot Hazeltine. 2000. “Task Switching and Multitask Performance.” In *Control of Cognitive Processes: Attention and Performance XVIII*, edited by S. Monsell and J. Driver, 275–423. Cambridge, MA, US: The MIT Press.

Pheng, L, and C Pong. 2003. “Integrating ISO 9001 and OHSAS 18001 for Construction.” *Journal of Construction Engineering and Management* 129 (3): 338–47. doi:10.1061/(ASCE)0733-9364(2003)129:3(338).

Pinto, Jeffrey K., and Dennis P. Slevin. 1987. “Critical Factors in Successful Project Implementation.” *IEEE Transactions on Engineering Management* EM-34 (1): 22–27. doi:10.1109/TEM.1987.6498856.

Pocock, James B., Steven kuennen, John A. Gambatese, and Jon Rauschkolb. 2006. “Constructability State of Practice Report.” *Journal of Construction Engineering and Management* 132 (4): 373–83. doi:10.1061/(ASCE)0733-9364(2006)132:4(373).

Rajendran, Sathyanarayanan. 2013. “Enhancing Construction Worker Safety Performance Using Leading Indicators.” *Practice Periodical on Structural Design and Construction* 18 (1): 45–51. doi:10.1061/(ASCE)SC.1943-5576.0000137.

Ramı´rez, R, L Alarcón, and P Knights. 2004. “Benchmarking System for Evaluating Management Practices in the Construction Industry.” *Journal of Management in Engineering* 20 (3): 110–17. doi:10.1061/(ASCE)0742-597X(2004)20:3(110).

Rankin, Jeff, Aminah Robinson Fayek, Gerry Meade, Carl Haas, and André Manseau. 2008. “Initial Metrics and Pilot Program Results for Measuring the Performance of the Canadian Construction Industry.” *Canadian Journal of Civil Engineering* 35 (9): 894–907. doi:10.1139/L08-018.

Rao, C. Radhakrishna. 1964. “The Use and Interpretation of Principal Component Analysis in Applied Research.” *Sankhyā: The Indian Journal of Statistics, Series A (1961-2002)* 26 (4): 329–58.

Rea, Louis M., and Richard Allen Parker. 1997. *Designing and Conducting Survey Research: a Comprehensive Guide*. Jossey-Bass Publishers.

Rounds, Jerald L., and Nai- Yuan Chi. 1985. “Total Quality Management for Construction.” *Journal of Construction Engineering and Management* 111 (2): 117–28. doi:10.1061/(ASCE)0733-9364(1985)111:2(117).

Saad Sarhan, Andrew Fox. 2013. “Barriers to Implementing Lean Construction in the UK Construction Industry.” *The Built & Human Environment Review* Volume 6: pages 1–17.

Salkind, Neil. 2010. *Encyclopedia of Research Design*. 2455 Teller Road, Thousand Oaks California 91320 United States: SAGE Publications, Inc. http://knowledge.sagepub.com/view/researchdesign/SAGE.xml.

Sanvido, Victor. 1992. “Critical Success Factors for Construction Projects.” *Journal of Construction Engineering and Management* 118 (1): 94–111. doi:10.1061/(ASCE)0733-9364(1992)118:1(94).

Sawacha, Edwin, Shamil Naoum, and Daniel Fong. 1999. “Factors Affecting Safety Performance on Construction Sites.” *International Journal of Project Management* 17 (5): 309–15. doi:10.1016/S0263-7863(98)00042-8.

Sedgwick, Philip. 2013. “Convenience Sampling.” *BMJ* 347 (October): f6304. doi:10.1136/bmj.f6304.

Shammas-Toma, Mazin, David Seymour, and Leslie Clark. 1998. “Obstacles to Implementing Total Quality Management in the UK Construction Industry.” *Construction Management and Economics* 16 (2): 177–92.

Shieh, Gwowen, Show-Li Jan, and Ronald H. Randles. 2007. “Power and Sample Size Determinations for the Wilcoxon Signed-rank Test.” *Journal of Statistical Computation and Simulation* 77 (8): 717–24. doi:10.1080/10629360600635245.

Siu, Oi-ling, David R. Phillips, and Tat-wing Leung. 2003. “Age Differences in Safety Attitudes and Safety Performance in Hong Kong Construction Workers.” *Journal of Safety Research* 34 (2): 199–205. doi:10.1016/S0022-4375(02)00072-5.

Smith, William J., David J. Timoney, and Dermot P. Lynch. 1997. “Emissions and Efficiency Comparison of Gasoline and LPG Fuels in a 1.4 Litre Passenger Car Engine”. SAE Technical Paper 972970. Warrendale, PA: SAE International. http://papers.sae.org/972970/.

Song, Lingguang, Yasser Mohamed, and Simaan AbouRizk. 2009. “Early Contractor Involvement in Design and Its Impact on Construction Schedule Performance.” *Journal of Management in Engineering* 25 (1): 12–20. doi:10.1061/(ASCE)0742-597X(2009)25:1(12).

Stevens, James D. 1996. “Blueprint for Measuring Project Quality.” *Journal of Management in Engineering* 12 (2): 34–39. doi:10.1061/(ASCE)0742-597X(1996)12:2(34).

Stewart, Rodney Anthony. 2007. “IT Enhanced Project Information Management in Construction: Pathways to Improved Performance and Strategic

Competitiveness.” *Automation in Construction* 16 (4): 511–17. doi:10.1016/j.autcon.2006.09.001.

Suhr, DD. 2005. “Principal Component Analysis Vs. Exploratory Factor Analysis.”

Takim, Roshana, and Akintola Akintoye. 2002. “Performance Indicators for Successful Construction Project Performance.” In *18th Annual ARCOM Conference*, 2:545–55. http://www.arcom.ac.uk/-docs/proceedings/ar2002-545-555_Takim_and_Akintoye.pdf.

Tam, C. M., S. X. Zeng, and Z. M. Deng. 2004. “Identifying Elements of Poor Construction Safety Management in China.” *Safety Science* 42 (7): 569–86. doi:10.1016/j.ssci.2003.09.001.

The KPI Working Group. 2000. “KPI Report for The Minister for Construction.” *Scribd*. https://www.scribd.com/doc/191295435/KPI-pdf.

Thomas. 2003. *Blending Qualitative and Quantitative Research Methods in Theses and Dissertations*. Corwin Press.

Thomas, Stephen R., Sanf- Hoon Lee, Richard L. Tucker, and Robert E. Chapman. 2004. “Impacts of Design/Information Technology on Project Outcomes.” *Journal of Construction Engineering and Management* 130 (4): 586–97. doi:10.1061/(ASCE)0733-9364(2004)130:4(586).

Toole, and John Gambatese. 2008. “The Trajectories of Prevention Through Design in Construction.” *Journal of Safety Research*, Prevention through Design, 39 (2): 225–30. doi:10.1016/j.jsr.2008.02.026.

Toole, Michael. 2005. “Increasing Engineers’ Role in Construction Safety: Opportunities and Barriers.” *Journal of Professional Issues in Engineering Education and Practice* 131 (3): 199–207. doi:10.1061/(ASCE)1052-3928(2005)131:3(199).

Toor, Shamas-ur-Rehman, and Stephen O. Ogunlana. 2010. “Beyond the ‘iron Triangle’: Stakeholder Perception of Key Performance Indicators (KPIs) for Large-scale Public Sector Development Projects.” *International Journal of Project Management* 28 (3): 228–36. doi:10.1016/j.ijproman.2009.05.005.

Tsui, Anne S., and Charles A. O’reilly. 1989. “Beyond Simple Demographic Effects: The Importance of Relational Demography in Superior-Subordinate Dyads.” *Academy of Management Journal* 32 (2): 402–23. doi:10.2307/256368.

US Census Bureau Construction Expenditures. 2015. “US Census Bureau Construction Spending Survey.” https://www.census.gov/construction/c30/c30index.html.

Vaughan, Joshua L., Michael L. Leming, Min Liu, and Edward Jaselskis. 2013. “Cost-Benefit Analysis of Construction Information Management System Implementation: Case Study.” *Journal of Construction Engineering and Management* 139 (4): 445–55. doi:10.1061/(ASCE)CO.1943-7862.0000611.

Wanberg, John, Christofer Harper, Matthew R. Hallowell, and Sathyanarayanan Rajendran. 2013. “Relationship Between Construction Safety and Quality Performance.” *Journal of Construction Engineering and Management* 139 (10): 04013003. doi:10.1061/(ASCE)CO.1943-7862.0000732.

Wang, Qi, Mohamed El- Gafy, and Jingmin Zha. 2010. “Bi-Level Framework for Measuring Performance to Improve Productivity of Construction Enterprises.” In

Construction Research Congress 2010, 970–79. American Society of Civil Engineers. http://ascelibrary.org/doi/abs/10.1061/41109%28373%2997.

Wiezel, Avi, and Ali Oztemir. 2004. "The Influence of Design Methods on Construction Productivity." In *Construction Research Congress*, 1–8. American Society of Civil Engineers. http://ascelibrary.org/doi/abs/10.1061/40671%282003%29124.

Wyse, Susan E. 2012. "Why Use Demographic Questions in Surveys?" *Snap Surveys Blog*. http://www.snapsurveys.com/blog/demographics-questions-surveys/.

Zaiontz, Charles. 2015. "Wilcoxon Signed-Ranks Test | Real Statistics Using Excel." http://www.real-statistics.com/non-parametric-tests/wilcoxon-signed-ranks-test/.

Zhang, Sijie, Jochen Teizer, Jin-Kook Lee, Charles M. Eastman, and Manu Venugopal. 2013. "Building Information Modeling (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules." *Automation in Construction* 29 (January): 183–95. doi:10.1016/j.autcon.2012.05.006.

Zhu, Xiao, Xiaolong Xue, Minghui Chen, and Hong Zhou. 2015. "Mobile IT Used in Construction : A Case for Scaffolding Safety Management." In *ICCREM 2013*, 482–91. American Society of Civil Engineers. Accessed April 22. http://ascelibrary.org/doi/abs/10.1061/9780784413135.046.

Zohar, Dov. 1980. "Safety Climate in Industrial Organizations: Theoretical and Applied Implications." *Journal of Applied Psychology* 65 (1): 96–102. doi:10.1037/0021-9010.65.1.96.

———. 2000. “A Group-level Model of Safety Climate: Testing the Effect of Group Climate on Microaccidents in Manufacturing Jobs.” *Journal of Applied Psychology* 85 (4): 587–96. doi:10.1037/0021-9010.85.4.587.

Appendix

7.4. Appendix A- Survey Questionnaire and IRB Approval

7.4.1. Appendix A1- IRB Approval

Institutional Review Board
Office of Research Integrity | Oregon State University
B308 Kerr Administration Building, Corvallis, OR 97331-2140
Telephone (541) 737-8008
irb@oregonstate.edu | http://research.oregonstate.edu/irb

EXEMPT DETERMINATION

Date of Notification	03/03/2015		
Study ID	6737		
Study Title	Framework for Forecasting and Evaluating Construction Project Performance Using Project Energy		
Principal Investigator	John Gambatese		
Study Team Members	Chukwuma Nnaji		
Submission Type	Initial Application	Date Acknowledged	03/03/2015
Level	Exempt	Category(ies)	2
Funding Source	None	Proposal #	N/A
PI on Grant or Contract	N/A	Cayuse #	N/A

The above referenced study was reviewed by the OSU Institutional Review Board (IRB) and determined to be exempt from full board review.

EXPIRATION DATE: 03/02/2020
The exemption is valid for 5 years from the date of approval.

Annual renewals are not required. If the research extends beyond the expiration date, the Investigator must request a new exemption. Investigators should submit a final report to the IRB if the project is completed prior to the 5 year term.

Documents included in this review:

- ☒ Protocol
- ☐ Consent forms
- ☐ Assent forms
- ☒ Alternative consent
- ☒ Recruiting tools
- ☒ Test instruments
- ☐ Attachment A: Radiation
- ☐ Alternative assent
- ☐ External IRB approvals
- ☐ Translated documents
- ☐ Attachment B: Human materials
- ☐ Grant/contract

Comments:

Principal Investigator responsibilities:

- Certain amendments to this study must be submitted to the IRB for review prior to initiating the change. These amendments may include, but are not limited to, changes in funding, , study population, study instruments, consent documents, recruitment material, sites of research, etc. For more information about the types of changes that require submission of a project revision to the IRB, please see: http://oregonstate.edu/research/irb/sites/default/files/website_guidancedocuments.pdf
- All study team members should be kept informed of the status of the research. The Principal Investigator is responsible for ensuring that all study team members have completed the online ethics training requirement, even if they do not need to be added to the study team via project revision.
- Reports of unanticipated problems involving risks to participants or others must be submitted to the IRB within three calendar days.
- The Principal Investigator is required to securely store all study related documents on the OSU campus for a minimum of seven years post study termination.

OSU IRB FWA00003920 1 IRB Form | v. date February 2015

7.4.2. Appendix A2- Survey Questionnaire

Identification of Site and Operational Factors that Impact Construction Workers

This study is being conducted to identify and evaluate the factors, conditions, and resources that aid or inhibit work quality and worker safety during the planning, erecting, maintaining, and demolishing of a structure. The different components that affect workers on a construction site and their impact on a construction worker will be identified and quantified respectively. This research is geared towards finding out if there is a relationship between a combination of impacting factors and the quality of work and safety of a worker. The correlation will be used to quantify the working conditions experienced on a jobsite and develop a framework for assessing and forecasting a project's performance.

Please note that the information you provide will be kept completely confidential, and will only be used to create the proposed framework. The data will remain anonymous and stored in a common database with other respondents. This will ensure that any information collected will not be traced to a specific individual or company.

Survey procedure

This survey consists of three sections as follows:

- Section 1: Personal demographics of respondent
- Section 2: Identification of impacting factors and magnitude of impact when the factors are negative
- Section 3: Identification of impacting factors and magnitude of impact when the factors are positive

An example of how to answer the questions is provided to assist you with timely completion of the survey. Please answer each survey question based on your personal experience on construction sites. Feel free to write a comment anywhere on this questionnaire.

If you have any questions, please do not hesitate to contact me or my advisor, Professor John Gambatese, at:

Chuma Nnaji
M.S. Candidate
Construction Engineering Mgmt.
School of Civil and Constr. Engrg.
Oregon State University
nnajic@onid.oregonstate.edu
Ph.: 541-908-0475

John Gambatese, PhD, PE
Professor
Construction Engineering Mgmt.
School of Civil and Constr. Engrg.
Oregon State University
john.gambatese@oregonstate.edu
Ph.: 541-737-8913

Section1: Demographics

Please answer the following questions about your background and experience. All information provided will be pooled anonymously into one database and kept confidential.

1. Age (years)

___ 18-21
___ 21-24
___ 25-34
___ 35-44
___ 45-54
___ 55-64
___ >65

2. Experience in construction (in years)

___ Less than 1
___ 1-5
___ 5-10
___ 10-20
___ >20

3. Level of education

___ No formal education
___ Grade School
___ High School
___ Vocational/trade School
___ Undergraduate degree (2-yr or 4-yr)
___ Graduate degree

4. Position

___ Field worker*
___ Foreman
___ Superintendent
___ Project Engineer
___ Project Manager
___ Owner's Representative
___ Other: _________________________

5. Trade (if applicable)

___ Craftsman (wood)
___ Electrician
___ Concrete and masonry works
___ Plumbing and mechanical fittings
___ Heavy equipment operator
___ Other: __________________________

6. Types of projects you work on (select all that apply):

___ Commercial buildings
___ Residential buildings
___ Roadways
___ Bridges
___ Industrial (refinery, factories, etc.)
___ Marine
___ Other: __________________________

7. Type of company you work for:

___ General Contractor
___ Owner
___ Sub-contractor
___ Other: __________________________

*In this research study, field workers (apprentices) refer to construction workers who have non-supervisory responsibilities.

Sections 2 and 3: Identification of Impacting Factors and Magnitudes of Impact

In Sections 2 and 3, please indicate the magnitude of impact that each of the listed work site and work operations components has on the quality of your work and on your safety when performing your typical assigned duties. Please use the following ratings:

- -3 = significant negative impact
- -2 = moderate negative impact
- -1 = minor negative impact
- 0 = no impact
- 1 = minor positive impact
- 2 = moderate positive impact
- 3 = significant positive impact

When assessing "impact", consider the effect of the corresponding component in relation to YOUR work and/or working conditions. <u>If you are unsure, please leave the rating blank.</u>

Please base your responses on your personal background and experience in the construction industry for a **typical project** that you work on.

<u>Example 1</u>: The table below shows a potential response from a concrete foreman. The foreman indicates that a congested site has minor negative impact on his/her safety, and moderate negative impact on the quality of his/her work on the site.

	Magnitude of impact on your SAFETY							**Magnitude of impact on the QUALITY of your work**						
Component	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
3. Project Management														
Congested site (equipment, materials, and people)			✓						✓					

<u>Example 2</u>: The following table illustrates possible feedback from a project manager. The Project manager indicates that easy-to-use equipment has a moderate positive impact on the quality of his/her work but has no impact on his/her safety.

	Magnitude of impact on your SAFETY							**Magnitude of impact on the QUALITY of your work**						
Component	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
5. Materials, Tools, and Equipment														
Easy-to-use equipment (requires only basic skills)				✓									✓	

Section 2: Identification of impacting factors and magnitude of impact when the factors are <u>negative</u>

<u>When assessing the magnitude of impact, consider the components in relation to YOUR personal work and/or working conditions.</u>

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
1. Company Culture															
1.1	Poorly or non-defined organizational structure														
1.2	Inability to retain skilled craftsmen														
1.3	Lack of regular performance reviews (bi-weekly or monthly)														
1.4	Higher than typical productivity required														
1.5	Short project schedule														
1.6	Poor attitude towards safety														
1.7	Competing company priorities take precedence over safety (e.g., quality, time, cost)														
1.8	High level of competition within company														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
2. Project Characteristics															
2.1	Fast pace of work														
2.2	Very unique work														
2.3	Adverse weather condition														
2.4	Large project (physical size)														
2.5	High cost project ($)														
2.6	Project located in densely populated (urban) area														
2.7	Very high quality of work required														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
3. Project Management															
3.1	Congested site (equipment, materials, and people)														
3.2	Many different crews/trades on site at the same time														
3.3	Extended work hours each day														
3.4	Night shifts														
3.5	In addition to weekdays, working on weekends and holidays														
3.6	Inexperienced (unqualified) supervisor														
3.7	Construction drawings not readily available														
3.8	No safety incentive														
3.9	Look-ahead (bi-weekly) schedule not available														
3.10	High number of project scope changes during construction														
3.11	Design-Bid-Build contract (hard-bid)														
3.12	Inexperienced crew														
3.13	Lack of personal protective equipment (PPE) and safety resources														
3.14	Low quality of instruction provided for work tasks														
3.15	High number of overlapping work activities for crew														
3.16	Many subcontractors on site at same time														
3.17	Many different tasks/activities being worked on by different crews at the same time														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
4. Task Scheduling & Management															
4.1	Task is highly repetitive														
4.2	Task is long and continuous (doing one thing for a long time; e.g., laying bricks all day)														
4.3	Task involves high risk of injury (e.g., working at height, lifting heavy materials, etc.)														
4.4	Assigned task is very complex (e.g., requires calculations, remembering many interconnected factors, or is mentally demanding)														
4.5	Frequent switching between tasks required														
4.6	High number of sub-tasks within one task														
4.7	Frequent interruption/interferences (maybe due to improper work sequence, flow, and scheduling)														
4.8	Unorthodox method of Foreman's supervision														
4.9	Unpredictability of the work tasks due to unknown information														
4.10	You are given new tasks very frequently														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
5. Materials, Tools, and Equipment															
5.1	Poor material, tools, and equipment storage														
5.2	Using complex equipment (requires advanced skills)														
5.3	Lack of familiarity with equipment														
5.4	Material, tools, and equipment not readily available														

5.5	Poor quality of equipment and tools														
5.6	Poor quality of pre-fabrication														
5.7	Poor quality materials														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
6. Engineering and Technology															
6.1	High amount of paperwork involved														
6.2	Low quality of detailed design drawings														
6.3	Slow response to Requests for Information (RFIs)														
6.4	Use of advanced technologies (e.g., paperless, wireless, etc.)														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
7. Communication															
7.1	More than one language spoken on construction site														
7.2	Lack of adequate communication within site management														
7.3	Lack of deserved positive feedback (compliments)														
7.4	Poor working relationships and cohesiveness with co-workers														
	Other:														

Section 3: Identification of impacting factors and magnitude of impact when the factors are positive

The rating tables below are similar to the tables above, except that the components have been adjusted to a more positive description. **When assessing the magnitude of impact, consider the components in relation to YOUR personal work and/or working conditions.**

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
1. Company Culture															
1.1	Well-defined organizational structure														
1.2	High retention rate of skilled craftsmen														
1.3	Regular performance reviews (bi-weekly or monthly)														
1.4	Lower than typical productivity required														
1.5	More time allowed in project schedule than typical														
1.6	Good attitude towards safety														
1.7	Safety takes precedence over other companies priorities (e.g., quality, time, cost)														
1.8	Relaxed atmosphere within company (no competition)														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
2. Project Characteristics															
2.1	Slow pace of work														
2.2	Project is not unique (regular building)														
2.3	Predictable weather condition														
2.4	Small project (physical size)														
2.5	Low cost project ($)														
2.6	Remote project (in very rural area)														
2.7	Low quality of work required														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
3. Project Management															
3.1	Non-congested site (equipment, materials, and people)														
3.2	No or minimal overlapping of different crews/trades on site														
3.3	Regular work hours (40 hrs/week)														
3.4	Day shifts only														
3.5	Working on weekdays only (not on weekends and holidays)														
3.6	Experienced supervisor														
3.7	Construction drawings available when needed														
3.8	Project-based safety incentive														
3.9	Look-ahead (bi-weekly) schedule available														
3.10	Low number of project scope changes during construction														
3.11	Design-Build contract														
3.12	Experienced crew														
3.13	Excellent personal protective equipment (PPE) and safety resources available														
3.14	Acceptable quality of instruction provided for work tasks														
3.15	No overlapping work activities for crew														
3.16	Subcontractors not on-site at same time														
3.17	Few different tasks/activities being worked on by different crews at the same time														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
4. Task Scheduling & Management															
4.1	Task is not repetitive														
4.2	Worker tasks are not long and monotonous (dull)														
4.3	Task involves low risk of injury (e.g., working on the ground, lifting light materials, etc.)														
4.4	Assigned task requires little or no calculation, mental stress, remembering, etc.														
4.5	Can concentrate on one task without needing to switch to another														
4.6	Few or no sub-tasks within one task														
4.7	No interruption/interferences (maybe due to proper work sequence, flow, and scheduling)														
4.8	Foreman's method of supervision is conventional														
4.9	Work tasks very predictable due to adequate information														
4.10	Workers are not given new tasks too frequently														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
5. Materials, Tools, and Equipment															
5.1	Very organized material, tools, and equipment storage														
5.2	Easy-to-use equipment (requires only basic skills)														
5.3	Familiar with equipment used for task														
5.4	Material, tools, and equipment is readily available														

5.5	Equipment and tools are of good quality														
5.6	Pre-fabrication is of good quality														
5.7	Materials are of good quality														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
6. Engineering and Technology															
6.1	Low amount of paperwork involved														
6.2	High quality of detailed design drawings														
6.3	Quick response to Requests for Information (RFIs)														
6.4	Use of commonly-used technologies														
	Other:														

		Magnitude of impact on your SAFETY							Magnitude of impact on the QUALITY of your work						
Component		-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
7. Communication															
7.1	Only one language spoken on construction site														
7.2	Good communication within site management														
7.3	Positive feedback (compliments) is regularly communicated to deserving workers														
7.4	Excellent working relationships and cohesiveness with co-workers														
	Other:														

Please provide additional comments and feedback (optional):

____

____

____

____

____

Thank you for completing the survey! We appreciate your help with the study.

If you would you be willing to be interviewed regarding your experience, please provide us with your name and phone number or e-mail:

Name (optional): ______________________________

Phone (optional): ______________________________

E-mail (optional): ______________________________

Appendix B- Test for Normality/ Variance, and Descriptive Summary

Descriptives

			Statistic	Std. Error
Poorly or non-defined organizational structure-QccN	Mean		-1.511	.2099
	95% Confidence Interval for Mean	Lower Bound	-1.934	
		Upper Bound	-1.088	
	5% Trimmed Mean		-1.667	
	Median		-2.000	
	Variance		1.983	
	Std. Deviation		1.4081	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		1.5	
	Skewness		1.506	.354
	Kurtosis		3.043	.695
Inability to retain skilled craftsmen- QccN	Mean		-1.778	.1930
	95% Confidence Interval for Mean	Lower Bound	-2.167	
		Upper Bound	-1.389	
	5% Trimmed Mean		-1.889	
	Median		-2.000	
	Variance		1.677	
	Std. Deviation		1.2949	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		1.077	.354
	Kurtosis		.589	.695
Lack of regular performance reviews- QccN	Mean		-.733	.1504
	95% Confidence Interval for Mean	Lower Bound	-1.036	
		Upper Bound	-.430	
	5% Trimmed Mean		-.784	
	Median		-1.000	
	Variance		1.018	
	Std. Deviation		1.0090	

	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		1.0	
	Skewness		.956	.354
	Kurtosis		3.332	.695
Higher than typical productivity required- QccN	Mean		-.956	.1852
	95% Confidence Interval for Mean	Lower Bound	-1.329	
		Upper Bound	-.582	
	5% Trimmed Mean		-1.037	
	Median		-1.000	
	Variance		1.543	
	Std. Deviation		1.2424	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		1.178	.354
	Kurtosis		1.927	.695
Short project schedule- QccN	Mean		-1.044	.1906
	95% Confidence Interval for Mean	Lower Bound	-1.429	
		Upper Bound	-.660	
	5% Trimmed Mean		-1.123	
	Median		-1.000	
	Variance		1.634	
	Std. Deviation		1.2784	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		.701	.354
	Kurtosis		1.447	.695
Poor attitude towards safety- QccN	Mean		-1.089	.1736
	95% Confidence Interval for Mean	Lower Bound	-1.439	
		Upper Bound	-.739	
	5% Trimmed Mean		-1.093	
	Median		-1.000	

	Variance		1.356	
	Std. Deviation		1.1643	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		-.001	.354
	Kurtosis		-.364	.695
Competing company priorities take precedence over safety- QccN	Mean		-1.044	.1710
	95% Confidence Interval for Mean	Lower Bound	-1.389	
		Upper Bound	-.700	
	5% Trimmed Mean		-1.043	
	Median		-1.000	
	Variance		1.316	
	Std. Deviation		1.1472	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		-.382	.354
	Kurtosis		-.795	.695
High level of competition within company- QccN	Mean		.511	.2123
	95% Confidence Interval for Mean	Lower Bound	.083	
		Upper Bound	.939	
	5% Trimmed Mean		.562	
	Median		1.000	
	Variance		2.028	
	Std. Deviation		1.4242	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		1.5	
	Skewness		-.493	.354
	Kurtosis		.333	.695
Poorly or non-defined organizational structure- SccN	Mean		-1.511	.2026
	95% Confidence Interval for Mean	Lower Bound	-1.919	
		Upper Bound	-1.103	

	5% Trimmed Mean		-1.660	
	Median		-2.000	
	Variance		1.846	
	Std. Deviation		1.3588	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		1.0	
	Skewness		1.589	.354
	Kurtosis		3.700	.695
Inability to retain skilled craftsmen- SccN	Mean		-1.378	.1861
	95% Confidence Interval for Mean	Lower Bound	-1.753	
		Upper Bound	-1.003	
	5% Trimmed Mean		-1.463	
	Median		-2.000	
	Variance		1.559	
	Std. Deviation		1.2484	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.5	
	Skewness		.772	.354
	Kurtosis		.546	.695
Lack of regular performance reviews- SccN	Mean		-.444	.1509
	95% Confidence Interval for Mean	Lower Bound	-.749	
		Upper Bound	-.140	
	5% Trimmed Mean		-.488	
	Median		.000	
	Variance		1.025	
	Std. Deviation		1.0125	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		1.0	
	Skewness		.598	.354
	Kurtosis		2.959	.695
Higher than typical level of	Mean		-1.067	.1723

productivity required- SccN	95% Confidence Interval for Mean	Lower Bound	-1.414	
		Upper Bound	-.719	
	5% Trimmed Mean		-1.117	
	Median		-1.000	
	Variance		1.336	
	Std. Deviation		1.1560	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		.689	.354
	Kurtosis		2.347	.695
Short project schedule- SccN	Mean		-1.089	.1848
	95% Confidence Interval for Mean	Lower Bound	-1.461	
		Upper Bound	-.716	
	5% Trimmed Mean		-1.142	
	Median		-1.000	
	Variance		1.537	
	Std. Deviation		1.2399	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		.550	.354
	Kurtosis		1.242	.695
Poor attitude towards safety- SccN	Mean		-2.333	.1621
	95% Confidence Interval for Mean	Lower Bound	-2.660	
		Upper Bound	-2.007	
	5% Trimmed Mean		-2.451	
	Median		-3.000	
	Variance		1.182	
	Std. Deviation		1.0871	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		1.493	.354

	Kurtosis		1.211	.695
Competing company priorities take precedence over safety - SccN	Mean		-1.844	.1588
	95% Confidence Interval for Mean	Lower Bound	-2.164	
		Upper Bound	-1.524	
	5% Trimmed Mean		-1.883	
	Median		-2.000	
	Variance		1.134	
	Std. Deviation		1.0651	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.503	.354
	Kurtosis		-.952	.695
High level of competition within company- SccN	Mean		-.089	.1551
	95% Confidence Interval for Mean	Lower Bound	-.402	
		Upper Bound	.224	
	5% Trimmed Mean		-.074	
	Median		.000	
	Variance		1.083	
	Std. Deviation		1.0406	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		-.322	.354
	Kurtosis		.879	.695
Fast pace of work- SpcN	Mean		-.667	.1651
	95% Confidence Interval for Mean	Lower Bound	-.999	
		Upper Bound	-.334	
	5% Trimmed Mean		-.710	
	Median		-1.000	
	Variance		1.227	
	Std. Deviation		1.1078	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	

	Interquartile Range		1.0	
	Skewness		.653	.354
	Kurtosis		2.330	.695
Very unique work- SpcN	Mean		-.067	.1723
	95% Confidence Interval for Mean	Lower Bound	-.414	
		Upper Bound	.281	
	5% Trimmed Mean		-.025	
	Median		.000	
	Variance		1.336	
	Std. Deviation		1.1560	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.5	
	Skewness		-.234	.354
	Kurtosis		.713	.695
Adverse weather condition-SpcN	Mean		-1.311	.1450
	95% Confidence Interval for Mean	Lower Bound	-1.603	
		Upper Bound	-1.019	
	5% Trimmed Mean		-1.315	
	Median		-1.000	
	Variance		.946	
	Std. Deviation		.9729	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		.212	.354
	Kurtosis		-.551	.695
Large project (physical size)-SpcN	Mean		.267	.1570
	95% Confidence Interval for Mean	Lower Bound	-.050	
		Upper Bound	.583	
	5% Trimmed Mean		.265	
	Median		.000	
	Variance		1.109	
	Std. Deviation		1.0531	
	Minimum		-3.0	

	Maximum	3.0	
	Range	6.0	
	Interquartile Range	1.0	
	Skewness	-.079	.354
	Kurtosis	1.593	.695
High cost project- SpcN	Mean	.533	.1333
	95% Confidence Interval for Mean — Lower Bound	.265	
	95% Confidence Interval for Mean — Upper Bound	.802	
	5% Trimmed Mean	.556	
	Median	.000	
	Variance	.800	
	Std. Deviation	.8944	
	Minimum	-3.0	
	Maximum	2.0	
	Range	5.0	
	Interquartile Range	1.0	
	Skewness	-.902	.354
	Kurtosis	4.363	.695
Project located in densely populated (urban) area- SpcN	Mean	-.289	.1759
	95% Confidence Interval for Mean — Lower Bound	-.643	
	95% Confidence Interval for Mean — Upper Bound	.066	
	5% Trimmed Mean	-.265	
	Median	.000	
	Variance	1.392	
	Std. Deviation	1.1798	
	Minimum	-3.0	
	Maximum	2.0	
	Range	5.0	
	Interquartile Range	1.0	
	Skewness	-.273	.354
	Kurtosis	.498	.695
Very high quality of work required- SpcN	Mean	.911	.1764
	95% Confidence Interval for Mean — Lower Bound	.556	
	95% Confidence Interval for Mean — Upper Bound	1.267	
	5% Trimmed Mean	.920	
	Median	1.000	
	Variance	1.401	

	Std. Deviation		1.1836	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		-.337	.354
	Kurtosis		1.279	.695
Fast pace of work- QpcN	Mean		-.533	.1639
	95% Confidence Interval for Mean	Lower Bound	-.864	
		Upper Bound	-.203	
	5% Trimmed Mean		-.543	
	Median		-1.000	
	Variance		1.209	
	Std. Deviation		1.0996	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.250	.354
	Kurtosis		.870	.695
Very unique work- QpcN	Mean		.333	.2035
	95% Confidence Interval for Mean	Lower Bound	-.077	
		Upper Bound	.743	
	5% Trimmed Mean		.370	
	Median		.000	
	Variance		1.864	
	Std. Deviation		1.3652	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		-.361	.354
	Kurtosis		.199	.695
Adverse weather condition-QpcN	Mean		-.889	.1498
	95% Confidence Interval for Mean	Lower Bound	-1.191	
		Upper Bound	-.587	
	5% Trimmed Mean		-.895	

	Median		-1.000	
	Variance		1.010	
	Std. Deviation		1.0050	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.050	.354
	Kurtosis		.888	.695
Large project (physical size)-QpcN	Mean		.400	.1206
	95% Confidence Interval for Mean	Lower Bound	.157	
		Upper Bound	.643	
	5% Trimmed Mean		.364	
	Median		.000	
	Variance		.655	
	Std. Deviation		.8090	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		1.013	.354
	Kurtosis		1.594	.695
High cost project - QpcN	Mean		.644	.1354
	95% Confidence Interval for Mean	Lower Bound	.372	
		Upper Bound	.917	
	5% Trimmed Mean		.556	
	Median		.000	
	Variance		.825	
	Std. Deviation		.9084	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		1.166	.354
	Kurtosis		.227	.695
Project located in densely populated (urban) area- QpcN	Mean		.089	.1224
	95% Confidence Interval for	Lower Bound	-.158	

	Mean	Upper Bound	.335	
	5% Trimmed Mean		.099	
	Median		.000	
	Variance		.674	
	Std. Deviation		.8208	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		.0	
	Skewness		-.685	.354
	Kurtosis		4.259	.695
Very high quality of work required- QpcN	Mean		1.889	.1627
	95% Confidence Interval for Mean	Lower Bound	1.561	
		Upper Bound	2.217	
	5% Trimmed Mean		1.932	
	Median		2.000	
	Variance		1.192	
	Std. Deviation		1.0918	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.648	.354
	Kurtosis		-.844	.695
Congested site- SpmN	Mean		-1.511	.1787
	95% Confidence Interval for Mean	Lower Bound	-1.871	
		Upper Bound	-1.151	
	5% Trimmed Mean		-1.593	
	Median		-2.000	
	Variance		1.437	
	Std. Deviation		1.1989	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.773	.354
	Kurtosis		.608	.695

Many different crews/trades on site at the same time- SpmN	Mean		-1.200	.1576
	95% Confidence Interval for Mean	Lower Bound	-1.518	
		Upper Bound	-.882	
	5% Trimmed Mean		-1.216	
	Median		-1.000	
	Variance		1.118	
	Std. Deviation		1.0574	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.5	
	Skewness		-.063	.354
	Kurtosis		-.453	.695
Extended work hours each day- SpmN	Mean		-.978	.1439
	95% Confidence Interval for Mean	Lower Bound	-1.268	
		Upper Bound	-.688	
	5% Trimmed Mean		-.969	
	Median		-1.000	
	Variance		.931	
	Std. Deviation		.9650	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.5	
	Skewness		.113	.354
	Kurtosis		1.244	.695
Night shifts- SpmN	Mean		-1.111	.1627
	95% Confidence Interval for Mean	Lower Bound	-1.439	
		Upper Bound	-.783	
	5% Trimmed Mean		-1.123	
	Median		-1.000	
	Variance		1.192	
	Std. Deviation		1.0918	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		2.0	

	Skewness		.010	.354
	Kurtosis		-.551	.695
In addition to weekdays, working on weekends and holidays- SpmN	Mean		-1.022	.1920
	95% Confidence Interval for Mean	Lower Bound	-1.409	
		Upper Bound	-.635	
	5% Trimmed Mean		-1.074	
	Median		-1.000	
	Variance		1.659	
	Std. Deviation		1.2879	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		.444	.354
	Kurtosis		-.221	.695
Inexperienced (unqualified) supervisor- SpmN	Mean		-1.800	.1787
	95% Confidence Interval for Mean	Lower Bound	-2.160	
		Upper Bound	-1.440	
	5% Trimmed Mean		-1.858	
	Median		-2.000	
	Variance		1.436	
	Std. Deviation		1.1985	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.590	.354
	Kurtosis		-.898	.695
Construction drawings not readily available - SpmN	Mean		-.556	.1254
	95% Confidence Interval for Mean	Lower Bound	-.808	
		Upper Bound	-.303	
	5% Trimmed Mean		-.556	
	Median		.000	
	Variance		.707	
	Std. Deviation		.8409	
	Minimum		-2.0	
	Maximum		1.0	

	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.537	.354
	Kurtosis		-.650	.695
No safety incentive- SpmN	Mean		-.489	.1670
	95% Confidence Interval for Mean	Lower Bound	-.826	
		Upper Bound	-.152	
	5% Trimmed Mean		-.481	
	Median		.000	
	Variance		1.256	
	Std. Deviation		1.1205	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		1.0	
	Skewness		-.232	.354
	Kurtosis		1.830	.695
Look-ahead (bi-weekly) schedule not available- SpmN	Mean		-.356	.1196
	95% Confidence Interval for Mean	Lower Bound	-.597	
		Upper Bound	-.115	
	5% Trimmed Mean		-.389	
	Median		.000	
	Variance		.643	
	Std. Deviation		.8021	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		1.301	.354
	Kurtosis		6.093	.695
High number of project scope changes during construction- SpmN	Mean		-.578	.1367
	95% Confidence Interval for Mean	Lower Bound	-.853	
		Upper Bound	-.302	
	5% Trimmed Mean		-.630	
	Median		-1.000	
	Variance		.840	
	Std. Deviation		.9167	

	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		1.074	.354
	Kurtosis		4.061	.695
Design-Bid-Build contract (hard-bid)- SpmN	Mean		-.044	.1489
	95% Confidence Interval for Mean	Lower Bound	-.345	
		Upper Bound	.256	
	5% Trimmed Mean		-.049	
	Median		.000	
	Variance		.998	
	Std. Deviation		.9990	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		.0	
	Skewness		.092	.354
	Kurtosis		2.961	.695
Inexperienced crew - SpmN	Mean		-1.889	.1393
	95% Confidence Interval for Mean	Lower Bound	-2.170	
		Upper Bound	-1.608	
	5% Trimmed Mean		-1.957	
	Median		-2.000	
	Variance		.874	
	Std. Deviation		.9347	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		.994	.354
	Kurtosis		1.185	.695
Lack of personal protective equipment (PPE) and safety resources- SpmN	Mean		-2.067	.1664
	95% Confidence Interval for Mean	Lower Bound	-2.402	
		Upper Bound	-1.731	
	5% Trimmed Mean		-2.154	
	Median		-2.000	

	Variance		1.245	
	Std. Deviation		1.1160	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.5	
	Skewness		1.060	.354
	Kurtosis		.177	.695
Low quality of instruction provided for work tasks- SpmN	Mean		-1.156	.1347
	95% Confidence Interval for Mean	Lower Bound	-1.427	
		Upper Bound	-.884	
	5% Trimmed Mean		-1.148	
	Median		-1.000	
	Variance		.816	
	Std. Deviation		.9034	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.5	
	Skewness		.127	.354
	Kurtosis		-.471	.695
High number of overlapping work activities for crew- SpmN	Mean		-1.156	.1650
	95% Confidence Interval for Mean	Lower Bound	-1.488	
		Upper Bound	-.823	
	5% Trimmed Mean		-1.167	
	Median		-1.000	
	Variance		1.225	
	Std. Deviation		1.1069	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		-.099	.354
	Kurtosis		-.793	.695
Many subcontractors on site at same time- SpmN	Mean		-.844	.1420
	95% Confidence Interval for Mean	Lower Bound	-1.131	
		Upper Bound	-.558	

	5% Trimmed Mean		-.852	
	Median		-1.000	
	Variance		.907	
	Std. Deviation		.9524	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.171	.354
	Kurtosis		1.195	.695
Many different tasks/activities being worked on by different crews at the same time- SpmN	Mean		-.956	.1739
	95% Confidence Interval for Mean	Lower Bound	-1.306	
		Upper Bound	-.605	
	5% Trimmed Mean		-.994	
	Median		-1.000	
	Variance		1.362	
	Std. Deviation		1.1669	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		.449	.354
	Kurtosis		1.926	.695
Congested site - QpmN	Mean		-.933	.1664
	95% Confidence Interval for Mean	Lower Bound	-1.269	
		Upper Bound	-.598	
	5% Trimmed Mean		-.969	
	Median		-1.000	
	Variance		1.245	
	Std. Deviation		1.1160	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		.274	.354
	Kurtosis		.836	.695
Many different crews/trades	Mean		-.667	.1589

on site at the same time - QpmN	95% Confidence Interval for Mean	Lower Bound	-.987	
		Upper Bound	-.346	
	5% Trimmed Mean		-.660	
	Median		-1.000	
	Variance		1.136	
	Std. Deviation		1.0660	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		-.013	.354
	Kurtosis		.133	.695
Extended work hours each day - QpmN	Mean		-.689	.1551
	95% Confidence Interval for Mean	Lower Bound	-1.002	
		Upper Bound	-.376	
	5% Trimmed Mean		-.759	
	Median		-1.000	
	Variance		1.083	
	Std. Deviation		1.0406	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		1.0	
	Skewness		1.101	.354
	Kurtosis		3.338	.695
Night shifts - QpmN	Mean		-.778	.1553
	95% Confidence Interval for Mean	Lower Bound	-1.091	
		Upper Bound	-.465	
	5% Trimmed Mean		-.759	
	Median		-1.000	
	Variance		1.086	
	Std. Deviation		1.0420	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.5	
	Skewness		-.091	.354

	Kurtosis		-.485	.695
In addition to weekdays, working on weekends and holidays - QpmN	Mean		-.822	.1500
	95% Confidence Interval for Mean	Lower Bound	-1.125	
		Upper Bound	-.520	
	5% Trimmed Mean		-.802	
	Median		-1.000	
	Variance		1.013	
	Std. Deviation		1.0065	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		-.374	.354
	Kurtosis		-.757	.695
Inexperienced (unqualified) supervisor - QpmN	Mean		-1.578	.1946
	95% Confidence Interval for Mean	Lower Bound	-1.970	
		Upper Bound	-1.186	
	5% Trimmed Mean		-1.685	
	Median		-2.000	
	Variance		1.704	
	Std. Deviation		1.3054	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		1.140	.354
	Kurtosis		1.963	.695
Construction drawings not readily available - QpmN	Mean		-1.533	.1639
	95% Confidence Interval for Mean	Lower Bound	-1.864	
		Upper Bound	-1.203	
	5% Trimmed Mean		-1.586	
	Median		-1.000	
	Variance		1.209	
	Std. Deviation		1.0996	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	

	Interquartile Range		1.0	
	Skewness		.572	.354
	Kurtosis		.913	.695
No safety incentive - QpmN	Mean		-.178	.1114
	95% Confidence Interval for Mean	Lower Bound	-.402	
		Upper Bound	.047	
	5% Trimmed Mean		-.148	
	Median		.000	
	Variance		.559	
	Std. Deviation		.7474	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		.0	
	Skewness		-1.062	.354
	Kurtosis		5.470	.695
Look-ahead (bi-weekly) schedule not available - QpmN	Mean		-.867	.1295
	95% Confidence Interval for Mean	Lower Bound	-1.128	
		Upper Bound	-.606	
	5% Trimmed Mean		-.907	
	Median		-1.000	
	Variance		.755	
	Std. Deviation		.8686	
	Minimum		-2.0	
	Maximum		1.0	
	Range		3.0	
	Interquartile Range		1.5	
	Skewness		.385	.354
	Kurtosis		-.435	.695
High number of project scope changes during construction - QpmN	Mean		-1.178	.1566
	95% Confidence Interval for Mean	Lower Bound	-1.493	
		Upper Bound	-.862	
	5% Trimmed Mean		-1.216	
	Median		-1.000	
	Variance		1.104	
	Std. Deviation		1.0507	
	Minimum		-3.0	

	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.495	.354
	Kurtosis		.843	.695
Design-Bid-Build contract (hard-bid) - QpmN	Mean		.044	.1588
	95% Confidence Interval for Mean	Lower Bound	-.276	
		Upper Bound	.364	
	5% Trimmed Mean		.025	
	Median		.000	
	Variance		1.134	
	Std. Deviation		1.0651	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		.5	
	Skewness		.499	.354
	Kurtosis		.851	.695
Inexperienced crew - QpmN	Mean		-1.644	.1625
	95% Confidence Interval for Mean	Lower Bound	-1.972	
		Upper Bound	-1.317	
	5% Trimmed Mean		-1.685	
	Median		-2.000	
	Variance		1.189	
	Std. Deviation		1.0904	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.5	
	Skewness		.444	.354
	Kurtosis		-.650	.695
Lack of personal protective equipment (PPE) and safety resources - QpmN	Mean		-.644	.1686
	95% Confidence Interval for Mean	Lower Bound	-.984	
		Upper Bound	-.305	
	5% Trimmed Mean		-.654	
	Median		.000	
	Variance		1.280	

	Std. Deviation		1.1313	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		.130	.354
	Kurtosis		1.290	.695
Low quality of instruction provided for work tasks - QpmN	Mean		-1.556	.1757
	95% Confidence Interval for Mean	Lower Bound	-1.910	
		Upper Bound	-1.201	
	5% Trimmed Mean		-1.660	
	Median		-2.000	
	Variance		1.389	
	Std. Deviation		1.1785	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		1.0	
	Skewness		1.490	.354
	Kurtosis		3.988	.695
High number of overlapping work activities for crew - QpmN	Mean		-1.111	.1688
	95% Confidence Interval for Mean	Lower Bound	-1.451	
		Upper Bound	-.771	
	5% Trimmed Mean		-1.142	
	Median		-1.000	
	Variance		1.283	
	Std. Deviation		1.1326	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		.915	.354
	Kurtosis		2.382	.695
Many subcontractors on site at same time - QpmN	Mean		-.689	.1304
	95% Confidence Interval for Mean	Lower Bound	-.952	
		Upper Bound	-.426	
	5% Trimmed Mean		-.685	

	Median		-1.000	
	Variance		.765	
	Std. Deviation		.8744	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		-.240	.354
	Kurtosis		.101	.695
Many different tasks/activities being worked on by different crews at the same time - QpmN	Mean		-.956	.1825
	95% Confidence Interval for Mean	Lower Bound	-1.323	
		Upper Bound	-.588	
	5% Trimmed Mean		-.994	
	Median		-1.000	
	Variance		1.498	
	Std. Deviation		1.2239	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		.379	.354
	Kurtosis		1.103	.695
Task is highly repetitive - StsmN	Mean		-.044	.2155
	95% Confidence Interval for Mean	Lower Bound	-.479	
		Upper Bound	.390	
	5% Trimmed Mean		-.049	
	Median		.000	
	Variance		2.089	
	Std. Deviation		1.4453	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		.175	.354
	Kurtosis		-.787	.695
Task is long and continuous - StsmN	Mean		-.244	.1802
	95% Confidence Interval for	Lower Bound	-.608	

	Mean	Upper Bound	.119	
	5% Trimmed Mean		-.272	
	Median		-1.000	
	Variance		1.462	
	Std. Deviation		1.2090	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		1.0	
	Skewness		.657	.354
	Kurtosis		.534	.695
Task involves high risk of injury- StsmN	Mean		-.889	.2016
	95% Confidence Interval for Mean	Lower Bound	-1.295	
		Upper Bound	-.483	
	5% Trimmed Mean		-.926	
	Median		-1.000	
	Variance		1.828	
	Std. Deviation		1.3521	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		.194	.354
	Kurtosis		-.550	.695
Assigned task is very complex - StsmN	Mean		-.356	.1391
	95% Confidence Interval for Mean	Lower Bound	-.636	
		Upper Bound	-.075	
	5% Trimmed Mean		-.364	
	Median		.000	
	Variance		.871	
	Std. Deviation		.9331	
	Minimum		-2.0	
	Maximum		2.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		.085	.354
	Kurtosis		-.112	.695

Frequent switching between tasks required- StsmN	Mean		-.933	.1326
	95% Confidence Interval for Mean	Lower Bound	-1.201	
		Upper Bound	-.666	
	5% Trimmed Mean		-.901	
	Median		-1.000	
	Variance		.791	
	Std. Deviation		.8893	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.5	
	Skewness		-.337	.354
	Kurtosis		-.187	.695
High number of sub-tasks within one task- StsmN	Mean		-.444	.1080
	95% Confidence Interval for Mean	Lower Bound	-.662	
		Upper Bound	-.227	
	5% Trimmed Mean		-.414	
	Median		.000	
	Variance		.525	
	Std. Deviation		.7247	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		-.952	.354
	Kurtosis		2.427	.695
Frequent interruption/interferences- StsmN	Mean		-1.289	.1215
	95% Confidence Interval for Mean	Lower Bound	-1.534	
		Upper Bound	-1.044	
	5% Trimmed Mean		-1.265	
	Median		-1.000	
	Variance		.665	
	Std. Deviation		.8153	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		1.0	

	Skewness		-.201	.354
	Kurtosis		-.341	.695
Unorthodox method of Foreman's supervision - StsmN	Mean		-1.133	.1544
	95% Confidence Interval for Mean	Lower Bound	-1.444	
		Upper Bound	-.822	
	5% Trimmed Mean		-1.093	
	Median		-1.000	
	Variance		1.073	
	Std. Deviation		1.0357	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.493	.354
	Kurtosis		-.892	.695
Unpredictability of the work tasks due to unknown information- StsmN	Mean		-1.222	.1417
	95% Confidence Interval for Mean	Lower Bound	-1.508	
		Upper Bound	-.937	
	5% Trimmed Mean		-1.216	
	Median		-1.000	
	Variance		.904	
	Std. Deviation		.9508	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		-.027	.354
	Kurtosis		-.372	.695
You are given new tasks very frequently- StsmN	Mean		-.667	.1146
	95% Confidence Interval for Mean	Lower Bound	-.898	
		Upper Bound	-.436	
	5% Trimmed Mean		-.654	
	Median		-1.000	
	Variance		.591	
	Std. Deviation		.7687	
	Minimum		-2.0	
	Maximum		1.0	

	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.349	.354
	Kurtosis		-.679	.695
Task is highly repetitive - QtsmN	Mean		.889	.1804
	95% Confidence Interval for Mean	Lower Bound	.525	
		Upper Bound	1.252	
	5% Trimmed Mean		.901	
	Median		1.000	
	Variance		1.465	
	Std. Deviation		1.2102	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		-.342	.354
	Kurtosis		-.436	.695
Task is long and continuous - QtsmN	Mean		.600	.1781
	95% Confidence Interval for Mean	Lower Bound	.241	
		Upper Bound	.959	
	5% Trimmed Mean		.586	
	Median		1.000	
	Variance		1.427	
	Std. Deviation		1.1947	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		-.080	.354
	Kurtosis		-.616	.695
Task involves high risk of injury- QtsmN	Mean		-.400	.1326
	95% Confidence Interval for Mean	Lower Bound	-.667	
		Upper Bound	-.133	
	5% Trimmed Mean		-.389	
	Median		.000	
	Variance		.791	
	Std. Deviation		.8893	

	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		-.519	.354
	Kurtosis		1.567	.695
Assigned task is very complex - QtsmN	Mean		-.156	.1852
	95% Confidence Interval for Mean	Lower Bound	-.529	
		Upper Bound	.218	
	5% Trimmed Mean		-.148	
	Median		.000	
	Variance		1.543	
	Std. Deviation		1.2424	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		-.064	.354
	Kurtosis		.414	.695
Frequent switching between tasks required- QtsmN	Mean		-.911	.1646
	95% Confidence Interval for Mean	Lower Bound	-1.243	
		Upper Bound	-.579	
	5% Trimmed Mean		-.926	
	Median		-1.000	
	Variance		1.219	
	Std. Deviation		1.1042	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		-.077	.354
	Kurtosis		.447	.695
High number of sub-tasks within one task- QtsmN	Mean		-.644	.1196
	95% Confidence Interval for Mean	Lower Bound	-.885	
		Upper Bound	-.403	
	5% Trimmed Mean		-.630	
	Median		-1.000	

	Variance		.643	
	Std. Deviation		.8021	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		-.471	.354
	Kurtosis		.707	.695
Frequent interruption/interferences- QtsmN	Mean		-1.378	.1159
	95% Confidence Interval for Mean	Lower Bound	-1.611	
		Upper Bound	-1.144	
	5% Trimmed Mean		-1.364	
	Median		-1.000	
	Variance		.604	
	Std. Deviation		.7772	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.428	.354
	Kurtosis		-.035	.695
Unorthodox method of Foreman's supervision - QtsmN	Mean		-1.044	.1768
	95% Confidence Interval for Mean	Lower Bound	-1.401	
		Upper Bound	-.688	
	5% Trimmed Mean		-1.068	
	Median		-1.000	
	Variance		1.407	
	Std. Deviation		1.1862	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		.517	.354
	Kurtosis		1.622	.695
Unpredictability of the work tasks due to unknown information- QtsmN	Mean		-1.533	.1477
	95% Confidence Interval for Mean	Lower Bound	-1.831	
		Upper Bound	-1.236	

	5% Trimmed Mean		-1.537	
	Median		-1.000	
	Variance		.982	
	Std. Deviation		.9909	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.050	.354
	Kurtosis		-.993	.695
You are given new tasks very frequently- QtsmN	Mean		-.822	.1359
	95% Confidence Interval for Mean	Lower Bound	-1.096	
		Upper Bound	-.548	
	5% Trimmed Mean		-.778	
	Median		-1.000	
	Variance		.831	
	Std. Deviation		.9118	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		-.557	.354
	Kurtosis		-.214	.695
Poor material, tools, and equipment storage-SmteN	Mean		-1.667	.1348
	95% Confidence Interval for Mean	Lower Bound	-1.938	
		Upper Bound	-1.395	
	5% Trimmed Mean		-1.685	
	Median		-2.000	
	Variance		.818	
	Std. Deviation		.9045	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.043	.354
	Kurtosis		-.777	.695
Using complex equipment	Mean		-.311	.1646

(requires advanced skills)-SmteN	95% Confidence Interval for Mean	Lower Bound	-.643	
		Upper Bound	.021	
	5% Trimmed Mean		-.290	
	Median		.000	
	Variance		1.219	
	Std. Deviation		1.1042	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		-.505	.354
	Kurtosis		.620	.695
Lack of familiarity with equipment -SmteN	Mean		-1.800	.1639
	95% Confidence Interval for Mean	Lower Bound	-2.130	
		Upper Bound	-1.470	
	5% Trimmed Mean		-1.858	
	Median		-2.000	
	Variance		1.209	
	Std. Deviation		1.0996	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.550	.354
	Kurtosis		-.551	.695
Material, tools, and equipment not readily available -SmteN	Mean		-.978	.1473
	95% Confidence Interval for Mean	Lower Bound	-1.275	
		Upper Bound	-.681	
	5% Trimmed Mean		-.975	
	Median		-1.000	
	Variance		.977	
	Std. Deviation		.9883	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		.250	.354

	Kurtosis		.551	.695
Poor quality of equipment and tools-SmteN	Mean		-1.578	.1812
	95% Confidence Interval for Mean	Lower Bound	-1.943	
		Upper Bound	-1.213	
	5% Trimmed Mean		-1.636	
	Median		-2.000	
	Variance		1.477	
	Std. Deviation		1.2152	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		.627	.354
	Kurtosis		.011	.695
Poor quality of pre-fabrication -SmteN	Mean		-1.089	.1583
	95% Confidence Interval for Mean	Lower Bound	-1.408	
		Upper Bound	-.770	
	5% Trimmed Mean		-1.043	
	Median		-1.000	
	Variance		1.128	
	Std. Deviation		1.0622	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.530	.354
	Kurtosis		-.962	.695
Poor quality materials-SmteN	Mean		-1.111	.1464
	95% Confidence Interval for Mean	Lower Bound	-1.406	
		Upper Bound	-.816	
	5% Trimmed Mean		-1.068	
	Median		-1.000	
	Variance		.965	
	Std. Deviation		.9822	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	

	Interquartile Range		2.0	
	Skewness		-.522	.354
	Kurtosis		-.679	.695
Poor material, tools, and equipment storage-QmteN	Mean		-1.511	.1372
	95% Confidence Interval for Mean	Lower Bound	-1.788	
		Upper Bound	-1.235	
	5% Trimmed Mean		-1.512	
	Median		-1.000	
	Variance		.846	
	Std. Deviation		.9200	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.058	.354
	Kurtosis		-.755	.695
Using complex equipment (requires advanced skills)-QmteN	Mean		.022	.1726
	95% Confidence Interval for Mean	Lower Bound	-.326	
		Upper Bound	.370	
	5% Trimmed Mean		.049	
	Median		.000	
	Variance		1.340	
	Std. Deviation		1.1578	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		1.5	
	Skewness		-.229	.354
	Kurtosis		1.484	.695
Lack of familiarity with equipment -QmteN	Mean		-1.356	.1625
	95% Confidence Interval for Mean	Lower Bound	-1.683	
		Upper Bound	-1.028	
	5% Trimmed Mean		-1.389	
	Median		-1.000	
	Variance		1.189	
	Std. Deviation		1.0904	
	Minimum		-3.0	

	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.547	.354
	Kurtosis		.544	.695
Material, tools, and equipment not readily available-QmteN	Mean		-1.511	.1730
	95% Confidence Interval for Mean	Lower Bound	-1.860	
		Upper Bound	-1.162	
	5% Trimmed Mean		-1.562	
	Median		-1.000	
	Variance		1.346	
	Std. Deviation		1.1604	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.5	
	Skewness		.485	.354
	Kurtosis		.293	.695
Poor quality of equipment and tools-QmteN	Mean		-1.800	.1511
	95% Confidence Interval for Mean	Lower Bound	-2.105	
		Upper Bound	-1.495	
	5% Trimmed Mean		-1.833	
	Median		-2.000	
	Variance		1.027	
	Std. Deviation		1.0135	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.400	.354
	Kurtosis		-.894	.695
Poor quality of pre-fabrication -QmteN	Mean		-1.911	.1583
	95% Confidence Interval for Mean	Lower Bound	-2.230	
		Upper Bound	-1.592	
	5% Trimmed Mean		-1.957	
	Median		-2.000	
	Variance		1.128	

	Std. Deviation		1.0622	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.530	.354
	Kurtosis		-.962	.695
Poor quality materials-QmteN	Mean		-2.089	.1415
	95% Confidence Interval for Mean	Lower Bound	-2.374	
		Upper Bound	-1.804	
	5% Trimmed Mean		-2.154	
	Median		-2.000	
	Variance		.901	
	Std. Deviation		.9492	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.684	.354
	Kurtosis		-.557	.695
High amount of paperwork involved- SetN	Mean		.133	.1082
	95% Confidence Interval for Mean	Lower Bound	-.085	
		Upper Bound	.351	
	5% Trimmed Mean		.093	
	Median		.000	
	Variance		.527	
	Std. Deviation		.7261	
	Minimum		-1.0	
	Maximum		2.0	
	Range		3.0	
	Interquartile Range		.0	
	Skewness		.908	.354
	Kurtosis		1.442	.695
Low quality of detailed design drawings - SetN	Mean		-.311	.1093
	95% Confidence Interval for Mean	Lower Bound	-.531	
		Upper Bound	-.091	
	5% Trimmed Mean		-.259	

	Median		.000	
	Variance		.537	
	Std. Deviation		.7331	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		-1.605	.354
	Kurtosis		3.710	.695
Slow response to Requests for Information (RFIs)- SetN	Mean		-.333	.1101
	95% Confidence Interval for Mean	Lower Bound	-.555	
		Upper Bound	-.111	
	5% Trimmed Mean		-.284	
	Median		.000	
	Variance		.545	
	Std. Deviation		.7385	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		-1.496	.354
	Kurtosis		3.322	.695
Use of advanced technologies - SetN	Mean		.422	.1291
	95% Confidence Interval for Mean	Lower Bound	.162	
		Upper Bound	.682	
	5% Trimmed Mean		.407	
	Median		.000	
	Variance		.749	
	Std. Deviation		.8657	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.581	.354
	Kurtosis		1.864	.695
High amount of paperwork involved- QetN	Mean		-.222	.1344
	95% Confidence Interval for	Lower Bound	-.493	

	Mean	Upper Bound	.049	
	5% Trimmed Mean		-.191	
	Median		.000	
	Variance		.813	
	Std. Deviation		.9017	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		-.508	.354
	Kurtosis		1.566	.695
Low quality of detailed design drawings - QetN	Mean		-1.556	.1213
	95% Confidence Interval for Mean	Lower Bound	-1.800	
		Upper Bound	-1.311	
	5% Trimmed Mean		-1.562	
	Median		-1.000	
	Variance		.662	
	Std. Deviation		.8134	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.211	.354
	Kurtosis		-.466	.695
Slow response to Requests for Information (RFIs)- QetN	Mean		-1.622	.1396
	95% Confidence Interval for Mean	Lower Bound	-1.904	
		Upper Bound	-1.341	
	5% Trimmed Mean		-1.636	
	Median		-2.000	
	Variance		.877	
	Std. Deviation		.9364	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.025	.354
	Kurtosis		-.852	.695

Use of advanced technologies - QetN	Mean		.800	.1896
	95% Confidence Interval for Mean	Lower Bound	.418	
		Upper Bound	1.182	
	5% Trimmed Mean		.852	
	Median		1.000	
	Variance		1.618	
	Std. Deviation		1.2721	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		-.507	.354
	Kurtosis		.691	.695
More than one language spoken on construction site-ScN	Mean		-1.311	.1676
	95% Confidence Interval for Mean	Lower Bound	-1.649	
		Upper Bound	-.973	
	5% Trimmed Mean		-1.315	
	Median		-1.000	
	Variance		1.265	
	Std. Deviation		1.1246	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		-.045	.354
	Kurtosis		-1.068	.695
Lack of adequate communication within site management-ScN	Mean		-1.511	.1443
	95% Confidence Interval for Mean	Lower Bound	-1.802	
		Upper Bound	-1.220	
	5% Trimmed Mean		-1.512	
	Median		-1.000	
	Variance		.937	
	Std. Deviation		.9682	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		1.0	

	Skewness		-.046	.354
	Kurtosis		-.912	.695
Lack of deserved positive feedback (compliments)-ScN	Mean		-.844	.1347
	95% Confidence Interval for Mean	Lower Bound	-1.116	
		Upper Bound	-.573	
	5% Trimmed Mean		-.802	
	Median		-1.000	
	Variance		.816	
	Std. Deviation		.9034	
	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		-.514	.354
	Kurtosis		-.179	.695
Poor working relationships and cohesiveness with co-workers-ScN	Mean		-1.711	.1334
	95% Confidence Interval for Mean	Lower Bound	-1.980	
		Upper Bound	-1.442	
	5% Trimmed Mean		-1.735	
	Median		-2.000	
	Variance		.801	
	Std. Deviation		.8950	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.576	.354
	Kurtosis		-.254	.695
More than one language spoken on construction site-QcN	Mean		-1.200	.1700
	95% Confidence Interval for Mean	Lower Bound	-1.543	
		Upper Bound	-.857	
	5% Trimmed Mean		-1.191	
	Median		-1.000	
	Variance		1.300	
	Std. Deviation		1.1402	
	Minimum		-3.0	
	Maximum		1.0	

	Range		4.0	
	Interquartile Range		2.0	
	Skewness		-.262	.354
	Kurtosis		-1.056	.695
Lack of adequate communication within site management-QcN	Mean		-1.556	.1254
	95% Confidence Interval for Mean	Lower Bound	-1.808	
		Upper Bound	-1.303	
	5% Trimmed Mean		-1.562	
	Median		-2.000	
	Variance		.707	
	Std. Deviation		.8409	
	Minimum		-3.0	
	Maximum		.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.183	.354
	Kurtosis		-.441	.695
Lack of deserved positive feedback (compliments)-QcN	Mean		-.911	.1518
	95% Confidence Interval for Mean	Lower Bound	-1.217	
		Upper Bound	-.605	
	5% Trimmed Mean		-.920	
	Median		-1.000	
	Variance		1.037	
	Std. Deviation		1.0185	
	Minimum		-3.0	
	Maximum		2.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		-.050	.354
	Kurtosis		1.059	.695
Poor working relationships and cohesiveness with co-workers-QcN	Mean		-1.600	.1363
	95% Confidence Interval for Mean	Lower Bound	-1.875	
		Upper Bound	-1.325	
	5% Trimmed Mean		-1.636	
	Median		-2.000	
	Variance		.836	
	Std. Deviation		.9145	

	Minimum		-3.0	
	Maximum		1.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		.403	.354
	Kurtosis		.314	.695
Well-defined organizational structure- SccP	Mean		1.578	.1540
	95% Confidence Interval for Mean	Lower Bound	1.267	
		Upper Bound	1.888	
	5% Trimmed Mean		1.642	
	Median		2.000	
	Variance		1.068	
	Std. Deviation		1.0333	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		-1.123	.354
	Kurtosis		.882	.695
High retention rate of skilled craftsmen - SccP	Mean		2.000	.1421
	95% Confidence Interval for Mean	Lower Bound	1.714	
		Upper Bound	2.286	
	5% Trimmed Mean		2.056	
	Median		2.000	
	Variance		.909	
	Std. Deviation		.9535	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.659	.354
	Kurtosis		-.442	.695
Regular performance reviews - SccP	Mean		1.022	.1403
	95% Confidence Interval for Mean	Lower Bound	.739	
		Upper Bound	1.305	
	5% Trimmed Mean		.969	
	Median		1.000	

	Variance		.886	
	Std. Deviation		.9412	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.639	.354
	Kurtosis		-.398	.695
Lower than typical productivity required- SccP	Mean		.467	.1869
	95% Confidence Interval for Mean	Lower Bound	.090	
		Upper Bound	.843	
	5% Trimmed Mean		.457	
	Median		.000	
	Variance		1.573	
	Std. Deviation		1.2541	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.549	.354
	Kurtosis		.169	.695
More time allowed in project schedule than typical - SccP	Mean		.867	.1608
	95% Confidence Interval for Mean	Lower Bound	.543	
		Upper Bound	1.191	
	5% Trimmed Mean		.846	
	Median		1.000	
	Variance		1.164	
	Std. Deviation		1.0787	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		.731	.354
	Kurtosis		-.078	.695
Good attitude towards safety- SccP	Mean		2.222	.1521
	95% Confidence Interval for Mean	Lower Bound	1.916	
		Upper Bound	2.529	

	5% Trimmed Mean		2.302	
	Median		3.000	
	Variance		1.040	
	Std. Deviation		1.0200	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.5	
	Skewness		-1.009	.354
	Kurtosis		-.272	.695
Safety takes precedence over other companies priorities - SccP	Mean		2.044	.1680
	95% Confidence Interval for Mean	Lower Bound	1.706	
		Upper Bound	2.383	
	5% Trimmed Mean		2.105	
	Median		2.000	
	Variance		1.271	
	Std. Deviation		1.1273	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.788	.354
	Kurtosis		-.832	.695
Relaxed atmosphere within company - SccP	Mean		.933	.1864
	95% Confidence Interval for Mean	Lower Bound	.558	
		Upper Bound	1.309	
	5% Trimmed Mean		.926	
	Median		1.000	
	Variance		1.564	
	Std. Deviation		1.2505	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.350	.354
	Kurtosis		-.757	.695
Well-defined organizational	Mean		1.778	.1141

structure - QccP	95% Confidence Interval for Mean	Lower Bound	1.548	
		Upper Bound	2.008	
	5% Trimmed Mean		1.809	
	Median		2.000	
	Variance		.586	
	Std. Deviation		.7654	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.547	.354
	Kurtosis		.357	.695
High retention rate of skilled craftsmen - QccP	Mean		2.244	.1277
	95% Confidence Interval for Mean	Lower Bound	1.987	
		Upper Bound	2.502	
	5% Trimmed Mean		2.327	
	Median		2.000	
	Variance		.734	
	Std. Deviation		.8569	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-1.185	.354
	Kurtosis		1.127	.695
Regular performance reviews - QccP	Mean		1.178	.1466
	95% Confidence Interval for Mean	Lower Bound	.882	
		Upper Bound	1.473	
	5% Trimmed Mean		1.142	
	Median		1.000	
	Variance		.968	
	Std. Deviation		.9837	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.526	.354

	Kurtosis		-.631	.695
Lower than typical productivity required- QccP	Mean		.622	.1967
	95% Confidence Interval for Mean	Lower Bound	.226	
		Upper Bound	1.019	
	5% Trimmed Mean		.630	
	Median		.000	
	Variance		1.740	
	Std. Deviation		1.3192	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.375	.354
	Kurtosis		-.127	.695
More time allowed in project schedule than typical - QccP	Mean		1.133	.1923
	95% Confidence Interval for Mean	Lower Bound	.746	
		Upper Bound	1.521	
	5% Trimmed Mean		1.173	
	Median		1.000	
	Variance		1.664	
	Std. Deviation		1.2898	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		-.193	.354
	Kurtosis		-.586	.695
Good attitude towards safety- QccP	Mean		1.267	.1723
	95% Confidence Interval for Mean	Lower Bound	.919	
		Upper Bound	1.614	
	5% Trimmed Mean		1.241	
	Median		1.000	
	Variance		1.336	
	Std. Deviation		1.1560	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	

	Interquartile Range		2.0	
	Skewness		.371	.354
	Kurtosis		-1.306	.695
Safety takes precedence over other companies priorities - QccP	Mean		1.156	.1932
	95% Confidence Interval for Mean	Lower Bound	.766	
		Upper Bound	1.545	
	5% Trimmed Mean		1.167	
	Median		1.000	
	Variance		1.680	
	Std. Deviation		1.2961	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.222	.354
	Kurtosis		-1.410	.695
Relaxed atmosphere within company - QccP	Mean		.822	.2067
	95% Confidence Interval for Mean	Lower Bound	.406	
		Upper Bound	1.239	
	5% Trimmed Mean		.852	
	Median		.000	
	Variance		1.922	
	Std. Deviation		1.3864	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		-.041	.354
	Kurtosis		-.124	.695
Slow pace of work-SpcP	Mean		.378	.1806
	95% Confidence Interval for Mean	Lower Bound	.014	
		Upper Bound	.742	
	5% Trimmed Mean		.333	
	Median		.000	
	Variance		1.468	
	Std. Deviation		1.2115	
	Minimum		-2.0	

	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.661	.354
	Kurtosis		.124	.695
Project is not unique -SpcP	Mean		.956	.2561
	95% Confidence Interval for Mean	Lower Bound	.439	
		Upper Bound	1.472	
	5% Trimmed Mean		.778	
	Median		1.000	
	Variance		2.953	
	Std. Deviation		1.7183	
	Minimum		-1.0	
	Maximum		10.0	
	Range		11.0	
	Interquartile Range		1.0	
	Skewness		3.419	.354
	Kurtosis		17.170	.695
Predictable weather condition -SpcP	Mean		1.178	.1396
	95% Confidence Interval for Mean	Lower Bound	.896	
		Upper Bound	1.459	
	5% Trimmed Mean		1.167	
	Median		1.000	
	Variance		.877	
	Std. Deviation		.9364	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		1.5	
	Skewness		-.024	.354
	Kurtosis		-.463	.695
Small project -SpcP	Mean		.489	.1512
	95% Confidence Interval for Mean	Lower Bound	.184	
		Upper Bound	.794	
	5% Trimmed Mean		.438	
	Median		.000	
	Variance		1.028	

	Std. Deviation		1.0140	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		.784	.354
	Kurtosis		.167	.695
Low cost project -SpcP	Mean		.022	.1291
	95% Confidence Interval for Mean	Lower Bound	-.238	
		Upper Bound	.282	
	5% Trimmed Mean		-.031	
	Median		.000	
	Variance		.749	
	Std. Deviation		.8657	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		.0	
	Skewness		1.056	.354
	Kurtosis		3.199	.695
Remote project - location -SpcP	Mean		-.267	.1602
	95% Confidence Interval for Mean	Lower Bound	-.589	
		Upper Bound	.056	
	5% Trimmed Mean		-.315	
	Median		.000	
	Variance		1.155	
	Std. Deviation		1.0745	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.565	.354
	Kurtosis		.840	.695
Low quality of work required - SpcP	Mean		-.511	.1759
	95% Confidence Interval for Mean	Lower Bound	-.866	
		Upper Bound	-.157	
	5% Trimmed Mean		-.531	

	Median		.000	
	Variance		1.392	
	Std. Deviation		1.1798	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		1.0	
	Skewness		.071	.354
	Kurtosis		1.409	.695
Slow pace of work -QpcP	Mean		.622	.1720
	95% Confidence Interval for Mean	Lower Bound	.276	
		Upper Bound	.969	
	5% Trimmed Mean		.605	
	Median		1.000	
	Variance		1.331	
	Std. Deviation		1.1538	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.338	.354
	Kurtosis		.119	.695
Project is not unique -QpcP	Mean		.844	.1588
	95% Confidence Interval for Mean	Lower Bound	.524	
		Upper Bound	1.164	
	5% Trimmed Mean		.827	
	Median		1.000	
	Variance		1.134	
	Std. Deviation		1.0651	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		1.5	
	Skewness		.442	.354
	Kurtosis		-.347	.695
Predictable weather condition -QpcP	Mean		1.222	.1553
	95% Confidence Interval for	Lower Bound	.909	

	Mean	Upper Bound	1.535	
	5% Trimmed Mean		1.191	
	Median		1.000	
	Variance		1.086	
	Std. Deviation		1.0420	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.161	.354
	Kurtosis		-1.251	.695
Small project -QpcP	Mean		.733	.1570
	95% Confidence Interval for Mean	Lower Bound	.417	
		Upper Bound	1.050	
	5% Trimmed Mean		.722	
	Median		1.000	
	Variance		1.109	
	Std. Deviation		1.0531	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.324	.354
	Kurtosis		.340	.695
Low cost project -QpcP	Mean		.044	.1455
	95% Confidence Interval for Mean	Lower Bound	-.249	
		Upper Bound	.338	
	5% Trimmed Mean		-.006	
	Median		.000	
	Variance		.953	
	Std. Deviation		.9760	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		.0	
	Skewness		.983	.354
	Kurtosis		2.948	.695

Remote project - location - QpcP	Mean		.111	.1564
	95% Confidence Interval for Mean	Lower Bound	-.204	
		Upper Bound	.426	
	5% Trimmed Mean		.093	
	Median		.000	
	Variance		1.101	
	Std. Deviation		1.0493	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.5	
	Skewness		.510	.354
	Kurtosis		.617	.695
Low quality of work required - QpcP	Mean		-.933	.2322
	95% Confidence Interval for Mean	Lower Bound	-1.401	
		Upper Bound	-.465	
	5% Trimmed Mean		-1.006	
	Median		-1.000	
	Variance		2.427	
	Std. Deviation		1.5580	
	Minimum		-3.0	
	Maximum		3.0	
	Range		6.0	
	Interquartile Range		2.0	
	Skewness		.262	.354
	Kurtosis		-.470	.695
Non-congested site - SpmP	Mean		1.711	.1408
	95% Confidence Interval for Mean	Lower Bound	1.427	
		Upper Bound	1.995	
	5% Trimmed Mean		1.735	
	Median		2.000	
	Variance		.892	
	Std. Deviation		.9444	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	

	Skewness		-.223	.354
	Kurtosis		-.796	.695
No or minimal overlapping of different crews/trades on site - SpmP	Mean		1.378	.1778
	95% Confidence Interval for Mean	Lower Bound	1.019	
		Upper Bound	1.736	
	5% Trimmed Mean		1.389	
	Median		1.000	
	Variance		1.422	
	Std. Deviation		1.1926	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		3.0	
	Skewness		.135	.354
	Kurtosis		-1.208	.695
Regular work hours - SpmP	Mean		1.356	.1391
	95% Confidence Interval for Mean	Lower Bound	1.075	
		Upper Bound	1.636	
	5% Trimmed Mean		1.340	
	Median		1.000	
	Variance		.871	
	Std. Deviation		.9331	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.091	.354
	Kurtosis		-.818	.695
Day shifts only - SpmP	Mean		1.156	.1489
	95% Confidence Interval for Mean	Lower Bound	.855	
		Upper Bound	1.456	
	5% Trimmed Mean		1.142	
	Median		1.000	
	Variance		.998	
	Std. Deviation		.9990	
	Minimum		-1.0	
	Maximum		3.0	

	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.104	.354
	Kurtosis		-.708	.695
Working on weekdays only - SpmP	Mean		.911	.1518
	95% Confidence Interval for Mean	Lower Bound	.605	
		Upper Bound	1.217	
	5% Trimmed Mean		.895	
	Median		1.000	
	Variance		1.037	
	Std. Deviation		1.0185	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.320	.354
	Kurtosis		-.580	.695
Experienced supervisor - SpmP	Mean		1.889	.1464
	95% Confidence Interval for Mean	Lower Bound	1.594	
		Upper Bound	2.184	
	5% Trimmed Mean		1.932	
	Median		2.000	
	Variance		.965	
	Std. Deviation		.9822	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.371	.354
	Kurtosis		-.941	.695
Construction drawings available when needed - SpmP	Mean		.933	.1400
	95% Confidence Interval for Mean	Lower Bound	.651	
		Upper Bound	1.215	
	5% Trimmed Mean		.870	
	Median		1.000	
	Variance		.882	
	Std. Deviation		.9391	

	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.654	.354
	Kurtosis		-.535	.695
Project-based safety incentive - SpmP	Mean		1.222	.1708
	95% Confidence Interval for Mean	Lower Bound	.878	
		Upper Bound	1.566	
	5% Trimmed Mean		1.191	
	Median		1.000	
	Variance		1.313	
	Std. Deviation		1.1459	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.395	.354
	Kurtosis		-1.274	.695
Look-ahead (bi-weekly) schedule available - SpmP	Mean		1.089	.1583
	95% Confidence Interval for Mean	Lower Bound	.770	
		Upper Bound	1.408	
	5% Trimmed Mean		1.068	
	Median		1.000	
	Variance		1.128	
	Std. Deviation		1.0622	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.292	.354
	Kurtosis		-.875	.695
Low number of project scope changes during construction - SpmP	Mean		.978	.1473
	95% Confidence Interval for Mean	Lower Bound	.681	
		Upper Bound	1.275	
	5% Trimmed Mean		.944	
	Median		1.000	

	Variance		.977	
	Std. Deviation		.9883	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.489	.354
	Kurtosis		-.359	.695
Design-Build contract - SpmP	Mean		.867	.1576
	95% Confidence Interval for Mean	Lower Bound	.549	
		Upper Bound	1.184	
	5% Trimmed Mean		.846	
	Median		1.000	
	Variance		1.118	
	Std. Deviation		1.0574	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.398	.354
	Kurtosis		.686	.695
Experienced crew - SpmP	Mean		1.933	.1435
	95% Confidence Interval for Mean	Lower Bound	1.644	
		Upper Bound	2.223	
	5% Trimmed Mean		1.981	
	Median		2.000	
	Variance		.927	
	Std. Deviation		.9630	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.501	.354
	Kurtosis		-.705	.695
Excellent personal protective equipment (PPE) and safety resources available - SpmP	Mean		2.044	.1420
	95% Confidence Interval for Mean	Lower Bound	1.758	
		Upper Bound	2.331	

	5% Trimmed Mean		2.105	
	Median		2.000	
	Variance		.907	
	Std. Deviation		.9524	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.587	.354
	Kurtosis		-.705	.695
Acceptable quality of instruction provided for work tasks - SpmP	Mean		1.422	.1403
	95% Confidence Interval for Mean	Lower Bound	1.139	
		Upper Bound	1.705	
	5% Trimmed Mean		1.414	
	Median		1.000	
	Variance		.886	
	Std. Deviation		.9412	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.235	.354
	Kurtosis		-.761	.695
No overlapping work activities for crew - SpmP	Mean		1.111	.1532
	95% Confidence Interval for Mean	Lower Bound	.802	
		Upper Bound	1.420	
	5% Trimmed Mean		1.068	
	Median		1.000	
	Variance		1.056	
	Std. Deviation		1.0274	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.558	.354
	Kurtosis		-.779	.695
Subcontractors not on-site at	Mean		1.000	.1651

same time - SpmP	95% Confidence Interval for Mean	Lower Bound	.667	
		Upper Bound	1.333	
	5% Trimmed Mean		.969	
	Median		1.000	
	Variance		1.227	
	Std. Deviation		1.1078	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.525	.354
	Kurtosis		-.829	.695
Few different tasks/activities being worked on by different crews at the same time - SpmP	Mean		1.044	.1619
	95% Confidence Interval for Mean	Lower Bound	.718	
		Upper Bound	1.371	
	5% Trimmed Mean		.994	
	Median		1.000	
	Variance		1.180	
	Std. Deviation		1.0862	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.5	
	Skewness		.799	.354
	Kurtosis		-.601	.695
Non-congested site - QpmP	Mean		1.444	.1441
	95% Confidence Interval for Mean	Lower Bound	1.154	
		Upper Bound	1.735	
	5% Trimmed Mean		1.438	
	Median		1.000	
	Variance		.934	
	Std. Deviation		.9666	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.085	.354

	Kurtosis		-.895	.695
No or minimal overlapping of different crews/trades on site - QpmP	Mean		1.378	.1749
	95% Confidence Interval for Mean	Lower Bound	1.025	
		Upper Bound	1.730	
	5% Trimmed Mean		1.389	
	Median		1.000	
	Variance		1.377	
	Std. Deviation		1.1734	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.5	
	Skewness		.087	.354
	Kurtosis		-1.165	.695
Regular work hours - QpmP	Mean		1.222	.1417
	95% Confidence Interval for Mean	Lower Bound	.937	
		Upper Bound	1.508	
	5% Trimmed Mean		1.191	
	Median		1.000	
	Variance		.904	
	Std. Deviation		.9508	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.193	.354
	Kurtosis		-.924	.695
Day shifts only - QpmP	Mean		1.178	.1396
	95% Confidence Interval for Mean	Lower Bound	.896	
		Upper Bound	1.459	
	5% Trimmed Mean		1.167	
	Median		1.000	
	Variance		.877	
	Std. Deviation		.9364	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	

	Interquartile Range		1.5	
	Skewness		-.024	.354
	Kurtosis		-.463	.695
Working on weekdays only - QpmP	Mean		.867	.1407
	95% Confidence Interval for Mean	Lower Bound	.583	
		Upper Bound	1.150	
	5% Trimmed Mean		.852	
	Median		1.000	
	Variance		.891	
	Std. Deviation		.9439	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		1.5	
	Skewness		.277	.354
	Kurtosis		-.294	.695
Experienced supervisor - QpmP	Mean		2.067	.1326
	95% Confidence Interval for Mean	Lower Bound	1.799	
		Upper Bound	2.334	
	5% Trimmed Mean		2.130	
	Median		2.000	
	Variance		.791	
	Std. Deviation		.8893	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.743	.354
	Kurtosis		-.054	.695
Construction drawings available when needed - QpmP	Mean		1.933	.1287
	95% Confidence Interval for Mean	Lower Bound	1.674	
		Upper Bound	2.193	
	5% Trimmed Mean		1.981	
	Median		2.000	
	Variance		.745	
	Std. Deviation		.8634	
	Minimum		.0	

	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.533	.354
	Kurtosis		-.203	.695
Project-based safety incentive - QpmP	Mean		.622	.1466
	95% Confidence Interval for Mean	Lower Bound	.327	
		Upper Bound	.918	
	5% Trimmed Mean		.525	
	Median		.000	
	Variance		.968	
	Std. Deviation		.9837	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		1.441	.354
	Kurtosis		.867	.695
Look-ahead (bi-weekly) schedule available - QpmP	Mean		1.378	.1598
	95% Confidence Interval for Mean	Lower Bound	1.056	
		Upper Bound	1.700	
	5% Trimmed Mean		1.364	
	Median		1.000	
	Variance		1.149	
	Std. Deviation		1.0721	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.101	.354
	Kurtosis		-1.228	.695
Low number of project scope changes during construction - QpmP	Mean		1.489	.1334
	95% Confidence Interval for Mean	Lower Bound	1.220	
		Upper Bound	1.758	
	5% Trimmed Mean		1.488	
	Median		1.000	
	Variance		.801	

	Std. Deviation		.8950	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.234	.354
	Kurtosis		-.654	.695
Design-Build contract - QpmP	Mean		1.067	.1664
	95% Confidence Interval for Mean	Lower Bound	.731	
		Upper Bound	1.402	
	5% Trimmed Mean		1.068	
	Median		1.000	
	Variance		1.245	
	Std. Deviation		1.1160	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		-.034	.354
	Kurtosis		-.091	.695
Experienced crew - QpmP	Mean		2.089	.1342
	95% Confidence Interval for Mean	Lower Bound	1.818	
		Upper Bound	2.359	
	5% Trimmed Mean		2.154	
	Median		2.000	
	Variance		.810	
	Std. Deviation		.9001	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.768	.354
	Kurtosis		-.093	.695
Excellent personal protective equipment (PPE) and safety resources available - QpmP	Mean		1.044	.1523
	95% Confidence Interval for Mean	Lower Bound	.738	
		Upper Bound	1.351	
	5% Trimmed Mean		.994	

	Median		1.000	
	Variance		1.043	
	Std. Deviation		1.0215	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.711	.354
	Kurtosis		-.541	.695
Acceptable quality of instruction provided for work tasks - QpmP	Mean		1.667	.1231
	95% Confidence Interval for Mean	Lower Bound	1.419	
		Upper Bound	1.915	
	5% Trimmed Mean		1.679	
	Median		2.000	
	Variance		.682	
	Std. Deviation		.8257	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.197	.354
	Kurtosis		-.713	.695
No overlapping work activities for crew - QpmP	Mean		1.156	.1489
	95% Confidence Interval for Mean	Lower Bound	.855	
		Upper Bound	1.456	
	5% Trimmed Mean		1.142	
	Median		1.000	
	Variance		.998	
	Std. Deviation		.9990	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.247	.354
	Kurtosis		-.491	.695
Subcontractors not on-site at same time - QpmP	Mean		.844	.1906
	95% Confidence Interval for	Lower Bound	.460	

	Mean	Upper Bound	1.229	
	5% Trimmed Mean		.877	
	Median		1.000	
	Variance		1.634	
	Std. Deviation		1.2784	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		-.106	.354
	Kurtosis		-.322	.695
Few different tasks/activities being worked on by different crews at the same time - QpmP	Mean		.978	.1755
	95% Confidence Interval for Mean	Lower Bound	.624	
		Upper Bound	1.331	
	5% Trimmed Mean		.975	
	Median		1.000	
	Variance		1.386	
	Std. Deviation		1.1772	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.395	.354
	Kurtosis		-.731	.695
Task is not repetitive- StsmP	Mean		.378	.1466
	95% Confidence Interval for Mean	Lower Bound	.082	
		Upper Bound	.673	
	5% Trimmed Mean		.364	
	Median		.000	
	Variance		.968	
	Std. Deviation		.9837	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.058	.354
	Kurtosis		.348	.695

Worker tasks are not long and monotonous (dull)- StsmP	Mean		.778	.1306
	95% Confidence Interval for Mean	Lower Bound	.515	
		Upper Bound	1.041	
	5% Trimmed Mean		.778	
	Median		1.000	
	Variance		.768	
	Std. Deviation		.8762	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		.248	.354
	Kurtosis		-.205	.695
Task involves low risk of injury - StsmP	Mean		1.489	.1787
	95% Confidence Interval for Mean	Lower Bound	1.129	
		Upper Bound	1.849	
	5% Trimmed Mean		1.537	
	Median		2.000	
	Variance		1.437	
	Std. Deviation		1.1989	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.5	
	Skewness		-.552	.354
	Kurtosis		-.051	.695
Assigned task requires little or no calculation, mental stress, remembering, etc- StsmP	Mean		.622	.1630
	95% Confidence Interval for Mean	Lower Bound	.294	
		Upper Bound	.951	
	5% Trimmed Mean		.611	
	Median		1.000	
	Variance		1.195	
	Std. Deviation		1.0931	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	

	Skewness		.055	.354
	Kurtosis		-.049	.695
Can concentrate on one task without needing to switch to another- StsmP	Mean		1.244	.1462
	95% Confidence Interval for Mean	Lower Bound	.950	
		Upper Bound	1.539	
	5% Trimmed Mean		1.216	
	Median		1.000	
	Variance		.962	
	Std. Deviation		.9806	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.538	.354
	Kurtosis		-.601	.695
Few or no sub-tasks within one task- StsmP	Mean		1.022	.1540
	95% Confidence Interval for Mean	Lower Bound	.712	
		Upper Bound	1.333	
	5% Trimmed Mean		.969	
	Median		1.000	
	Variance		1.068	
	Std. Deviation		1.0333	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.730	.354
	Kurtosis		-.569	.695
No interruption/interferences - StsmP	Mean		1.289	.1296
	95% Confidence Interval for Mean	Lower Bound	1.028	
		Upper Bound	1.550	
	5% Trimmed Mean		1.265	
	Median		1.000	
	Variance		.756	
	Std. Deviation		.8692	
	Minimum		.0	
	Maximum		3.0	

	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.040	.354
	Kurtosis		-.717	.695
Foreman's method of supervision is conventional-StsmP	Mean		.978	.1507
	95% Confidence Interval for Mean	Lower Bound	.674	
		Upper Bound	1.282	
	5% Trimmed Mean		.975	
	Median		1.000	
	Variance		1.022	
	Std. Deviation		1.0111	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		-.230	.354
	Kurtosis		.274	.695
Work tasks very predictable due to adequate information-StsmP	Mean		1.356	.1354
	95% Confidence Interval for Mean	Lower Bound	1.083	
		Upper Bound	1.628	
	5% Trimmed Mean		1.340	
	Median		1.000	
	Variance		.825	
	Std. Deviation		.9084	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.024	.354
	Kurtosis		-.813	.695
Workers are not given new tasks too frequently- StsmP	Mean		1.200	.1371
	95% Confidence Interval for Mean	Lower Bound	.924	
		Upper Bound	1.476	
	5% Trimmed Mean		1.167	
	Median		1.000	
	Variance		.845	
	Std. Deviation		.9195	

	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.5	
	Skewness		.316	.354
	Kurtosis		-.674	.695
Task is not repetitive - QtsmP	Mean		.400	.1723
	95% Confidence Interval for Mean	Lower Bound	.053	
		Upper Bound	.747	
	5% Trimmed Mean		.389	
	Median		.000	
	Variance		1.336	
	Std. Deviation		1.1560	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		.163	.354
	Kurtosis		-.014	.695
Worker tasks are not long and monotonous (dull)- QtsmP	Mean		1.089	.1485
	95% Confidence Interval for Mean	Lower Bound	.790	
		Upper Bound	1.388	
	5% Trimmed Mean		1.068	
	Median		1.000	
	Variance		.992	
	Std. Deviation		.9960	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		.249	.354
	Kurtosis		-.615	.695
Task involves low risk of injury - QtsmP	Mean		1.200	.1544
	95% Confidence Interval for Mean	Lower Bound	.889	
		Upper Bound	1.511	
	5% Trimmed Mean		1.167	
	Median		1.000	

	Variance		1.073	
	Std. Deviation		1.0357	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.349	.354
	Kurtosis		-1.030	.695
Assigned task requires little or no calculation, mental stress, remembering, etc- QtsmP	Mean		1.000	.1712
	95% Confidence Interval for Mean	Lower Bound	.655	
		Upper Bound	1.345	
	5% Trimmed Mean		1.000	
	Median		1.000	
	Variance		1.318	
	Std. Deviation		1.1481	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		-.094	.354
	Kurtosis		-.727	.695
Can concentrate on one task without needing to switch to another- QtsmP	Mean		1.444	.1369
	95% Confidence Interval for Mean	Lower Bound	1.169	
		Upper Bound	1.720	
	5% Trimmed Mean		1.438	
	Median		1.000	
	Variance		.843	
	Std. Deviation		.9184	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.447	.354
	Kurtosis		-.639	.695
Few or no sub-tasks within one task- QtsmP	Mean		1.356	.1496
	95% Confidence Interval for Mean	Lower Bound	1.054	
		Upper Bound	1.657	

	5% Trimmed Mean		1.364	
	Median		1.000	
	Variance		1.007	
	Std. Deviation		1.0035	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		-.077	.354
	Kurtosis		-.536	.695
No interruption/interferences - QtsmP	Mean		1.689	.1379
	95% Confidence Interval for Mean	Lower Bound	1.411	
		Upper Bound	1.967	
	5% Trimmed Mean		1.710	
	Median		2.000	
	Variance		.856	
	Std. Deviation		.9250	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.226	.354
	Kurtosis		-.712	.695
Foreman's method of supervision is conventional- QtsmP	Mean		1.178	.1660
	95% Confidence Interval for Mean	Lower Bound	.843	
		Upper Bound	1.512	
	5% Trimmed Mean		1.191	
	Median		1.000	
	Variance		1.240	
	Std. Deviation		1.1137	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		-.161	.354
	Kurtosis		.107	.695
Work tasks very predictable	Mean		1.644	.1316

due to adequate information-QtsmP	95% Confidence Interval for Mean	Lower Bound	1.379	
		Upper Bound	1.910	
	5% Trimmed Mean		1.660	
	Median		2.000	
	Variance		.780	
	Std. Deviation		.8831	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.255	.354
	Kurtosis		-.527	.695
Workers are not given new tasks too frequently- QtsmP	Mean		1.289	.1408
	95% Confidence Interval for Mean	Lower Bound	1.005	
		Upper Bound	1.573	
	5% Trimmed Mean		1.265	
	Median		1.000	
	Variance		.892	
	Std. Deviation		.9444	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.223	.354
	Kurtosis		-.796	.695
Very organized material, tools, and equipment storage- SmtsP	Mean		1.644	.1462
	95% Confidence Interval for Mean	Lower Bound	1.350	
		Upper Bound	1.939	
	5% Trimmed Mean		1.660	
	Median		2.000	
	Variance		.962	
	Std. Deviation		.9806	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.122	.354

	Kurtosis		-.954	.695
Easy-to-use equipment (requires only basic skills)- SmtsP	Mean		1.489	.1545
	95% Confidence Interval for Mean	Lower Bound	1.178	
		Upper Bound	1.800	
	5% Trimmed Mean		1.488	
	Median		1.000	
	Variance		1.074	
	Std. Deviation		1.0362	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.031	.354
	Kurtosis		-1.118	.695
Familiar with equipment used for task- SmtsP	Mean		1.867	.1544
	95% Confidence Interval for Mean	Lower Bound	1.556	
		Upper Bound	2.178	
	5% Trimmed Mean		1.932	
	Median		2.000	
	Variance		1.073	
	Std. Deviation		1.0357	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		2.0	
	Skewness		-.750	.354
	Kurtosis		.050	.695
Material, tools, and equipment is readily available - SmtsP	Mean		1.578	.1507
	95% Confidence Interval for Mean	Lower Bound	1.274	
		Upper Bound	1.882	
	5% Trimmed Mean		1.586	
	Median		2.000	
	Variance		1.022	
	Std. Deviation		1.0111	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	

	Interquartile Range		1.0	
	Skewness		-.153	.354
	Kurtosis		-1.016	.695
Equipment and tools are of good quality - SmtsP	Mean		1.689	.1518
	95% Confidence Interval for Mean	Lower Bound	1.383	
		Upper Bound	1.995	
	5% Trimmed Mean		1.710	
	Median		2.000	
	Variance		1.037	
	Std. Deviation		1.0185	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.5	
	Skewness		-.271	.354
	Kurtosis		-.987	.695
Pre-fabrication is of good quality - SmtsP	Mean		1.511	.1512
	95% Confidence Interval for Mean	Lower Bound	1.206	
		Upper Bound	1.816	
	5% Trimmed Mean		1.512	
	Median		2.000	
	Variance		1.028	
	Std. Deviation		1.0140	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		-.100	.354
	Kurtosis		-1.049	.695
Materials are of good quality - SmtsP	Mean		1.467	.1443
	95% Confidence Interval for Mean	Lower Bound	1.176	
		Upper Bound	1.757	
	5% Trimmed Mean		1.463	
	Median		1.000	
	Variance		.936	
	Std. Deviation		.9677	
	Minimum		.0	

	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.020	.354
	Kurtosis		-.909	.695
Very organized material, tools, and equipment storage- QmtsP	Mean		1.800	.1477
	95% Confidence Interval for Mean	Lower Bound	1.502	
		Upper Bound	2.098	
	5% Trimmed Mean		1.833	
	Median		2.000	
	Variance		.982	
	Std. Deviation		.9909	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.311	.354
	Kurtosis		-.936	.695
Easy-to-use equipment (requires only basic skills)- QmtsP	Mean		1.467	.1443
	95% Confidence Interval for Mean	Lower Bound	1.176	
		Upper Bound	1.757	
	5% Trimmed Mean		1.463	
	Median		1.000	
	Variance		.936	
	Std. Deviation		.9677	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.020	.354
	Kurtosis		-.909	.695
Familiar with equipment used for task-QmtsP	Mean		1.889	.1357
	95% Confidence Interval for Mean	Lower Bound	1.615	
		Upper Bound	2.162	
	5% Trimmed Mean		1.932	
	Median		2.000	
	Variance		.828	

	Std. Deviation		.9101	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.340	.354
	Kurtosis		-.729	.695
Material, tools, and equipment is readily available -QmtsP	Mean		1.800	.1371
	95% Confidence Interval for Mean	Lower Bound	1.524	
		Upper Bound	2.076	
	5% Trimmed Mean		1.833	
	Median		2.000	
	Variance		.845	
	Std. Deviation		.9195	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.5	
	Skewness		-.316	.354
	Kurtosis		-.674	.695
Equipment and tools are of good quality -QmtsP	Mean		1.911	.1304
	95% Confidence Interval for Mean	Lower Bound	1.648	
		Upper Bound	2.174	
	5% Trimmed Mean		1.951	
	Median		2.000	
	Variance		.765	
	Std. Deviation		.8744	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.249	.354
	Kurtosis		-.814	.695
Pre-fabrication is of good quality -QmtsP	Mean		1.978	.1573
	95% Confidence Interval for Mean	Lower Bound	1.661	
		Upper Bound	2.295	
	5% Trimmed Mean		2.031	

	Median		2.000	
	Variance		1.113	
	Std. Deviation		1.0551	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.683	.354
	Kurtosis		-.738	.695
Materials are of good quality - QmtsP	Mean		2.089	.1450
	95% Confidence Interval for Mean	Lower Bound	1.797	
		Upper Bound	2.381	
	5% Trimmed Mean		2.154	
	Median		2.000	
	Variance		.946	
	Std. Deviation		.9729	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.5	
	Skewness		-.804	.354
	Kurtosis		-.334	.695
Low amount of paperwork involved-SetP	Mean		.400	.1504
	95% Confidence Interval for Mean	Lower Bound	.097	
		Upper Bound	.703	
	5% Trimmed Mean		.358	
	Median		.000	
	Variance		1.018	
	Std. Deviation		1.0090	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		1.0	
	Skewness		1.050	.354
	Kurtosis		1.791	.695
High quality of detailed design drawings -SetP	Mean		.667	.1231
	95% Confidence Interval for	Lower Bound	.419	

	Mean	Upper Bound	.915	
	5% Trimmed Mean		.630	
	Median		1.000	
	Variance		.682	
	Std. Deviation		.8257	
	Minimum		-1.0	
	Maximum		3.0	
	Range		4.0	
	Interquartile Range		1.0	
	Skewness		.704	.354
	Kurtosis		.184	.695
Quick response to Requests for Information (RFIs)-SetP	Mean		.733	.1363
	95% Confidence Interval for Mean	Lower Bound	.459	
		Upper Bound	1.008	
	5% Trimmed Mean		.654	
	Median		.000	
	Variance		.836	
	Std. Deviation		.9145	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.942	.354
	Kurtosis		-.222	.695
Use of commonly-used technologies-SetP	Mean		.844	.1309
	95% Confidence Interval for Mean	Lower Bound	.581	
		Upper Bound	1.108	
	5% Trimmed Mean		.802	
	Median		1.000	
	Variance		.771	
	Std. Deviation		.8779	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.527	.354
	Kurtosis		-.963	.695

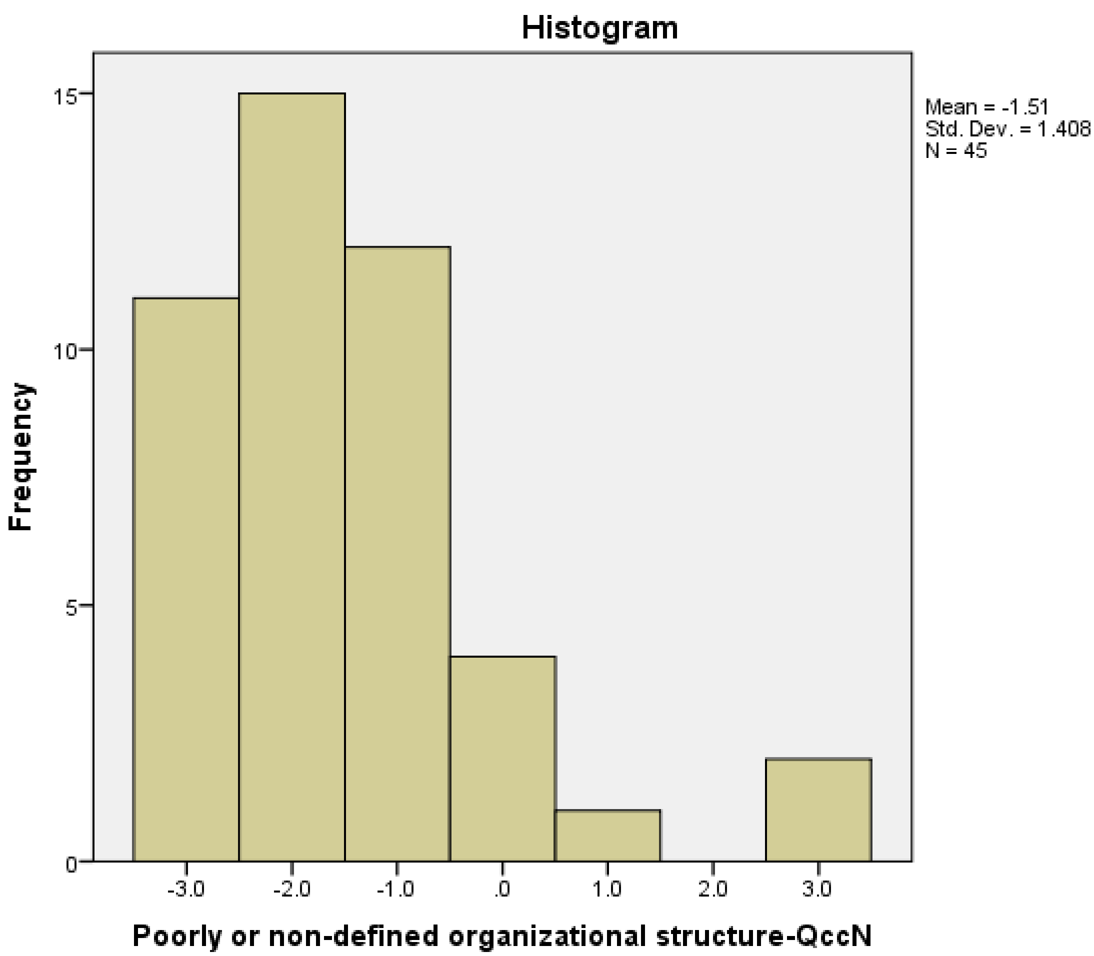
Low amount of paperwork involved-QetP	Mean		.778	.1678
	95% Confidence Interval for Mean	Lower Bound	.440	
		Upper Bound	1.116	
	5% Trimmed Mean		.772	
	Median		.000	
	Variance		1.268	
	Std. Deviation		1.1259	
	Minimum		-2.0	
	Maximum		3.0	
	Range		5.0	
	Interquartile Range		2.0	
	Skewness		.361	.354
	Kurtosis		-.093	.695
High quality of detailed design drawings -QetP	Mean		1.867	.1407
	95% Confidence Interval for Mean	Lower Bound	1.583	
		Upper Bound	2.150	
	5% Trimmed Mean		1.907	
	Median		2.000	
	Variance		.891	
	Std. Deviation		.9439	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.572	.354
	Kurtosis		-.425	.695
Quick response to Requests for Information (RFIs)-QetP	Mean		1.756	.1462
	95% Confidence Interval for Mean	Lower Bound	1.461	
		Upper Bound	2.050	
	5% Trimmed Mean		1.784	
	Median		2.000	
	Variance		.962	
	Std. Deviation		.9806	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.5	

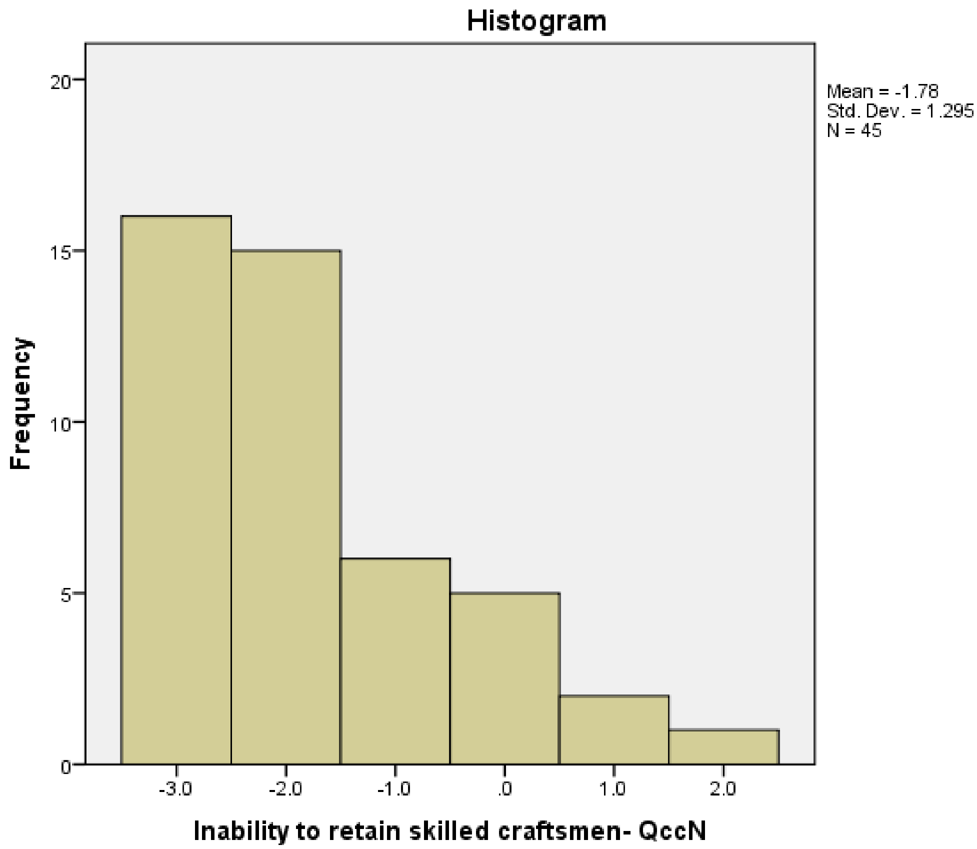
	Skewness		-.386	.354
	Kurtosis		-.774	.695
Use of commonly-used technologies-QetP	Mean		1.489	.1408
	95% Confidence Interval for Mean	Lower Bound	1.205	
		Upper Bound	1.773	
	5% Trimmed Mean		1.488	
	Median		1.000	
	Variance		.892	
	Std. Deviation		.9444	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.0	
	Skewness		.033	.354
	Kurtosis		-.831	.695
Only one language spoken on construction site- ScP	Mean		1.311	.1676
	95% Confidence Interval for Mean	Lower Bound	.973	
		Upper Bound	1.649	
	5% Trimmed Mean		1.290	
	Median		1.000	
	Variance		1.265	
	Std. Deviation		1.1246	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		.246	.354
	Kurtosis		-1.311	.695
Good communication within site management- ScP	Mean		1.756	.1625
	95% Confidence Interval for Mean	Lower Bound	1.428	
		Upper Bound	2.083	
	5% Trimmed Mean		1.784	
	Median		2.000	
	Variance		1.189	
	Std. Deviation		1.0904	
	Minimum		.0	
	Maximum		3.0	

	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.257	.354
	Kurtosis		-1.255	.695
Positive feedback (compliments) is regularly communicated to deserving workers- ScP	Mean		1.467	.1639
	95% Confidence Interval for Mean	Lower Bound	1.136	
		Upper Bound	1.797	
	5% Trimmed Mean		1.463	
	Median		1.000	
	Variance		1.209	
	Std. Deviation		1.0996	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		1.5	
	Skewness		.142	.354
	Kurtosis		-1.282	.695
Excellent working relationships and cohesiveness with co-workers- ScP	Mean		1.844	.1588
	95% Confidence Interval for Mean	Lower Bound	1.524	
		Upper Bound	2.164	
	5% Trimmed Mean		1.883	
	Median		2.000	
	Variance		1.134	
	Std. Deviation		1.0651	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.385	.354
	Kurtosis		-1.119	.695
Only one language spoken on construction site- QcP	Mean		1.533	.1787
	95% Confidence Interval for Mean	Lower Bound	1.173	
		Upper Bound	1.893	
	5% Trimmed Mean		1.537	
	Median		1.000	
	Variance		1.436	
	Std. Deviation		1.1985	

	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		3.0	
	Skewness		.001	.354
	Kurtosis		-1.544	.695
Good communication within site management- QcP	Mean		1.933	.1363
	95% Confidence Interval for Mean	Lower Bound	1.659	
		Upper Bound	2.208	
	5% Trimmed Mean		1.981	
	Median		2.000	
	Variance		.836	
	Std. Deviation		.9145	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.610	.354
	Kurtosis		-.282	.695
Positive feedback (compliments) is regularly communicated to deserving workers- QcP	Mean		1.711	.1545
	95% Confidence Interval for Mean	Lower Bound	1.400	
		Upper Bound	2.022	
	5% Trimmed Mean		1.735	
	Median		2.000	
	Variance		1.074	
	Std. Deviation		1.0362	
	Minimum		.0	
	Maximum		3.0	
	Range		3.0	
	Interquartile Range		2.0	
	Skewness		-.149	.354
	Kurtosis		-1.160	.695
Excellent working relationships and cohesiveness with co-workers- QcP	Mean		2.022	.1473
	95% Confidence Interval for Mean	Lower Bound	1.725	
		Upper Bound	2.319	
	5% Trimmed Mean		2.080	

	Median	2.000	
	Variance	.977	
	Std. Deviation	.9883	
	Minimum	.0	
	Maximum	3.0	
	Range	3.0	
	Interquartile Range	2.0	
	Skewness	-.637	.354
	Kurtosis	-.672	.695

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Mean = -1.78
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15
10
5
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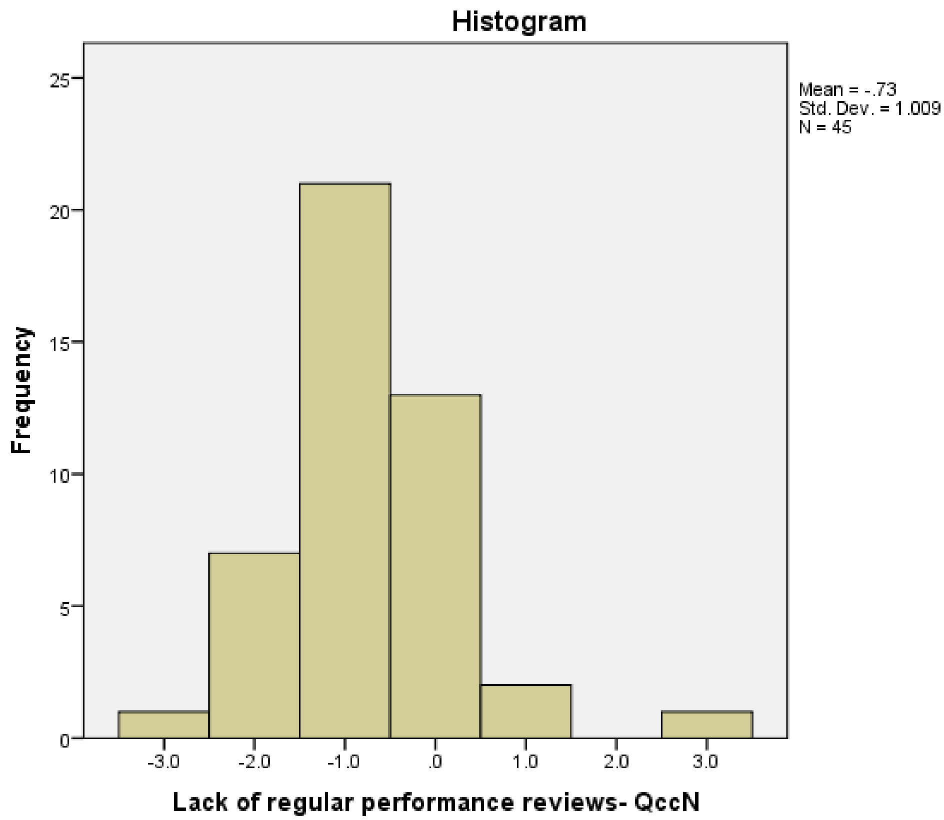
1.0
2.0
Inability to retain skilled craftsmen- QccN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Mean = -.73
Std. Dev. = 1.009
N = 45
Frequency
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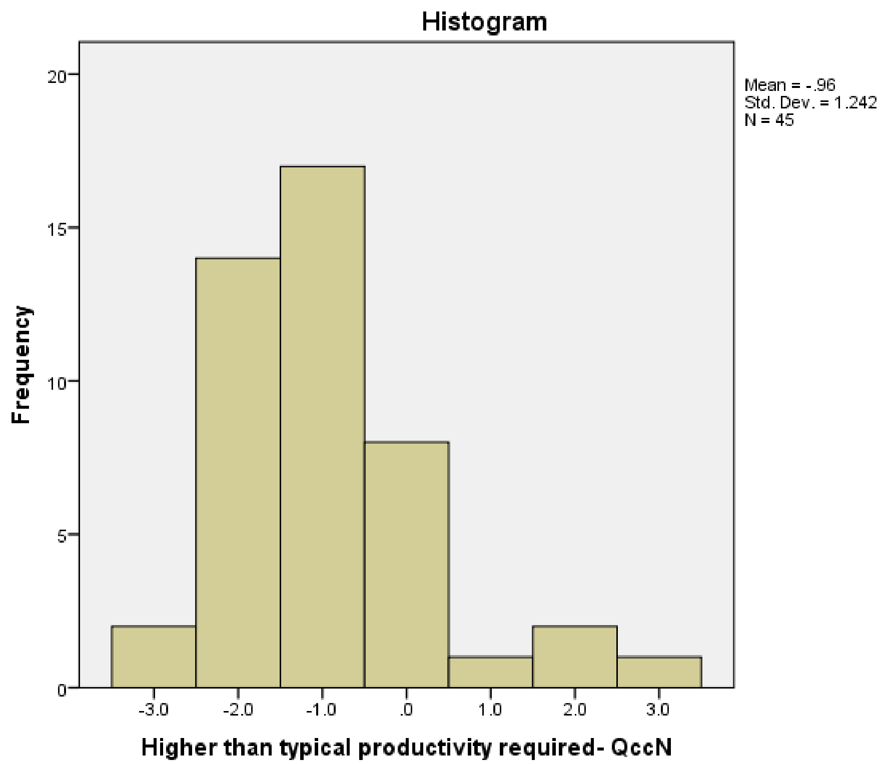
.0
1.0
2.0
3.0
Lack of regular performance reviews- QccN


Histogram
Mean = -.96
Std. Dev. = 1.242
N = 45
Frequency
20
15
10
5
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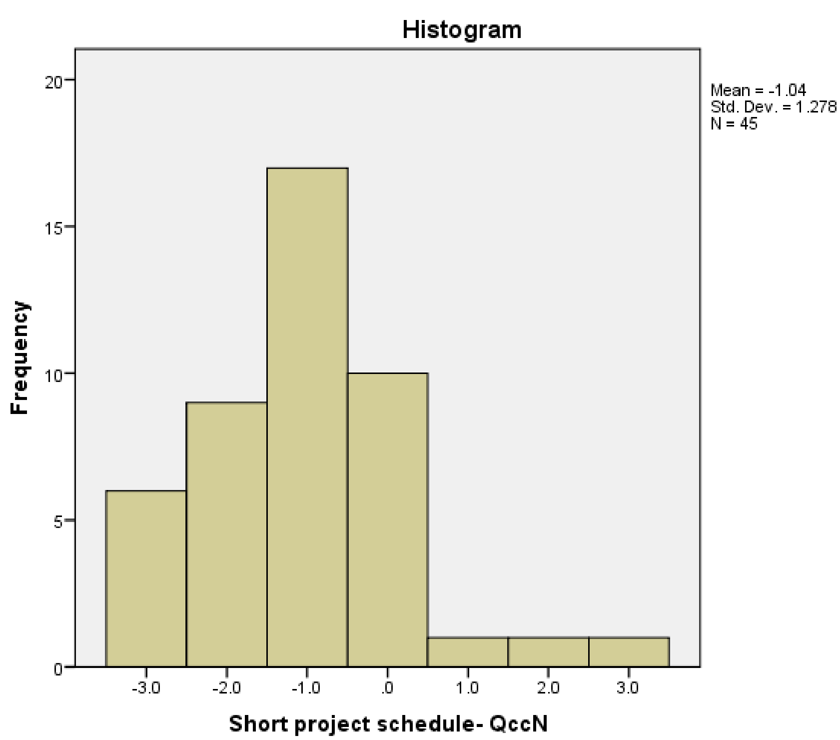
-2.0
-1.0
.0
1.0
2.0
3.0
Higher than typical productivity required- QccN


Histogram
Mean = -1.04
Std. Dev. = 1.278
N = 45
Frequency
20
15
10
5
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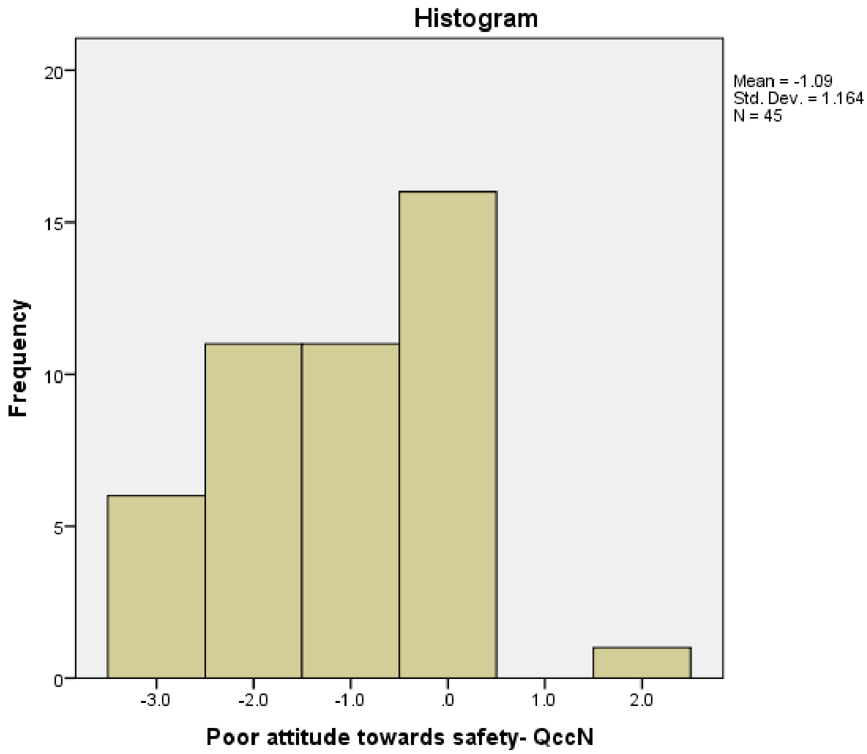
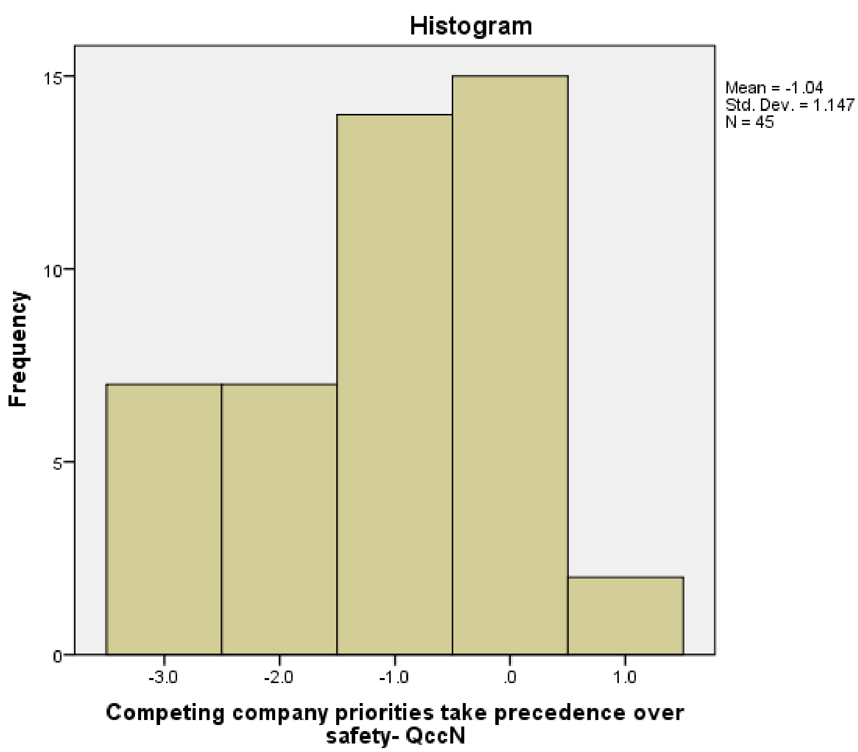
-3.0
-2.0
-1.0
.0
1.0
2.0
3.0
Short project schedule- QccN


Histogram
Mean = -1.09
Std. Dev. = 1.164
N = 45
Frequency
20
15
10
5
0
-3.0
-2.0
-1.0
.0
1.0
2.0
Poor attitude towards safety- QccN


Histogram
Mean = -1.04
Std. Dev. = 1.147
N = 45
Frequency
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10
5
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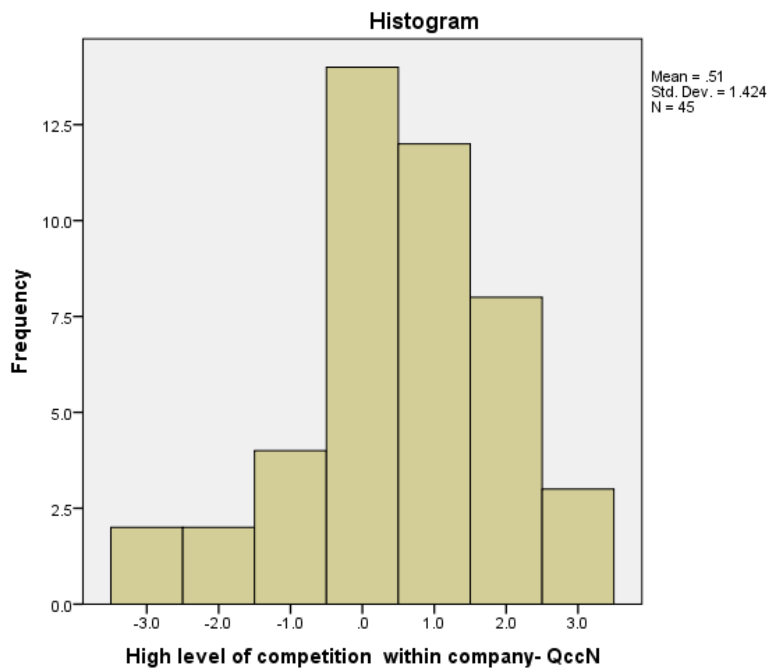
-2.0
-1.0
.0
1.0
Competing company priorities take precedence over safety- QccN


Histogram
Mean = .51
Std. Dev. = 1.424
N = 45
Frequency
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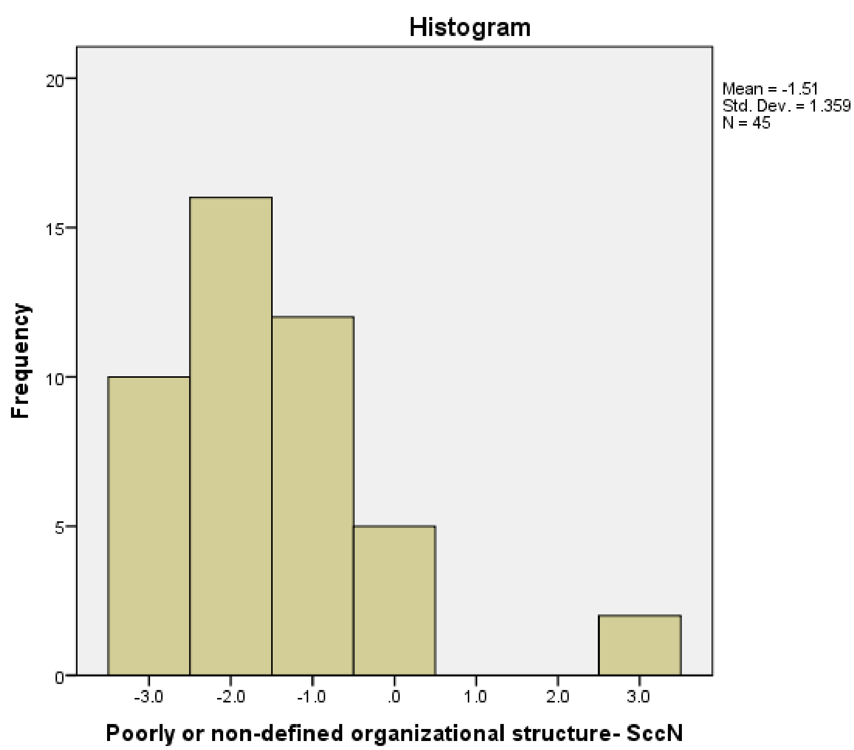
10.0
7.5
5.0
2.5
0.0
-3.0
-2.0
-1.0
.0
1.0
2.0
3.0
High level of competition within company- QccN


Histogram
Mean = -1.51
Std. Dev. = 1.359
N = 45
Frequency
20
15
10
5
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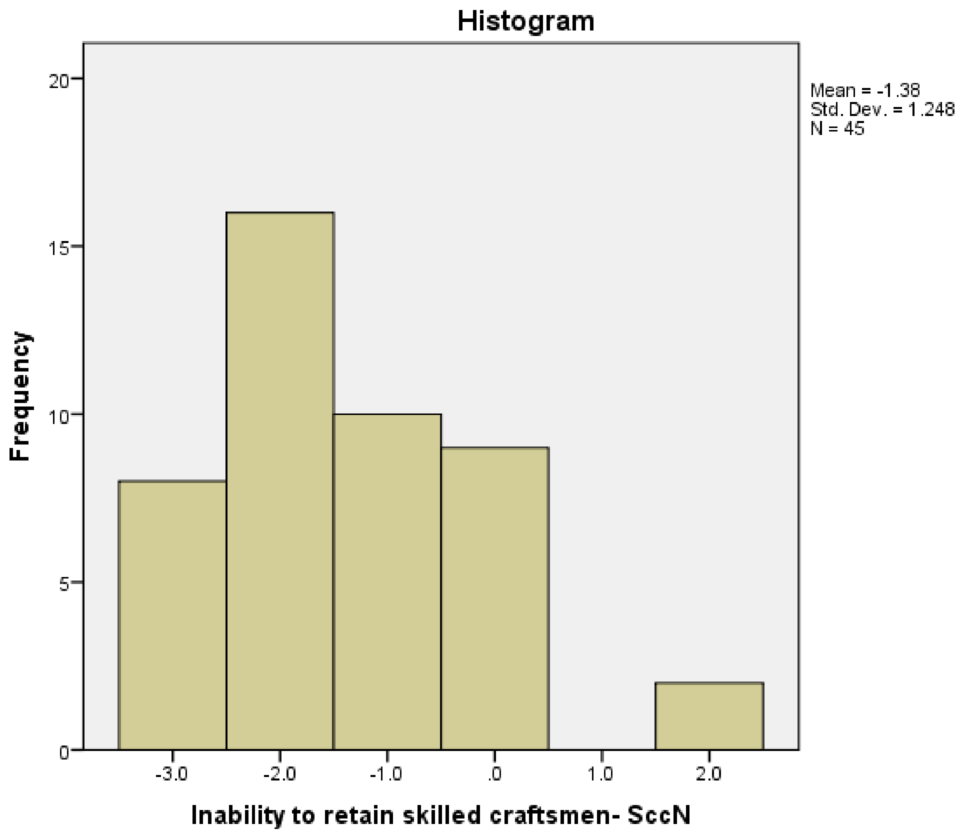
-3.0
-2.0
-1.0
.0
1.0
2.0
3.0
Poorly or non-defined organizational structure- SccN


Histogram
Mean = -1.38
Std. Dev. = 1.248
N = 45
Frequency
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15
10
5
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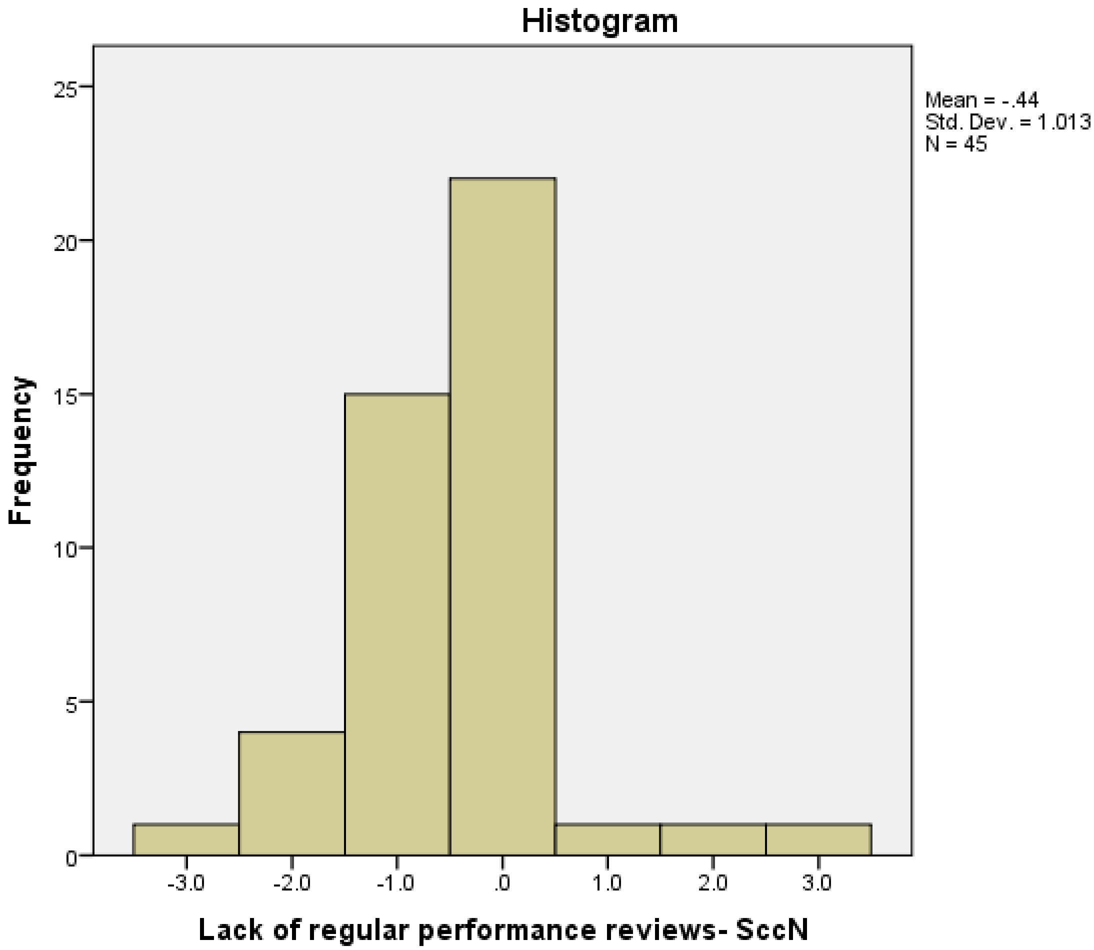
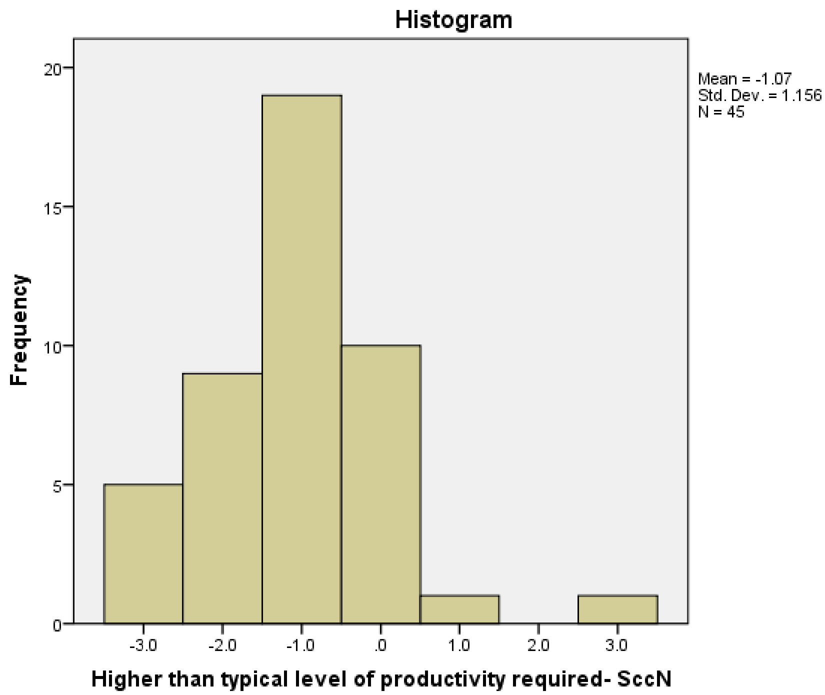
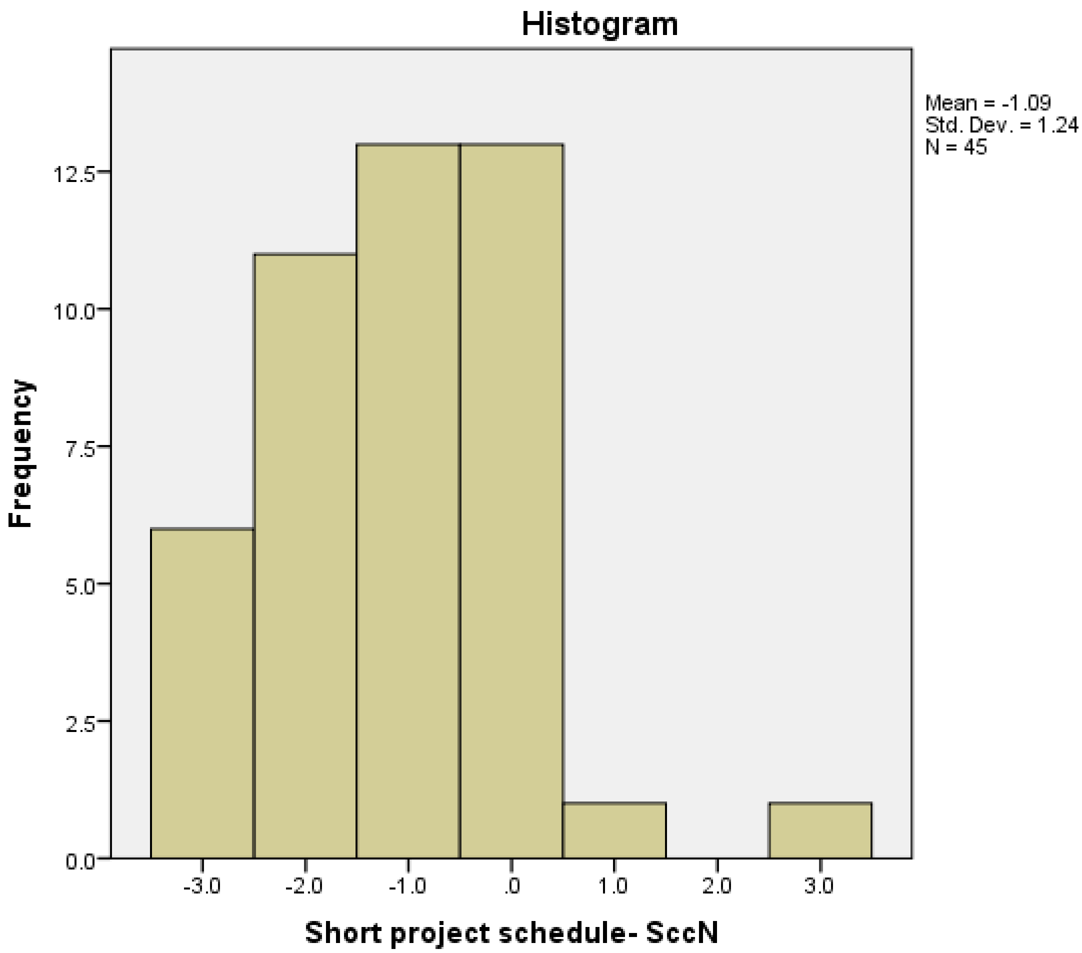
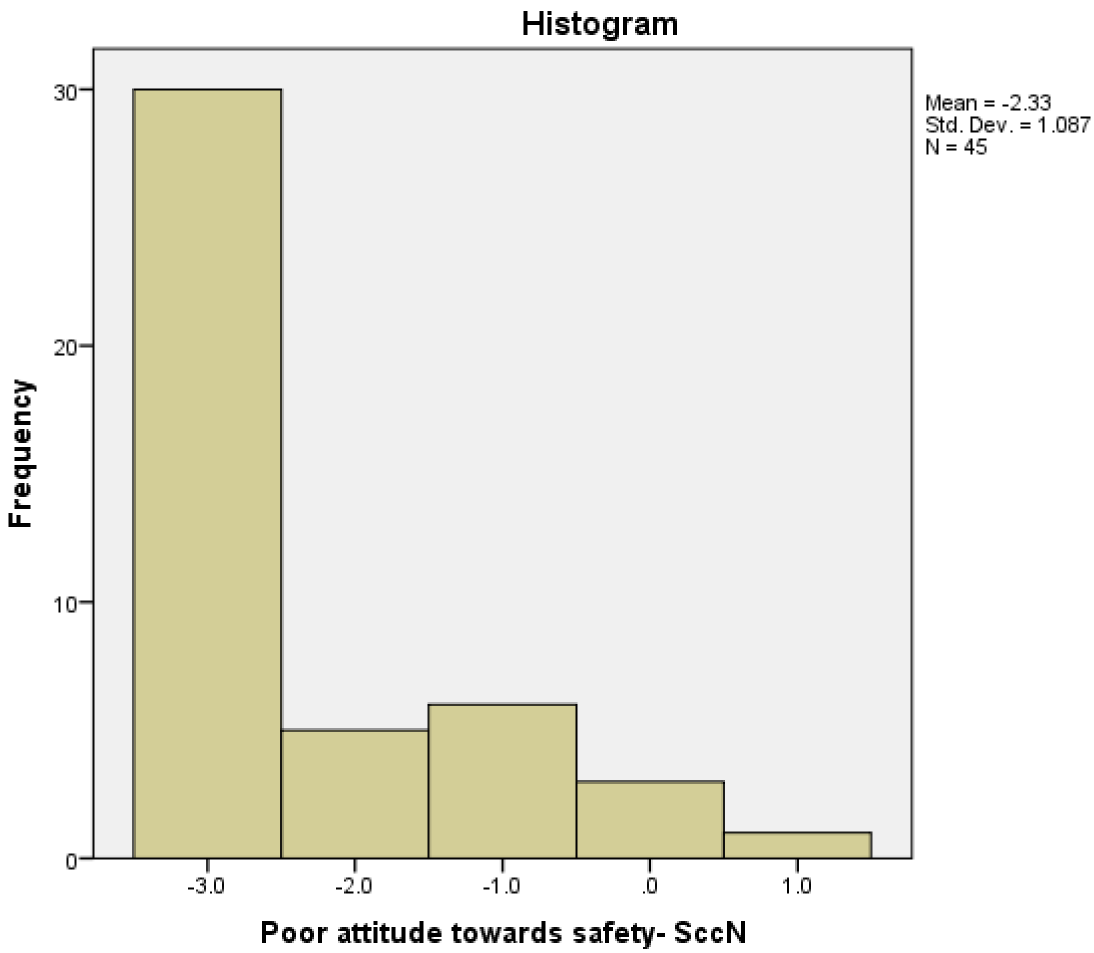
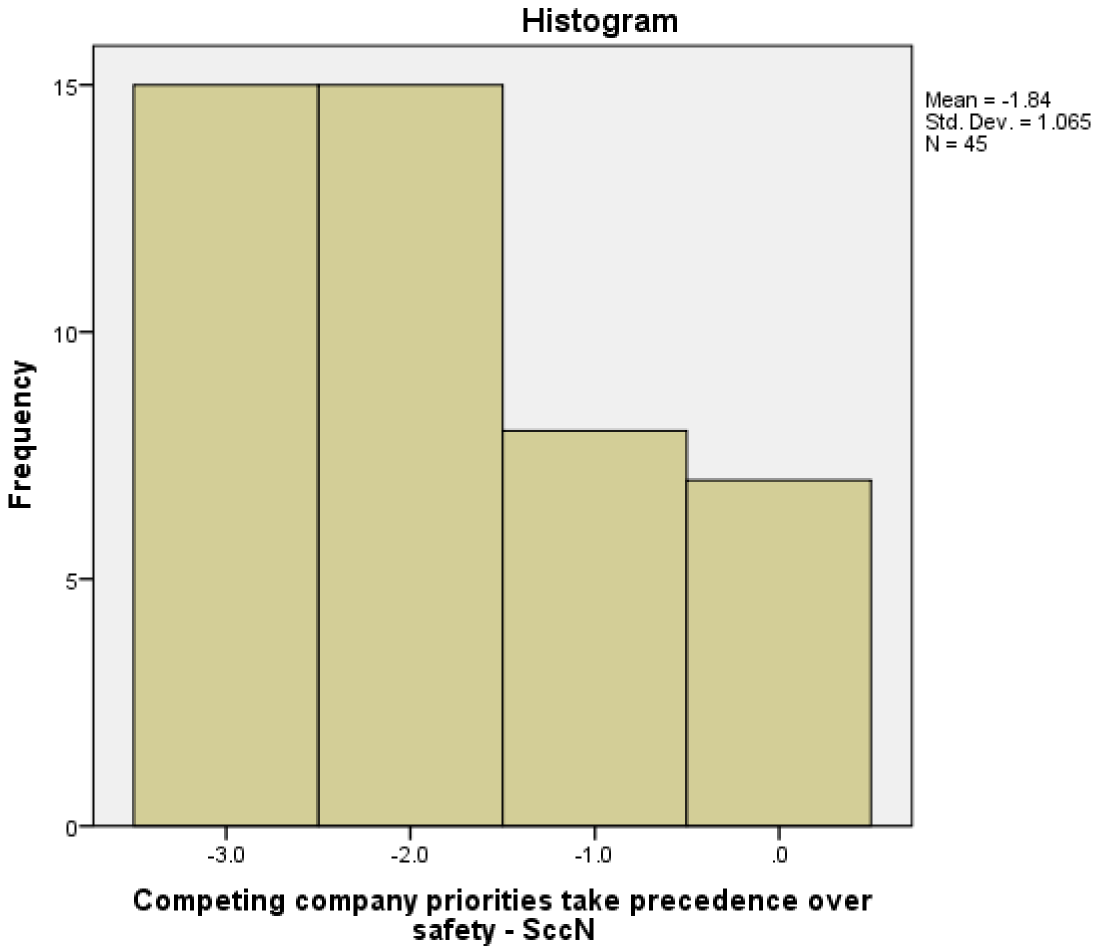
-3.0
-2.0
-1.0
.0
1.0
2.0
Inability to retain skilled craftsmen- SccN

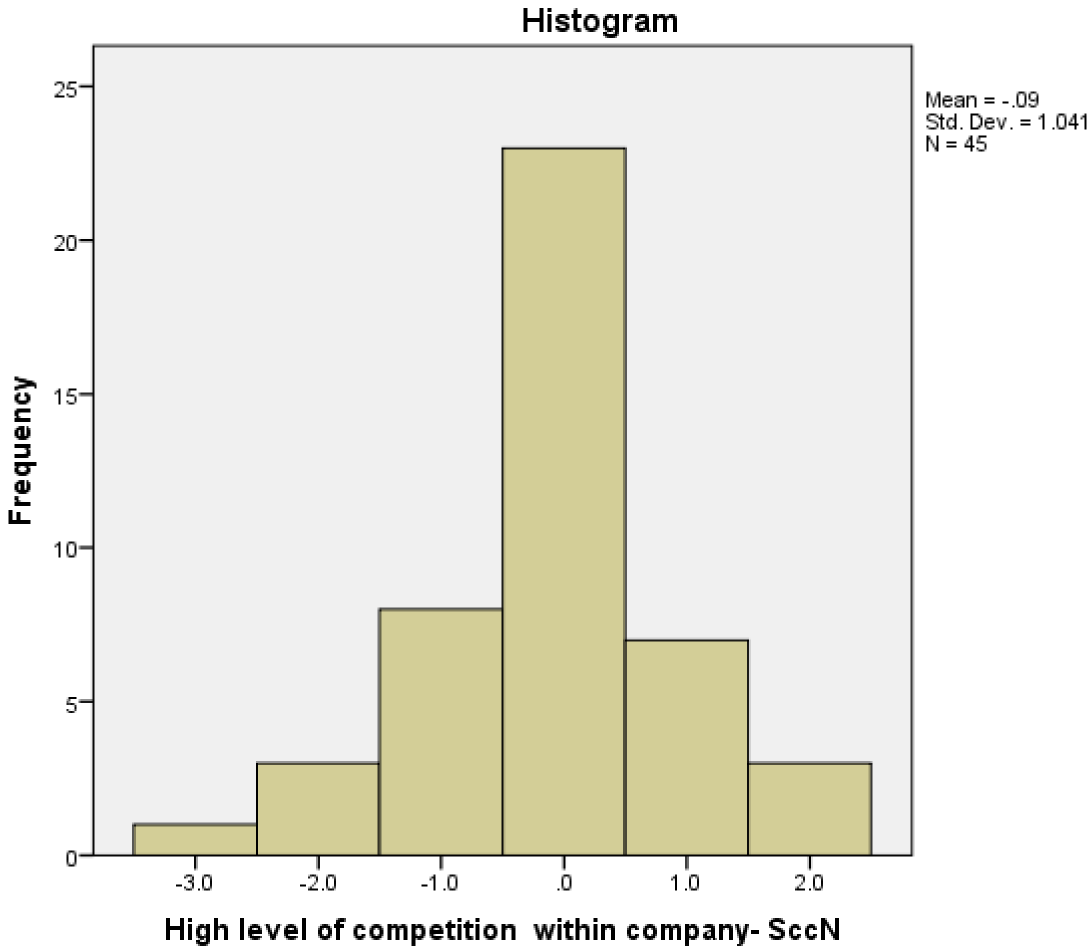

Histogram
Mean = -.44
Std. Dev. = 1.013
N = 45
Frequency
25
20
15
10
5
0
-3.0
-2.0
-1.0
.0
1.0
2.0
3.0
Lack of regular performance reviews- SccN

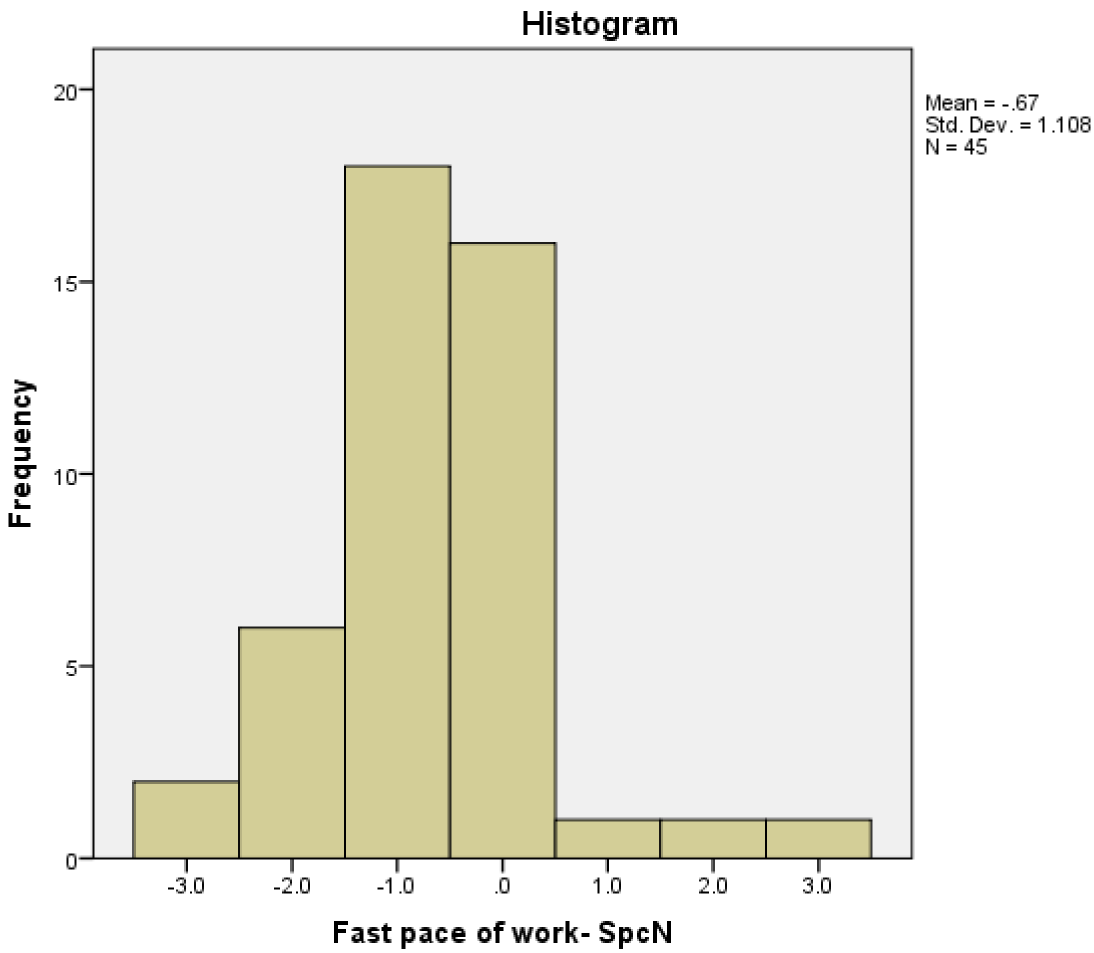

Histogram
Mean = -1.07
Std. Dev. = 1.156
N = 45
Frequency
20
15
10
5
0
-3.0
-2.0
-1.0
.0
1.0
2.0
3.0
Higher than typical level of productivity required- SccN


Histogram
Mean = -1.09
Std. Dev. = 1.24
N = 45
Frequency
12.5
10.0
7.5
5.0
2.5
0.0
-3.0
-2.0
-1.0
.0
1.0
2.0
3.0
Short project schedule- SccN

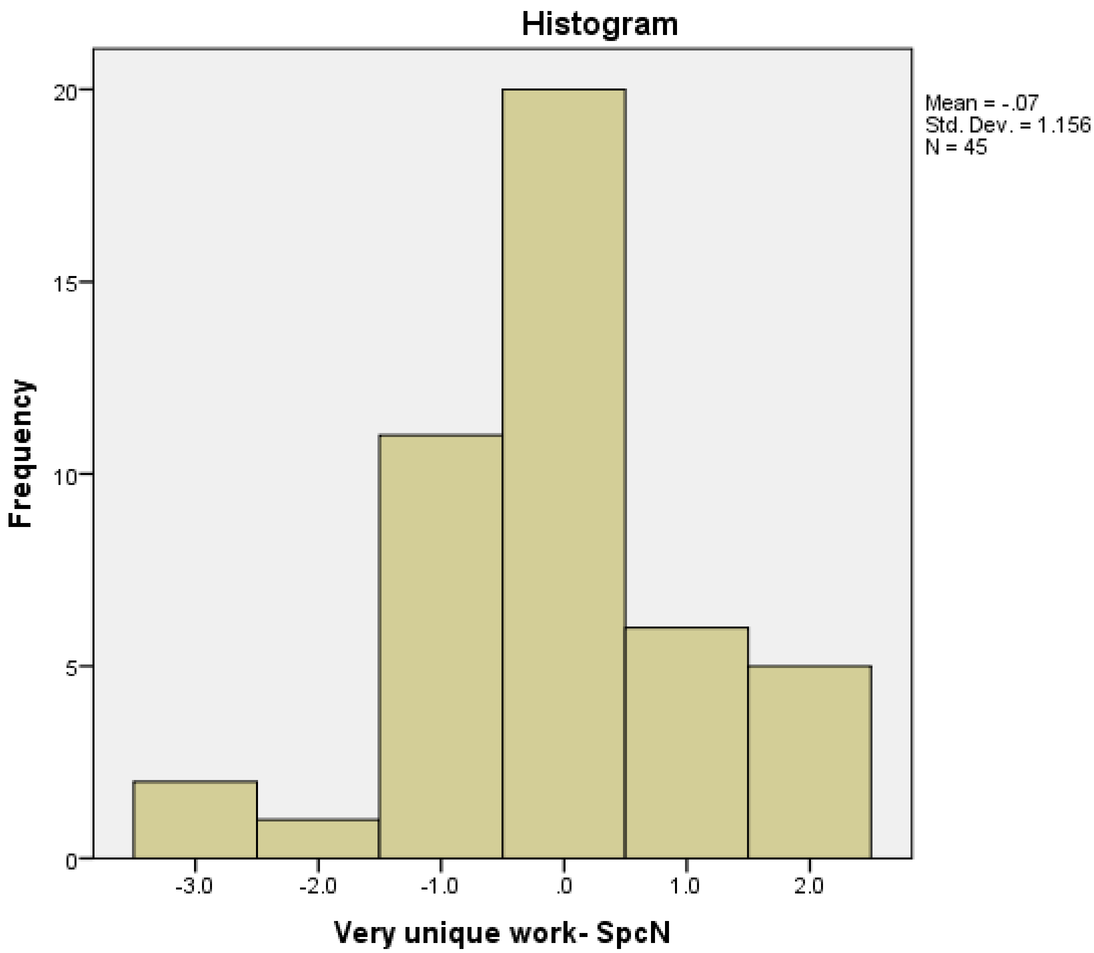

Histogram
Mean = -2.33
Std. Dev. = 1.087
N = 45
Frequency
30
20
10
0
-3.0
-2.0
-1.0
.0
1.0
Poor attitude towards safety- SccN

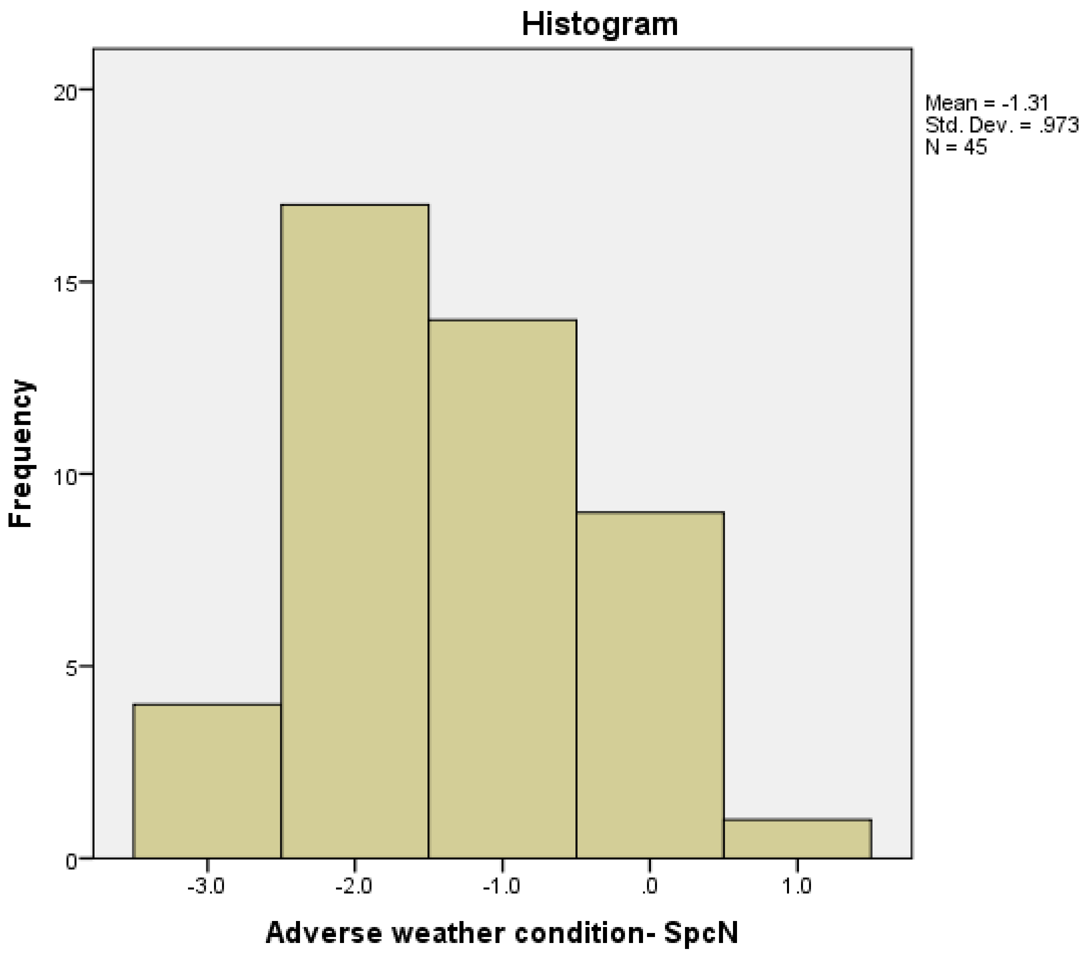

Histogram
Mean = -1.84
Std. Dev. = 1.065
N = 45
Frequency
15
10
5
0
-3.0
-2.0
-1.0
.0
Competing company priorities take precedence over safety - SccN

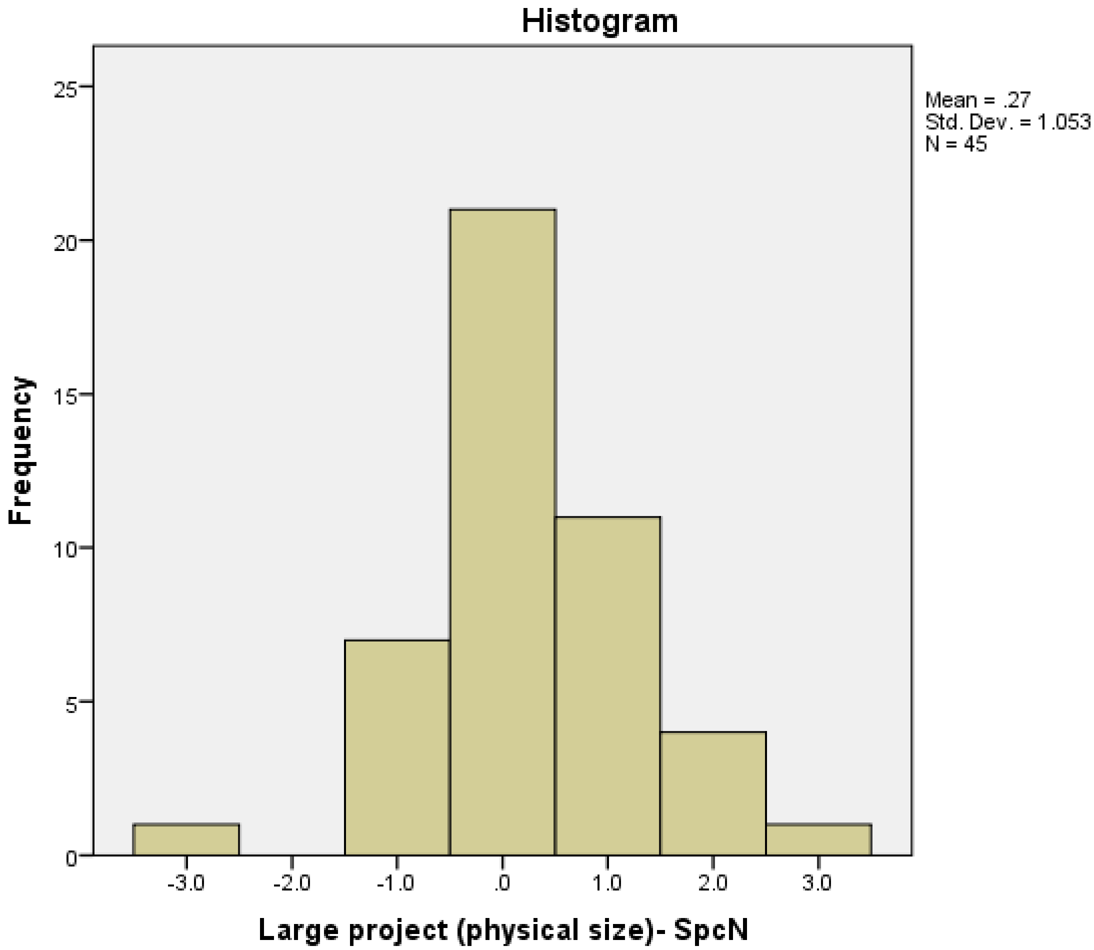

Histogram
Mean = -.09
Std. Dev. = 1.041
N = 45
Frequency
25
20
15
10
5
0
-3.0
-2.0
-1.0
.0
1.0
2.0
High level of competition within company- SccN



Histogram
Mean = -.67
Std. Dev. = 1.108
N = 45
Frequency
20
15
10
5
0
-3.0
-2.0
-1.0
.0
1.0
2.0
3.0
Fast pace of work- SpcN


Histogram
Mean = -.07
Std. Dev. = 1.156
N = 45
Frequency
20
15
10
5
0
-3.0
-2.0
-1.0
.0
1.0
2.0
Very unique work- SpcN


Histogram
Mean = -1.31
Std. Dev. = .973
N = 45
Frequency
0
5
10
15
20
-3.0
-2.0
-1.0
.0
1.0
Adverse weather condition- SpcN


Histogram
Mean = .27
Std. Dev. = 1.053
N = 45
Frequency
25
20
15
10
5
0
-3.0
-2.0
-1.0
.0
1.0
2.0
3.0
Large project (physical size)- SpcN

Appendix D- Response Frequency

Poorly or non-defined organizational structure-QccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	15	8.9	26.8	26.8
	moderate negative impact	18	10.7	32.1	58.9
	minor negative impact	16	9.5	28.6	87.5
	no impact	4	2.4	7.1	94.6
	minor positive impact	1	.6	1.8	96.4
	significant positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Inability to retain skilled craftsmen- QccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	23	13.7	41.1	41.1
	moderate negative impact	17	10.1	30.4	71.4
	minor negative impact	8	4.8	14.3	85.7
	no impact	5	3.0	8.9	94.6
	minor positive impact	2	1.2	3.6	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Lack of regular performance reviews- QccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.4	5.4

	moderate negative impact	8	4.8	14.3	19.6
	minor negative impact	25	14.9	44.6	64.3
	no impact	16	9.5	28.6	92.9
	minor positive impact	3	1.8	5.4	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Higher than typical productivity required- QccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.4	5.4
	moderate negative impact	20	11.9	35.7	41.1
	minor negative impact	19	11.3	33.9	75.0
	no impact	10	6.0	17.9	92.9
	minor positive impact	1	.6	1.8	94.6
	moderate positive impact	2	1.2	3.6	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Short project schedule- QccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	7	4.2	13.0	13.0
	moderate negative impact	11	6.5	20.4	33.3
	minor negative impact	22	13.1	40.7	74.1
	no impact	11	6.5	20.4	94.4
	minor positive impact	1	.6	1.9	96.3
	moderate positive impact	1	.6	1.9	98.1
	significant positive impact	1	.6	1.9	100.0

		Frequency	Percent	Valid Percent	Cumulative Percent
	Total	54	32.1	100.0	
Missing	System	114	67.9		
Total		168	100.0		

Poor attitude towards safety- QccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	8	4.8	14.3	14.3
	moderate negative impact	14	8.3	25.0	39.3
	minor negative impact	12	7.1	21.4	60.7
	no impact	21	12.5	37.5	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Competing company priorities take precedence over safety- QccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	10	6.0	17.9	17.9
	moderate negative impact	8	4.8	14.3	32.1
	minor negative impact	16	9.5	28.6	60.7
	no impact	19	11.3	33.9	94.6
	minor positive impact	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High level of competition within company- QccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.4	5.4

		Frequency	Percent	Valid Percent	Cumulative Percent
	moderate negative impact	2	1.2	3.6	8.9
	minor negative impact	8	4.8	14.3	23.2
	no impact	17	10.1	30.4	53.6
	minor positive impact	13	7.7	23.2	76.8
	moderate positive impact	9	5.4	16.1	92.9
	significant positive impact	4	2.4	7.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Poorly or non-defined organizational structure- SccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	15	8.9	26.8	26.8
	moderate negative impact	18	10.7	32.1	58.9
	minor negative impact	15	8.9	26.8	85.7
	no impact	6	3.6	10.7	96.4
	significant positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Inability to retain skilled craftsmen- SccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	12	7.1	21.4	21.4
	moderate negative impact	19	11.3	33.9	55.4
	minor negative impact	13	7.7	23.2	78.6
	no impact	10	6.0	17.9	96.4
	moderate positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Lack of regular performance reviews- SccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	4	2.4	7.3	9.1
	minor negative impact	18	10.7	32.7	41.8
	no impact	28	16.7	50.9	92.7
	minor positive impact	2	1.2	3.6	96.4
	moderate positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Higher than typical level of productivity required- SccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	9	5.4	16.1	16.1
	moderate negative impact	12	7.1	21.4	37.5
	minor negative impact	21	12.5	37.5	75.0
	no impact	11	6.5	19.6	94.6
	minor positive impact	1	.6	1.8	96.4
	moderate positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Short project schedule- SccN

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	significant negative impact	8	4.8	14.5	14.5
	moderate negative impact	12	7.1	21.8	36.4
	minor negative impact	17	10.1	30.9	67.3
	no impact	16	9.5	29.1	96.4
	minor positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Poor attitude towards safety- SccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	39	23.2	69.6	69.6
	moderate negative impact	6	3.6	10.7	80.4
	minor negative impact	6	3.6	10.7	91.1
	no impact	4	2.4	7.1	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Competing company priorities take precedence over safety - SccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	22	13.1	39.3	39.3
	moderate negative impact	17	10.1	30.4	69.6
	minor negative impact	9	5.4	16.1	85.7
	no impact	8	4.8	14.3	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High level of competition within company- SccN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	2	1.2	3.6	3.6
	moderate negative impact	4	2.4	7.1	10.7
	minor negative impact	10	6.0	17.9	28.6
	no impact	30	17.9	53.6	82.1
	minor positive impact	7	4.2	12.5	94.6
	moderate positive impact	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Fast pace of work- SpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	4	2.4	7.1	7.1
	moderate negative impact	10	6.0	17.9	25.0
	minor negative impact	21	12.5	37.5	62.5
	no impact	18	10.7	32.1	94.6
	minor positive impact	1	.6	1.8	96.4
	moderate positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Very unique work- SpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	2	1.2	3.6	3.6
	moderate negative impact	3	1.8	5.4	8.9

		Frequency	Percent	Valid Percent	Cumulative Percent
	minor negative impact	14	8.3	25.0	33.9
	no impact	24	14.3	42.9	76.8
	minor positive impact	8	4.8	14.3	91.1
	moderate positive impact	5	3.0	8.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Adverse weather condition- SpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	6	3.6	10.7	10.7
	moderate negative impact	21	12.5	37.5	48.2
	minor negative impact	18	10.7	32.1	80.4
	no impact	9	5.4	16.1	96.4
	minor positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Large project (physical size)- SpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	minor negative impact	9	5.4	16.1	17.9
	no impact	27	16.1	48.2	66.1
	minor positive impact	14	8.3	25.0	91.1
	moderate positive impact	4	2.4	7.1	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High cost project- SpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	minor negative impact	1	.6	1.8	3.6
	no impact	30	17.9	53.6	57.1
	minor positive impact	18	10.7	32.1	89.3
	moderate positive impact	6	3.6	10.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Project located in densely populated (urban) area- SpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	4	2.4	7.1	7.1
	moderate negative impact	3	1.8	5.4	12.5
	minor negative impact	17	10.1	30.4	42.9
	no impact	20	11.9	35.7	78.6
	minor positive impact	9	5.4	16.1	94.6
	moderate positive impact	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Very high quality of work required- SpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	no impact	26	15.5	46.4	48.2
	minor positive impact	12	7.1	21.4	69.6
	moderate positive impact	13	7.7	23.2	92.9

		Frequency	Percent	Valid Percent	Cumulative Percent
	significant positive impact	4	2.4	7.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Fast pace of work- QpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.4	5.4
	moderate negative impact	6	3.6	10.7	16.1
	minor negative impact	23	13.7	41.1	57.1
	no impact	19	11.3	33.9	91.1
	minor positive impact	2	1.2	3.6	94.6
	moderate positive impact	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Very unique work- QpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.5	5.5
	moderate negative impact	1	.6	1.8	7.3
	minor negative impact	10	6.0	18.2	25.5
	no impact	15	8.9	27.3	52.7
	minor positive impact	17	10.1	30.9	83.6
	moderate positive impact	7	4.2	12.7	96.4
	significant positive impact	2	1.2	3.6	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Adverse weather condition- QpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	4	2.4	7.1	7.1
	moderate negative impact	9	5.4	16.1	23.2
	minor negative impact	24	14.3	42.9	66.1
	no impact	17	10.1	30.4	96.4
	minor positive impact	1	.6	1.8	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Large project (physical size)- QpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	1	.6	1.8	1.8
	minor negative impact	4	2.4	7.1	8.9
	no impact	34	20.2	60.7	69.6
	minor positive impact	13	7.7	23.2	92.9
	moderate positive impact	3	1.8	5.4	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High cost project - QpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	minor negative impact	1	.6	1.8	1.8
	no impact	33	19.6	58.9	60.7
	minor positive impact	12	7.1	21.4	82.1
	moderate positive impact	8	4.8	14.3	96.4

		Frequency	Percent	Valid Percent	Cumulative Percent
	significant positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Project located in densely populated (urban) area- QpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	2	1.2	3.6	3.6
	moderate negative impact	1	.6	1.8	5.4
	minor negative impact	6	3.6	10.7	16.1
	no impact	37	22.0	66.1	82.1
	minor positive impact	8	4.8	14.3	96.4
	moderate positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Very high quality of work required- QpcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no impact	13	7.7	23.2	23.2
	minor positive impact	5	3.0	8.9	32.1
	moderate positive impact	18	10.7	32.1	64.3
	significant positive impact	20	11.9	35.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Congested site- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	significant negative impact	16	9.5	28.6	28.6
	moderate negative impact	15	8.9	26.8	55.4
	minor negative impact	17	10.1	30.4	85.7
	no impact	5	3.0	8.9	94.6
	minor positive impact	2	1.2	3.6	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Many different crews/trades on site at the same time- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	8	4.8	14.3	14.3
	moderate negative impact	14	8.3	25.0	39.3
	minor negative impact	20	11.9	35.7	75.0
	no impact	12	7.1	21.4	96.4
	minor positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Extended work hours each day- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	5	3.0	8.9	8.9
	moderate negative impact	12	7.1	21.4	30.4
	minor negative impact	23	13.7	41.1	71.4
	no impact	15	8.9	26.8	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Night shifts- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	6	3.6	10.7	10.7
	moderate negative impact	13	7.7	23.2	33.9
	minor negative impact	20	11.9	35.7	69.6
	no impact	14	8.3	25.0	94.6
	minor positive impact	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

In addition to weekdays, working on weekends and holidays- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	7	4.2	12.5	12.5
	moderate negative impact	17	10.1	30.4	42.9
	minor negative impact	15	8.9	26.8	69.6
	no impact	12	7.1	21.4	91.1
	minor positive impact	3	1.8	5.4	96.4
	moderate positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Inexperienced (unqualified) supervisor- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	21	12.5	37.5	37.5
	moderate negative impact	18	10.7	32.1	69.6
	minor negative impact	7	4.2	12.5	82.1

	no impact	9	5.4	16.1	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Construction drawings not readily available - SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	9	5.4	16.1	17.9
	minor negative impact	14	8.3	25.0	42.9
	no impact	30	17.9	53.6	96.4
	minor positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

No safety incentive- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	6	3.6	10.7	10.7
	moderate negative impact	8	4.8	14.3	25.0
	minor negative impact	12	7.1	21.4	46.4
	no impact	27	16.1	48.2	94.6
	minor positive impact	2	1.2	3.6	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Look-ahead (bi-weekly) schedule not available- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	4	2.4	7.1	8.9
	minor negative impact	20	11.9	35.7	44.6
	no impact	29	17.3	51.8	96.4
	minor positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High number of project scope changes during construction- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	7	4.2	12.5	14.3
	minor negative impact	23	13.7	41.1	55.4
	no impact	23	13.7	41.1	96.4
	minor positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Design-Bid-Build contract (hard-bid)- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	3	1.8	5.4	7.1
	minor negative impact	8	4.8	14.3	21.4
	no impact	37	22.0	66.1	87.5
	minor positive impact	4	2.4	7.1	94.6

	moderate positive impact	2	1.2	3.6	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Inexperienced crew - SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	15	8.9	27.3	27.3
	moderate negative impact	26	15.5	47.3	74.5
	minor negative impact	8	4.8	14.5	89.1
	no impact	5	3.0	9.1	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Lack of personal protective equipment (PPE) and safety resources- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	30	17.9	53.6	53.6
	moderate negative impact	14	8.3	25.0	78.6
	minor negative impact	5	3.0	8.9	87.5
	no impact	6	3.6	10.7	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Low quality of instruction provided for work tasks- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	6	3.6	10.7	10.7
	moderate negative impact	16	9.5	28.6	39.3
	minor negative impact	19	11.3	33.9	73.2
	no impact	14	8.3	25.0	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High number of overlapping work activities for crew- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	7	4.2	12.5	12.5
	moderate negative impact	14	8.3	25.0	37.5
	minor negative impact	16	9.5	28.6	66.1
	no impact	17	10.1	30.4	96.4
	minor positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Many subcontractors on site at same time- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	5	3.0	8.9	8.9
	moderate negative impact	10	6.0	17.9	26.8
	minor negative impact	24	14.3	42.9	69.6
	no impact	15	8.9	26.8	96.4
	minor positive impact	1	.6	1.8	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	

Missing	System	112	66.7		
Total		168	100.0		

Many different tasks/activities being worked on by different crews at the same time- SpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	7	4.2	12.5	12.5
	moderate negative impact	9	5.4	16.1	28.6
	minor negative impact	23	13.7	41.1	69.6
	no impact	15	8.9	26.8	96.4
	minor positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Congested site - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	8	4.8	14.3	14.3
	moderate negative impact	11	6.5	19.6	33.9
	minor negative impact	20	11.9	35.7	69.6
	no impact	15	8.9	26.8	96.4
	moderate positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Many different crews/trades on site at the same time - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	4	2.4	7.1	7.1

		Frequency	Percent	Valid Percent	Cumulative Percent
	moderate negative impact	11	6.5	19.6	26.8
	minor negative impact	18	10.7	32.1	58.9
	no impact	18	10.7	32.1	91.1
	minor positive impact	4	2.4	7.1	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Extended work hours each day - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.4	5.4
	moderate negative impact	8	4.8	14.3	19.6
	minor negative impact	26	15.5	46.4	66.1
	no impact	16	9.5	28.6	94.6
	minor positive impact	1	.6	1.8	96.4
	moderate positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Night shifts - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.4	5.4
	moderate negative impact	11	6.5	19.6	25.0
	minor negative impact	20	11.9	35.7	60.7
	no impact	17	10.1	30.4	91.1
	minor positive impact	5	3.0	8.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		

Total		168	100.0		

In addition to weekdays, working on weekends and holidays - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	4	2.4	7.1	7.1
	moderate negative impact	16	9.5	28.6	35.7
	minor negative impact	13	7.7	23.2	58.9
	no impact	21	12.5	37.5	96.4
	minor positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Inexperienced (unqualified) supervisor - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	17	10.1	30.4	30.4
	moderate negative impact	20	11.9	35.7	66.1
	minor negative impact	9	5.4	16.1	82.1
	no impact	8	4.8	14.3	96.4
	minor positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Construction drawings not readily available - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	14	8.3	25.0	25.0
	moderate negative impact	16	9.5	28.6	53.6

		Frequency	Percent	Valid Percent	Cumulative Percent
	minor negative impact	20	11.9	35.7	89.3
	no impact	5	3.0	8.9	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

No safety incentive - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.4	5.4
	moderate negative impact	2	1.2	3.6	8.9
	minor negative impact	8	4.8	14.3	23.2
	no impact	40	23.8	71.4	94.6
	minor positive impact	2	1.2	3.6	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Look-ahead (bi-weekly) schedule not available - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	16	9.5	28.6	30.4
	minor negative impact	24	14.3	42.9	73.2
	no impact	12	7.1	21.4	94.6
	minor positive impact	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High number of project scope changes during construction - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	5	3.0	8.9	8.9
	moderate negative impact	18	10.7	32.1	41.1
	minor negative impact	20	11.9	35.7	76.8
	no impact	11	6.5	19.6	96.4
	minor positive impact	1	.6	1.8	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Design-Bid-Build contract (hard-bid) - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	5	3.0	8.9	8.9
	minor negative impact	10	6.0	17.9	26.8
	no impact	30	17.9	53.6	80.4
	minor positive impact	6	3.6	10.7	91.1
	moderate positive impact	4	2.4	7.1	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Inexperienced crew - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	14	8.3	25.9	25.9
	moderate negative impact	19	11.3	35.2	61.1
	minor negative impact	11	6.5	20.4	81.5
	no impact	9	5.4	16.7	98.1

	minor positive impact	1	.6	1.9	100.0
	Total	54	32.1	100.0	
Missing	System	114	67.9		
Total		168	100.0		

Lack of personal protective equipment (PPE) and safety resources - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	4	2.4	7.1	7.1
	moderate negative impact	10	6.0	17.9	25.0
	minor negative impact	11	6.5	19.6	44.6
	no impact	29	17.3	51.8	96.4
	minor positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Low quality of instruction provided for work tasks - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	13	7.7	23.2	23.2
	moderate negative impact	21	12.5	37.5	60.7
	minor negative impact	14	8.3	25.0	85.7
	no impact	6	3.6	10.7	96.4
	minor positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High number of overlapping work activities for crew - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	5	3.0	8.9	8.9
	moderate negative impact	18	10.7	32.1	41.1
	minor negative impact	15	8.9	26.8	67.9
	no impact	16	9.5	28.6	96.4
	minor positive impact	1	.6	1.8	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Many subcontractors on site at same time - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.4	5.4
	moderate negative impact	7	4.2	12.5	17.9
	minor negative impact	23	13.7	41.1	58.9
	no impact	20	11.9	35.7	94.6
	minor positive impact	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Many different tasks/activities being worked on by different crews at the same time - QpmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	7	4.2	12.5	12.5
	moderate negative impact	10	6.0	17.9	30.4
	minor negative impact	18	10.7	32.1	62.5
	no impact	18	10.7	32.1	94.6
	minor positive impact	2	1.2	3.6	98.2
	significant positive impact	1	.6	1.8	100.0

		Frequency	Percent	Valid Percent	Cumulative Percent
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Task is highly repetitive - StsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	9	5.4	16.4	18.2
	minor negative impact	14	8.3	25.5	43.6
	no impact	14	8.3	25.5	69.1
	minor positive impact	7	4.2	12.7	81.8
	moderate positive impact	9	5.4	16.4	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Task is long and continuous - StsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	4	2.4	7.1	8.9
	minor negative impact	26	15.5	46.4	55.4
	no impact	14	8.3	25.0	80.4
	minor positive impact	5	3.0	8.9	89.3
	moderate positive impact	5	3.0	8.9	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Task involves high risk of injury- StsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	9	5.4	16.1	16.1
	moderate negative impact	14	8.3	25.0	41.1
	minor negative impact	16	9.5	28.6	69.6
	no impact	10	6.0	17.9	87.5
	minor positive impact	5	3.0	8.9	96.4
	moderate positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Assigned task is very complex - StsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	5	3.0	8.9	10.7
	minor negative impact	18	10.7	32.1	42.9
	no impact	22	13.1	39.3	82.1
	minor positive impact	7	4.2	12.5	94.6
	moderate positive impact	2	1.2	3.6	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Frequent switching between tasks required- StsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.4	5.4
	moderate negative impact	10	6.0	17.9	23.2
	minor negative impact	25	14.9	44.6	67.9

	no impact	16	9.5	28.6	96.4
	minor positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High number of sub-tasks within one task- StsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	1	.6	1.8	3.6
	minor negative impact	22	13.1	39.3	42.9
	no impact	29	17.3	51.8	94.6
	minor positive impact	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Frequent interruption/interferences- StsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	4	2.4	7.1	7.1
	moderate negative impact	17	10.1	30.4	37.5
	minor negative impact	26	15.5	46.4	83.9
	no impact	9	5.4	16.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Unorthodox method of Foreman’s supervision - StsmN

		Frequency	Percent	Valid Percent	Cumulative Percent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	8	4.8	14.3	14.3
	moderate negative impact	13	7.7	23.2	37.5
	minor negative impact	18	10.7	32.1	69.6
	no impact	17	10.1	30.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Unpredictability of the work tasks due to unknown information- StsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	8	4.8	14.3	14.3
	moderate negative impact	15	8.9	26.8	41.1
	minor negative impact	22	13.1	39.3	80.4
	no impact	10	6.0	17.9	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

You are given new tasks very frequently- StsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	8	4.8	14.3	14.3
	minor negative impact	21	12.5	37.5	51.8
	no impact	26	15.5	46.4	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Task is highly repetitive - QtsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	3	1.8	5.5	5.5
	minor negative impact	7	4.2	12.7	18.2
	no impact	9	5.4	16.4	34.5
	minor positive impact	19	11.3	34.5	69.1
	moderate positive impact	12	7.1	21.8	90.9
	significant positive impact	5	3.0	9.1	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Task is long and continuous - QtsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	3	1.8	5.4	5.4
	minor negative impact	12	7.1	21.4	26.8
	no impact	12	7.1	21.4	48.2
	minor positive impact	17	10.1	30.4	78.6
	moderate positive impact	8	4.8	14.3	92.9
	significant positive impact	4	2.4	7.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Task involves high risk of injury- QtsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	2	1.2	3.6	3.6
	moderate negative impact	6	3.6	10.7	14.3
	minor negative impact	15	8.9	26.8	41.1
	no impact	29	17.3	51.8	92.9
	minor positive impact	2	1.2	3.6	96.4

		Frequency	Percent	Valid Percent	Cumulative Percent
	moderate positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Assigned task is very complex - QtsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.4	5.4
	moderate negative impact	3	1.8	5.4	10.7
	minor negative impact	16	9.5	28.6	39.3
	no impact	18	10.7	32.1	71.4
	minor positive impact	12	7.1	21.4	92.9
	moderate positive impact	2	1.2	3.6	96.4
	significant positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Frequent switching between tasks required- QtsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	5	3.0	8.9	8.9
	moderate negative impact	6	3.6	10.7	19.6
	minor negative impact	28	16.7	50.0	69.6
	no impact	14	8.3	25.0	94.6
	minor positive impact	2	1.2	3.6	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High number of sub-tasks within one task- QtsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	9	5.4	16.1	17.9
	minor negative impact	23	13.7	41.1	58.9
	no impact	20	11.9	35.7	94.6
	minor positive impact	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Frequent interruption/interferences- QtsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	8	4.8	14.3	14.3
	moderate negative impact	16	9.5	28.6	42.9
	minor negative impact	27	16.1	48.2	91.1
	no impact	5	3.0	8.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Unorthodox method of Foreman's supervision - QtsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	8	4.8	14.3	14.3
	moderate negative impact	14	8.3	25.0	39.3
	minor negative impact	16	9.5	28.6	67.9
	no impact	17	10.1	30.4	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		

Total		168	100.0		

Unpredictability of the work tasks due to unknown information- QtsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	14	8.3	25.0	25.0
	moderate negative impact	17	10.1	30.4	55.4
	minor negative impact	17	10.1	30.4	85.7
	no impact	8	4.8	14.3	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

You are given new tasks very frequently- QtsmN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	2	1.2	3.6	3.6
	moderate negative impact	11	6.5	19.6	23.2
	minor negative impact	17	10.1	30.4	53.6
	no impact	25	14.9	44.6	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Poor material, tools, and equipment storage-SmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	12	7.1	21.4	21.4
	moderate negative impact	19	11.3	33.9	55.4
	minor negative impact	20	11.9	35.7	91.1
	no impact	5	3.0	8.9	100.0

		Frequency	Percent	Valid Percent	Cumulative Percent
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Using complex equipment (requires advanced skills)-SmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	2	1.2	3.6	3.6
	moderate negative impact	6	3.6	10.7	14.3
	minor negative impact	11	6.5	19.6	33.9
	no impact	29	17.3	51.8	85.7
	minor positive impact	6	3.6	10.7	96.4
	moderate positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Lack of familiarity with equipment -SmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	22	13.1	39.3	39.3
	moderate negative impact	16	9.5	28.6	67.9
	minor negative impact	11	6.5	19.6	87.5
	no impact	6	3.6	10.7	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Material, tools, and equipment not readily available -SmteN

		Frequency	Percent	Valid Percent	Cumulative Percent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	6	3.6	10.7	10.7
	moderate negative impact	13	7.7	23.2	33.9
	minor negative impact	18	10.7	32.1	66.1
	no impact	18	10.7	32.1	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Poor quality of equipment and tools-SmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	19	11.3	33.9	33.9
	moderate negative impact	15	8.9	26.8	60.7
	minor negative impact	11	6.5	19.6	80.4
	no impact	10	6.0	17.9	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Poor quality of pre-fabrication -SmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	9	5.4	16.4	16.4
	moderate negative impact	10	6.0	18.2	34.5
	minor negative impact	16	9.5	29.1	63.6
	no impact	20	11.9	36.4	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Poor quality materials-SmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	8	4.8	14.3	14.3
	moderate negative impact	11	6.5	19.6	33.9
	minor negative impact	21	12.5	37.5	71.4
	no impact	16	9.5	28.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Poor material, tools, and equipment storage-QmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	10	6.0	17.9	17.9
	moderate negative impact	20	11.9	35.7	53.6
	minor negative impact	19	11.3	33.9	87.5
	no impact	7	4.2	12.5	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Using complex equipment (requires advanced skills)-QmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	2	1.2	3.6	3.6
	moderate negative impact	2	1.2	3.6	7.1
	minor negative impact	10	6.0	17.9	25.0
	no impact	27	16.1	48.2	73.2
	minor positive impact	10	6.0	17.9	91.1
	moderate positive impact	4	2.4	7.1	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	

Missing	System	112	66.7		
Total		168	100.0		

Lack of familiarity with equipment -QmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	11	6.5	19.6	19.6
	moderate negative impact	19	11.3	33.9	53.6
	minor negative impact	15	8.9	26.8	80.4
	no impact	10	6.0	17.9	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Material, tools, and equipment not readily available-QmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	16	9.5	29.1	29.1
	moderate negative impact	12	7.1	21.8	50.9
	minor negative impact	16	9.5	29.1	80.0
	no impact	10	6.0	18.2	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Poor quality of equipment and tools-QmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	19	11.3	33.9	33.9
	moderate negative impact	19	11.3	33.9	67.9

		Frequency	Percent	Valid Percent	Cumulative Percent
	minor negative impact	10	6.0	17.9	85.7
	no impact	8	4.8	14.3	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Poor quality of pre-fabrication -QmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	21	12.5	38.2	38.2
	moderate negative impact	15	8.9	27.3	65.5
	minor negative impact	11	6.5	20.0	85.5
	no impact	8	4.8	14.5	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Poor quality materials-QmteN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	23	13.7	41.1	41.1
	moderate negative impact	18	10.7	32.1	73.2
	minor negative impact	10	6.0	17.9	91.1
	no impact	5	3.0	8.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High amount of paperwork involved- SetN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	minor negative impact	8	4.8	14.3	14.3

	no impact	38	22.6	67.9	82.1
	minor positive impact	7	4.2	12.5	94.6
	moderate positive impact	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Low quality of detailed design drawings - SetN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	3	1.8	5.4	7.1
	minor negative impact	16	9.5	28.6	35.7
	no impact	34	20.2	60.7	96.4
	minor positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Slow response to Requests for Information (RFIs)- SetN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	2	1.2	3.6	3.6
	moderate negative impact	3	1.8	5.4	8.9
	minor negative impact	11	6.5	19.6	28.6
	no impact	38	22.6	67.9	96.4
	minor positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Use of advanced technologies - SetN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	1	.6	1.8	1.8
	minor negative impact	3	1.8	5.4	7.1
	no impact	32	19.0	57.1	64.3
	minor positive impact	14	8.3	25.0	89.3
	moderate positive impact	4	2.4	7.1	96.4
	significant positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High amount of paperwork involved- QetN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	4	2.4	7.1	8.9
	minor negative impact	16	9.5	28.6	37.5
	no impact	27	16.1	48.2	85.7
	minor positive impact	6	3.6	10.7	96.4
	moderate positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Low quality of detailed design drawings - QetN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	12	7.1	21.4	21.4
	moderate negative impact	19	11.3	33.9	55.4
	minor negative impact	21	12.5	37.5	92.9
	no impact	4	2.4	7.1	100.0
	Total	56	33.3	100.0	

		Frequency	Percent	Valid Percent	Cumulative Percent
Missing	System	112	66.7		
Total		168	100.0		

Slow response to Requests for Information (RFIs)- QetN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	13	7.7	23.2	23.2
	moderate negative impact	20	11.9	35.7	58.9
	minor negative impact	17	10.1	30.4	89.3
	no impact	6	3.6	10.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Use of advanced technologies - QetN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	2	1.2	3.6	5.4
	minor negative impact	3	1.8	5.4	10.7
	no impact	19	11.3	33.9	44.6
	minor positive impact	13	7.7	23.2	67.9
	moderate positive impact	14	8.3	25.0	92.9
	significant positive impact	4	2.4	7.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

More than one language spoken on construction site-ScN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	11	6.5	19.6	19.6

		Frequency	Percent	Valid Percent	Cumulative Percent
	moderate negative impact	16	9.5	28.6	48.2
	minor negative impact	16	9.5	28.6	76.8
	no impact	12	7.1	21.4	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Lack of adequate communication within site management-ScN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	13	7.7	23.2	23.2
	moderate negative impact	17	10.1	30.4	53.6
	minor negative impact	17	10.1	30.4	83.9
	no impact	9	5.4	16.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Lack of deserved positive feedback (compliments)-ScN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	3	1.8	5.4	5.4
	moderate negative impact	10	6.0	17.9	23.2
	minor negative impact	21	12.5	37.5	60.7
	no impact	21	12.5	37.5	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Poor working relationships and cohesiveness with co-workers-ScN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	11	6.5	19.6	19.6
	moderate negative impact	27	16.1	48.2	67.9
	minor negative impact	11	6.5	19.6	87.5
	no impact	7	4.2	12.5	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

More than one language spoken on construction site-QcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	11	6.5	19.6	19.6
	moderate negative impact	12	7.1	21.4	41.1
	minor negative impact	15	8.9	26.8	67.9
	no impact	17	10.1	30.4	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Lack of adequate communication within site management-QcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	8	4.8	14.3	14.3
	moderate negative impact	27	16.1	48.2	62.5
	minor negative impact	15	8.9	26.8	89.3
	no impact	6	3.6	10.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Lack of deserved positive feedback (compliments)-QcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	6	3.6	10.7	10.7
	moderate negative impact	10	6.0	17.9	28.6
	minor negative impact	26	15.5	46.4	75.0
	no impact	12	7.1	21.4	96.4
	minor positive impact	1	.6	1.8	98.2
	moderate positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Poor working relationships and cohesiveness with co-workers-QcN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	13	7.7	23.2	23.2
	moderate negative impact	21	12.5	37.5	60.7
	minor negative impact	17	10.1	30.4	91.1
	no impact	4	2.4	7.1	98.2
	minor positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Well-defined organizational structure- SccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	minor negative impact	4	2.4	7.1	7.1
	no impact	4	2.4	7.1	14.3
	minor positive impact	12	7.1	21.4	35.7
	moderate positive impact	29	17.3	51.8	87.5

		Frequency	Percent	Valid Percent	Cumulative Percent
	significant positive impact	7	4.2	12.5	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High retention rate of skilled craftsmen - SccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no impact	5	3.0	8.9	8.9
	minor positive impact	8	4.8	14.3	23.2
	moderate positive impact	25	14.9	44.6	67.9
	significant positive impact	18	10.7	32.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Regular performance reviews - SccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no impact	18	10.7	32.1	32.1
	minor positive impact	21	12.5	37.5	69.6
	moderate positive impact	12	7.1	21.4	91.1
	significant positive impact	5	3.0	8.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Lower than typical productivity required- SccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	2	1.2	3.6	3.6
	minor negative impact	6	3.6	10.7	14.3

	no impact	27	16.1	48.2	62.5
	minor positive impact	11	6.5	19.6	82.1
	moderate positive impact	4	2.4	7.1	89.3
	significant positive impact	6	3.6	10.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

More time allowed in project schedule than typical - SccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	minor negative impact	2	1.2	3.6	3.6
	no impact	19	11.3	33.9	37.5
	minor positive impact	20	11.9	35.7	73.2
	moderate positive impact	7	4.2	12.5	85.7
	significant positive impact	8	4.8	14.3	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Good attitude towards safety- SccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no impact	5	3.0	8.9	8.9
	minor positive impact	7	4.2	12.5	21.4
	moderate positive impact	10	6.0	17.9	39.3
	significant positive impact	34	20.2	60.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Safety takes precedence over other companies priorities - SccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no impact	8	4.8	14.3	14.3
	minor positive impact	6	3.6	10.7	25.0
	moderate positive impact	13	7.7	23.2	48.2
	significant positive impact	29	17.3	51.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Relaxed atmosphere within company - SccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	minor negative impact	6	3.6	10.7	10.7
	no impact	16	9.5	28.6	39.3
	minor positive impact	16	9.5	28.6	67.9
	moderate positive impact	8	4.8	14.3	82.1
	significant positive impact	10	6.0	17.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Well-defined organizational structure - QccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no impact	4	2.4	7.1	7.1
	minor positive impact	13	7.7	23.2	30.4
	moderate positive impact	31	18.5	55.4	85.7
	significant positive impact	8	4.8	14.3	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High retention rate of skilled craftsmen - QccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no impact	4	2.4	7.1	7.1
	minor positive impact	4	2.4	7.1	14.3
	moderate positive impact	24	14.3	42.9	57.1
	significant positive impact	24	14.3	42.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Regular performance reviews - QccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no impact	14	8.3	25.0	25.0
	minor positive impact	22	13.1	39.3	64.3
	moderate positive impact	13	7.7	23.2	87.5
	significant positive impact	7	4.2	12.5	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Lower than typical productivity required- QccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	2	1.2	3.6	3.6
	minor negative impact	5	3.0	8.9	12.5
	no impact	20	11.9	35.7	48.2
	minor positive impact	18	10.7	32.1	80.4
	moderate positive impact	3	1.8	5.4	85.7
	significant positive impact	8	4.8	14.3	100.0
	Total	56	33.3	100.0	

Missing	System	112	66.7		
Total		168	100.0		

More time allowed in project schedule than typical - QccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	1	.6	1.8	1.8
	minor negative impact	3	1.8	5.4	7.1
	no impact	13	7.7	23.2	30.4
	minor positive impact	16	9.5	28.6	58.9
	moderate positive impact	14	8.3	25.0	83.9
	significant positive impact	9	5.4	16.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Good attitude towards safety- QccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no impact	19	11.3	33.9	33.9
	minor positive impact	14	8.3	25.0	58.9
	moderate positive impact	10	6.0	17.9	76.8
	significant positive impact	13	7.7	23.2	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Safety takes precedence over other companies priorities - QccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	minor negative impact	2	1.2	3.6	3.6
	no impact	22	13.1	39.3	42.9

		Frequency	Percent	Valid Percent	Cumulative Percent
	minor positive impact	8	4.8	14.3	57.1
	moderate positive impact	13	7.7	23.2	80.4
	significant positive impact	11	6.5	19.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Relaxed atmosphere within company - QccP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	1	.6	1.8	1.8
	moderate negative impact	1	.6	1.8	3.6
	minor negative impact	4	2.4	7.1	10.7
	no impact	20	11.9	35.7	46.4
	minor positive impact	10	6.0	17.9	64.3
	moderate positive impact	11	6.5	19.6	83.9
	significant positive impact	9	5.4	16.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Slow pace of work-SpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	1	.6	1.8	1.8
	minor negative impact	12	7.1	21.4	23.2
	no impact	19	11.3	33.9	57.1
	minor positive impact	13	7.7	23.2	80.4
	moderate positive impact	6	3.6	10.7	91.1
	significant positive impact	5	3.0	8.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Project is not unique -SpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	minor negative impact	4	2.4	7.1	7.1
	no impact	18	10.7	32.1	39.3
	minor positive impact	20	11.9	35.7	75.0
	moderate positive impact	10	6.0	17.9	92.9
	significant positive impact	3	1.8	5.4	98.2
	10.0	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Predictable weather condition -SpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	minor negative impact	2	1.2	3.6	3.6
	no impact	12	7.1	21.4	25.0
	minor positive impact	19	11.3	33.9	58.9
	moderate positive impact	19	11.3	33.9	92.9
	significant positive impact	4	2.4	7.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Small project -SpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	minor negative impact	6	3.6	10.7	10.7
	no impact	29	17.3	51.8	62.5
	minor positive impact	10	6.0	17.9	80.4

	moderate positive impact	9	5.4	16.1	96.4
	significant positive impact	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Low cost project -SpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	1	.6	1.8	1.8
	minor negative impact	8	4.8	14.3	16.1
	no impact	38	22.6	67.9	83.9
	minor positive impact	5	3.0	8.9	92.9
	moderate positive impact	3	1.8	5.4	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Remote project - location -SpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	5	3.0	9.1	9.1
	minor negative impact	16	9.5	29.1	38.2
	no impact	24	14.3	43.6	81.8
	minor positive impact	7	4.2	12.7	94.5
	moderate positive impact	2	1.2	3.6	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Low quality of work required -SpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	significant negative impact	4	2.4	7.3	7.3
	moderate negative impact	5	3.0	9.1	16.4
	minor negative impact	14	8.3	25.5	41.8
	no impact	26	15.5	47.3	89.1
	minor positive impact	3	1.8	5.5	94.5
	moderate positive impact	2	1.2	3.6	98.2
	significant positive impact	1	.6	1.8	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Slow pace of work -QpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	1	.6	1.8	1.8
	minor negative impact	7	4.2	12.5	14.3
	no impact	16	9.5	28.6	42.9
	minor positive impact	20	11.9	35.7	78.6
	moderate positive impact	7	4.2	12.5	91.1
	significant positive impact	5	3.0	8.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Project is not unique -QpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	minor negative impact	3	1.8	5.5	5.5
	no impact	20	11.9	36.4	41.8
	minor positive impact	16	9.5	29.1	70.9

	moderate positive impact	12	7.1	21.8	92.7
	significant positive impact	4	2.4	7.3	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Predictable weather condition -QpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	18	10.7	32.1	33.9
	1.0	11	6.5	19.6	53.6
	2.0	20	11.9	35.7	89.3
	3.0	6	3.6	10.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Small project -QpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	moderate negative impact	1	.6	1.8	1.8
	minor negative impact	2	1.2	3.6	5.4
	no impact	28	16.7	50.0	55.4
	minor positive impact	13	7.7	23.2	78.6
	moderate positive impact	9	5.4	16.1	94.6
	significant positive impact	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Low cost project -QpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	3	1.8	5.4	5.4
	-1.0	8	4.8	14.3	19.6
	.0	35	20.8	62.5	82.1
	1.0	6	3.6	10.7	92.9
	2.0	2	1.2	3.6	96.4
	3.0	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Remote project - location -QpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	2	1.2	3.6	3.6
	-1.0	10	6.0	17.9	21.4
	.0	30	17.9	53.6	75.0
	1.0	8	4.8	14.3	89.3
	2.0	5	3.0	8.9	98.2
	3.0	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Low quality of work required -QpcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-3.0	12	7.1	21.4	21.4
	-2.0	10	6.0	17.9	39.3
	-1.0	5	3.0	8.9	48.2
	.0	20	11.9	35.7	83.9
	1.0	2	1.2	3.6	87.5

	2.0	6	3.6	10.7	98.2
	3.0	1	.6	1.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Non-congested site - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	6	3.6	10.7	10.7
	1.0	13	7.7	23.2	33.9
	2.0	22	13.1	39.3	73.2
	3.0	15	8.9	26.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

No or minimal overlapping of different crews/trades on site - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	11	6.5	19.6	21.4
	1.0	16	9.5	28.6	50.0
	2.0	13	7.7	23.2	73.2
	3.0	15	8.9	26.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Regular work hours - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	.0	9	5.4	16.1	16.1
	1.0	16	9.5	28.6	44.6
	2.0	24	14.3	42.9	87.5
	3.0	7	4.2	12.5	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Day shifts only - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	13	7.7	23.2	25.0
	1.0	16	9.5	28.6	53.6
	2.0	20	11.9	35.7	89.3
	3.0	6	3.6	10.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Working on weekdays only - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	2	1.2	3.6	3.6
	.0	17	10.1	30.4	33.9
	1.0	16	9.5	28.6	62.5
	2.0	16	9.5	28.6	91.1
	3.0	5	3.0	8.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Experienced supervisor - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	4	2.4	7.1	7.1
	1.0	12	7.1	21.4	28.6
	2.0	18	10.7	32.1	60.7
	3.0	22	13.1	39.3	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Construction drawings available when needed - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	18	10.7	32.1	32.1
	1.0	19	11.3	33.9	66.1
	2.0	12	7.1	21.4	87.5
	3.0	7	4.2	12.5	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Project-based safety incentive - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	16	9.5	28.6	28.6
	1.0	16	9.5	28.6	57.1
	2.0	10	6.0	17.9	75.0
	3.0	14	8.3	25.0	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Look-ahead (bi-weekly) schedule available - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	15	8.9	26.8	28.6
	1.0	16	9.5	28.6	57.1
	2.0	15	8.9	26.8	83.9
	3.0	9	5.4	16.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Low number of project scope changes during construction - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	17	10.1	30.4	32.1
	1.0	20	11.9	35.7	67.9
	2.0	13	7.7	23.2	91.1
	3.0	5	3.0	8.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Design-Build contract - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	1	.6	1.8	1.8
	.0	21	12.5	37.5	39.3
	1.0	21	12.5	37.5	76.8
	2.0	7	4.2	12.5	89.3
	3.0	6	3.6	10.7	100.0

	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Experienced crew - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	4	2.4	7.1	7.1
	1.0	10	6.0	17.9	25.0
	2.0	19	11.3	33.9	58.9
	3.0	23	13.7	41.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Excellent personal protective equipment (PPE) and safety resources available - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	3	1.8	5.4	5.4
	1.0	11	6.5	19.6	25.0
	2.0	15	8.9	26.8	51.8
	3.0	27	16.1	48.2	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Acceptable quality of instruction provided for work tasks - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	7	4.2	12.5	12.5
	1.0	21	12.5	37.5	50.0
	2.0	17	10.1	30.4	80.4

		Frequency	Percent	Valid Percent	Cumulative Percent
	3.0	11	6.5	19.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

No overlapping work activities for crew - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	15	8.9	27.3	27.3
	1.0	19	11.3	34.5	61.8
	2.0	13	7.7	23.6	85.5
	3.0	8	4.8	14.5	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Subcontractors not on-site at same time - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	21	12.5	37.5	39.3
	1.0	17	10.1	30.4	69.6
	2.0	10	6.0	17.9	87.5
	3.0	7	4.2	12.5	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Few different tasks/activities being worked on by different crews at the same time - SpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	21	12.5	38.2	38.2

	1.0	20	11.9	36.4	74.5
	2.0	5	3.0	9.1	83.6
	3.0	9	5.4	16.4	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Non-congested site - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	10	6.0	18.2	18.2
	1.0	16	9.5	29.1	47.3
	2.0	20	11.9	36.4	83.6
	3.0	9	5.4	16.4	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

No or minimal overlapping of different crews/trades on site - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	11	6.5	19.6	21.4
	1.0	18	10.7	32.1	53.6
	2.0	12	7.1	21.4	75.0
	3.0	14	8.3	25.0	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Regular work hours - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	12	7.1	21.4	21.4
	1.0	17	10.1	30.4	51.8
	2.0	21	12.5	37.5	89.3
	3.0	6	3.6	10.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Day shifts only - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	11	6.5	19.6	21.4
	1.0	19	11.3	33.9	55.4
	2.0	19	11.3	33.9	89.3
	3.0	6	3.6	10.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Working on weekdays only - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	2	1.2	3.6	3.6
	.0	16	9.5	28.6	32.1
	1.0	20	11.9	35.7	67.9
	2.0	14	8.3	25.0	92.9
	3.0	4	2.4	7.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Experienced supervisor - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	3	1.8	5.4	5.4
	1.0	8	4.8	14.3	19.6
	2.0	22	13.1	39.3	58.9
	3.0	23	13.7	41.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Construction drawings available when needed - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	3	1.8	5.4	5.4
	1.0	9	5.4	16.1	21.4
	2.0	25	14.9	44.6	66.1
	3.0	19	11.3	33.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Project-based safety incentive - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	30	17.9	53.6	53.6
	1.0	12	7.1	21.4	75.0
	2.0	8	4.8	14.3	89.3
	3.0	6	3.6	10.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		

Total		168	100.0		

Look-ahead (bi-weekly) schedule available - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	13	7.7	23.2	23.2
	1.0	15	8.9	26.8	50.0
	2.0	16	9.5	28.6	78.6
	3.0	12	7.1	21.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Low number of project scope changes during construction - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	6	3.6	10.7	10.7
	1.0	22	13.1	39.3	50.0
	2.0	18	10.7	32.1	82.1
	3.0	10	6.0	17.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Design-Build contract - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	1	.6	1.8	1.8
	-1.0	1	.6	1.8	3.6
	.0	16	9.5	28.6	32.1
	1.0	14	8.3	25.0	57.1
	2.0	18	10.7	32.1	89.3

	3.0	6	3.6	10.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Experienced crew - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	3	1.8	5.4	5.4
	1.0	8	4.8	14.3	19.6
	2.0	21	12.5	37.5	57.1
	3.0	24	14.3	42.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Excellent personal protective equipment (PPE) and safety resources available - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	19	11.3	33.9	33.9
	1.0	19	11.3	33.9	67.9
	2.0	8	4.8	14.3	82.1
	3.0	10	6.0	17.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Acceptable quality of instruction provided for work tasks - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	2	1.2	3.6	3.6
	1.0	21	12.5	37.5	41.1

	2.0	21	12.5	37.5	78.6
	3.0	12	7.1	21.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

No overlapping work activities for crew - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	13	7.7	23.6	25.5
	1.0	21	12.5	38.2	63.6
	2.0	13	7.7	23.6	87.3
	3.0	7	4.2	12.7	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Subcontractors not on-site at same time - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	2	1.2	3.6	3.6
	-1.0	5	3.0	8.9	12.5
	.0	16	9.5	28.6	41.1
	1.0	15	8.9	26.8	67.9
	2.0	12	7.1	21.4	89.3
	3.0	6	3.6	10.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Few different tasks/activities being worked on by different crews at the same time - QpmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	3	1.8	5.5	5.5
	.0	20	11.9	36.4	41.8
	1.0	16	9.5	29.1	70.9
	2.0	8	4.8	14.5	85.5
	3.0	8	4.8	14.5	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Task is not repetitive- StsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	2	1.2	3.6	3.6
	-1.0	8	4.8	14.5	18.2
	.0	16	9.5	29.1	47.3
	1.0	22	13.1	40.0	87.3
	2.0	5	3.0	9.1	96.4
	3.0	2	1.2	3.6	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Worker tasks are not long and monotonous (dull)- StsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	2	1.2	3.6	3.6
	.0	17	10.1	30.9	34.5
	1.0	22	13.1	40.0	74.5
	2.0	12	7.1	21.8	96.4
	3.0	1	.6	1.8	98.2
	9.0	1	.6	1.8	100.0

	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Task involves low risk of injury - StsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	1	.6	1.8	1.8
	.0	11	6.5	20.0	21.8
	1.0	10	6.0	18.2	40.0
	2.0	20	11.9	36.4	76.4
	3.0	13	7.7	23.6	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Assigned task requires little or no calculation, mental stress, remembering, etc- StsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	1	.6	1.8	1.8
	-1.0	5	3.0	9.1	10.9
	.0	18	10.7	32.7	43.6
	1.0	18	10.7	32.7	76.4
	2.0	11	6.5	20.0	96.4
	3.0	2	1.2	3.6	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Can concentrate on one task without needing to switch to another- StsmP

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	.0	11	6.5	20.0	20.0
	1.0	25	14.9	45.5	65.5
	2.0	12	7.1	21.8	87.3
	3.0	7	4.2	12.7	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Few or no sub-tasks within one task- StsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	17	10.1	30.9	30.9
	1.0	20	11.9	36.4	67.3
	2.0	12	7.1	21.8	89.1
	3.0	6	3.6	10.9	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

No interruption/interferences - StsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	10	6.0	18.2	18.2
	1.0	20	11.9	36.4	54.5
	2.0	20	11.9	36.4	90.9
	3.0	5	3.0	9.1	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Foreman's method of supervision is conventional- StsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	1	.6	1.8	1.8
	.0	15	8.9	27.3	29.1
	1.0	17	10.1	30.9	60.0
	2.0	17	10.1	30.9	90.9
	3.0	5	3.0	9.1	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Work tasks very predictable due to adequate information- StsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	10	6.0	18.2	18.2
	1.0	17	10.1	30.9	49.1
	2.0	21	12.5	38.2	87.3
	3.0	7	4.2	12.7	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Workers are not given new tasks too frequently- StsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	12	7.1	21.8	21.8
	1.0	22	13.1	40.0	61.8
	2.0	16	9.5	29.1	90.9
	3.0	5	3.0	9.1	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Task is not repetitive - QtsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	3	1.8	5.5	5.5
	-1.0	9	5.4	16.4	21.8
	.0	18	10.7	32.7	54.5
	1.0	16	9.5	29.1	83.6
	2.0	6	3.6	10.9	94.5
	3.0	3	1.8	5.5	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Worker tasks are not long and monotonous (dull)- QtsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	2	1.2	3.6	3.6
	.0	15	8.9	27.3	30.9
	1.0	19	11.3	34.5	65.5
	2.0	15	8.9	27.3	92.7
	3.0	4	2.4	7.3	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Task involves low risk of injury - QtsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	16	9.5	29.1	29.1
	1.0	16	9.5	29.1	58.2
	2.0	17	10.1	30.9	89.1
	3.0	6	3.6	10.9	100.0

	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Assigned task requires little or no calculation, mental stress, remembering, etc- QtsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	5	3.0	9.1	9.1
	.0	15	8.9	27.3	36.4
	1.0	17	10.1	30.9	67.3
	2.0	14	8.3	25.5	92.7
	3.0	4	2.4	7.3	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Can concentrate on one task without needing to switch to another- QtsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	6	3.6	10.9	10.9
	1.0	28	16.7	50.9	61.8
	2.0	13	7.7	23.6	85.5
	3.0	8	4.8	14.5	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Few or no sub-tasks within one task- QtsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.9	1.9
	.0	9	5.4	16.7	18.5

	1.0	20	11.9	37.0	55.6
	2.0	18	10.7	33.3	88.9
	3.0	6	3.6	11.1	100.0
	Total	54	32.1	100.0	
Missing	System	114	67.9		
Total		168	100.0		

No interruption/interferences - QtsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	6	3.6	10.9	10.9
	1.0	14	8.3	25.5	36.4
	2.0	21	12.5	38.2	74.5
	3.0	14	8.3	25.5	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Foreman's method of supervision is conventional- QtsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	1	.6	1.8	1.8
	.0	15	8.9	27.3	29.1
	1.0	17	10.1	30.9	60.0
	2.0	13	7.7	23.6	83.6
	3.0	9	5.4	16.4	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Quick response to Requests for Information (RFIs)-SetP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	29	17.3	51.8	51.8
	1.0	14	8.3	25.0	76.8
	2.0	10	6.0	17.9	94.6
	3.0	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Use of commonly-used technologies-SetP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	23	13.7	41.8	41.8
	1.0	14	8.3	25.5	67.3
	2.0	15	8.9	27.3	94.5
	3.0	3	1.8	5.5	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Low amount of paperwork involved-QetP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	1	.6	1.8	1.8
	-1.0	2	1.2	3.6	5.4
	.0	25	14.9	44.6	50.0
	1.0	13	7.7	23.2	73.2
	2.0	11	6.5	19.6	92.9
	3.0	4	2.4	7.1	100.0
	Total	56	33.3	100.0	

Missing	System	112	66.7		
Total		168	100.0		

High quality of detailed design drawings -QetP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	6	3.6	10.7	10.7
	1.0	9	5.4	16.1	26.8
	2.0	22	13.1	39.3	66.1
	3.0	19	11.3	33.9	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Quick response to Requests for Information (RFIs)-QetP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	7	4.2	12.5	12.5
	1.0	10	6.0	17.9	30.4
	2.0	24	14.3	42.9	73.2
	3.0	15	8.9	26.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Use of commonly-used technologies-QetP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	9	5.4	16.1	16.1
	1.0	18	10.7	32.1	48.2
	2.0	20	11.9	35.7	83.9
	3.0	9	5.4	16.1	100.0

	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Only one language spoken on construction site- ScP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	17	10.1	30.4	32.1
	1.0	14	8.3	25.0	57.1
	2.0	13	7.7	23.2	80.4
	3.0	11	6.5	19.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Good communication within site management- ScP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	8	4.8	14.3	14.3
	1.0	13	7.7	23.2	37.5
	2.0	15	8.9	26.8	64.3
	3.0	20	11.9	35.7	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Positive feedback (compliments) is regularly communicated to deserving workers- ScP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	12	7.1	21.4	21.4
	1.0	17	10.1	30.4	51.8

	2.0	13	7.7	23.2	75.0
	3.0	14	8.3	25.0	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Excellent working relationships and cohesiveness with co-workers- ScP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	7	4.2	12.5	12.5
	1.0	13	7.7	23.2	35.7
	2.0	14	8.3	25.0	60.7
	3.0	22	13.1	39.3	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Only one language spoken on construction site- QcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	14	8.3	25.0	26.8
	1.0	12	7.1	21.4	48.2
	2.0	14	8.3	25.0	73.2
	3.0	15	8.9	26.8	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Good communication within site management- QcP

		Frequency	Percent	Valid Percent	Cumulative Percent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	5	3.0	8.9	8.9
	1.0	9	5.4	16.1	25.0
	2.0	24	14.3	42.9	67.9
	3.0	18	10.7	32.1	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Positive feedback (compliments) is regularly communicated to deserving workers- QcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	7	4.2	12.5	12.5
	1.0	17	10.1	30.4	42.9
	2.0	15	8.9	26.8	69.6
	3.0	17	10.1	30.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Excellent working relationships and cohesiveness with co-workers- QcP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	5	3.0	8.9	8.9
	1.0	9	5.4	16.1	25.0
	2.0	17	10.1	30.4	55.4
	3.0	25	14.9	44.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

Work tasks very predictable due to adequate information- QtsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	5	3.0	9.1	9.1
	1.0	14	8.3	25.5	34.5
	2.0	24	14.3	43.6	78.2
	3.0	12	7.1	21.8	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Workers are not given new tasks too frequently- QtsmP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	10	6.0	18.2	18.2
	1.0	23	13.7	41.8	60.0
	2.0	16	9.5	29.1	89.1
	3.0	6	3.6	10.9	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Very organized material, tools, and equipment storage- SmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	6	3.6	10.9	10.9
	1.0	15	8.9	27.3	38.2
	2.0	17	10.1	30.9	69.1
	3.0	17	10.1	30.9	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Easy-to-use equipment (requires only basic skills)- SmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	9	5.4	16.4	16.4
	1.0	16	9.5	29.1	45.5
	2.0	17	10.1	30.9	76.4
	3.0	13	7.7	23.6	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Familiar with equipment used for task- SmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	4	2.4	7.3	9.1
	1.0	9	5.4	16.4	25.5
	2.0	20	11.9	36.4	61.8
	3.0	21	12.5	38.2	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Material, tools, and equipment is readily available - SmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	9	5.4	16.4	16.4
	1.0	14	8.3	25.5	41.8
	2.0	19	11.3	34.5	76.4
	3.0	13	7.7	23.6	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		

Total		168	100.0		

Equipment and tools are of good quality - SmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	7	4.2	12.7	12.7
	1.0	12	7.1	21.8	34.5
	2.0	20	11.9	36.4	70.9
	3.0	16	9.5	29.1	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Pre-fabrication is of good quality - SmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	10	6.0	18.2	18.2
	1.0	13	7.7	23.6	41.8
	2.0	21	12.5	38.2	80.0
	3.0	11	6.5	20.0	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Materials are of good quality - SmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	9	5.4	16.4	16.4
	1.0	16	9.5	29.1	45.5
	2.0	19	11.3	34.5	80.0
	3.0	11	6.5	20.0	100.0
	Total	55	32.7	100.0	

Missing	System	113	67.3		
Total		168	100.0		

Very organized material, tools, and equipment storage- QmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	5	3.0	9.1	9.1
	1.0	13	7.7	23.6	32.7
	2.0	19	11.3	34.5	67.3
	3.0	18	10.7	32.7	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Easy-to-use equipment (requires only basic skills)-QmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	8	4.8	14.5	14.5
	1.0	18	10.7	32.7	47.3
	2.0	19	11.3	34.5	81.8
	3.0	10	6.0	18.2	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Familiar with equipment used for task-QmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	3	1.8	5.5	5.5
	1.0	13	7.7	23.6	29.1
	2.0	22	13.1	40.0	69.1
	3.0	17	10.1	30.9	100.0

		Frequency	Percent	Valid Percent	Cumulative Percent
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Material, tools, and equipment is readily available -QmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	5	3.0	9.1	9.1
	1.0	13	7.7	23.6	32.7
	2.0	21	12.5	38.2	70.9
	3.0	16	9.5	29.1	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Pre-fabrication is of good quality -QmtsP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	8	4.8	14.5	14.5
	1.0	7	4.2	12.7	27.3
	2.0	16	9.5	29.1	56.4
	3.0	24	14.3	43.6	100.0
	Total	55	32.7	100.0	
Missing	System	113	67.3		
Total		168	100.0		

Low amount of paperwork involved-SetP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.0	2	1.2	3.6	3.6
	-1.0	2	1.2	3.6	7.1
	.0	34	20.2	60.7	67.9

	1.0	11	6.5	19.6	87.5
	2.0	4	2.4	7.1	94.6
	3.0	3	1.8	5.4	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

High quality of detailed design drawings -SetP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.0	1	.6	1.8	1.8
	.0	25	14.9	44.6	46.4
	1.0	17	10.1	30.4	76.8
	2.0	11	6.5	19.6	96.4
	3.0	2	1.2	3.6	100.0
	Total	56	33.3	100.0	
Missing	System	112	66.7		
Total		168	100.0		

7.5. Appendix E – Relative Impact Index

7.5.1. Appendix C1- Fieldworker

Safety

Negative Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Lack of personal protective equipment (PPE) and safety resources- SpmN	-66.67	Very high quality of work required-SpcN	36.67
2	Poor attitude towards safety- SccN	-60.00	Large project (physical size)- SpcN	26.67
3	Lack of familiarity with equipment - SmteN	-60.00	High cost project- SpcN	23.33
4	Poor working relationships and cohesiveness with co-workers-ScN	-56.67	Use of advanced technologies - SetN	16.67
5	Competing company priorities take precedence over safety - SccN	-53.33	Fast pace of work- SpcN	10.00
6	More than one language spoken on construction site-ScN	-53.33	Design-Bid-Build contract (hard-bid)- SpmN	10.00
7	Poor material, tools, and equipment storage-SmteN	-50.00	Task is highly repetitive - StsmN	10.00
8	Frequent interruption/interferences-StsmN	-46.67	High amount of paperwork involved- SetN	10.00
9	Poor quality of equipment and tools-SmteN	-46.67	Extended work hours each day-SpmN	3.33
10	Poor quality of pre-fabrication -SmteN	-46.67	Assigned task is very complex - StsmN	3.33

Positive Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Excellent personal protective equipment (PPE) and safety resources available - SpmP	73.33	Low quality of work required -SpcP	3.33
2	Familiar with equipment used for task- SmtsP	73.33	Low amount of paperwork involved-SetP	16.67
3	Materials are of good quality - SmtsP	73.33	Low cost project -SpcP	20.00
4	Experienced crew - SpmP	70.00	Remote project - location -SpcP	23.33
5	Easy-to-use equipment (requires only basic skills)- SmtsP	70.00	Worker tasks are not long and monotonous (dull)- StsmP	23.33
6	Equipment and tools are of good quality - SmtsP	70.00	Project is not unique -SpcP	26.67
7	Good attitude towards safety- SccP	66.67	Well-defined organizational structure- SccP	30.00
8	Project-based safety incentive - SpmP	66.67	Regular performance reviews - SccP	30.00
9	Acceptable quality of instruction provided for work tasks - SpmP	66.67	Lower than typical productivity required- SccP	30.00
10	Very organized material, tools, and equipment storage- SmtsP	66.67	Small project -SpcP	30.00

Quality

Negative Description- OW				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Poor quality of pre-fabrication -QmteN	-63.33	Extended work hours each day - QpmN	3.33
2	Poor quality materials-QmteN	-56.67	High level of competition within company- QccN	6.67
3	Unpredictability of the work tasks due to unknown information- QtsmN	-53.33	Use of advanced technologies - QetN	10.00
4	Material, tools, and equipment not readily available-QmteN	-53.33	Design-Bid-Build contract (hard-bid) - QpmN	16.67

5	Poor quality of equipment and tools-QmteN	-53.33	Assigned task is very complex -QtsmN	16.67
6	Slow response to Requests for Information (RFIs)- QetN	-53.33	Large project (physical size)- QpcN	23.33
7	Poor material, tools, and equipment storage-QmteN	-50.00	Task is long and continuous -QtsmN	26.67
8	Frequent interruption/interferences-QtsmN	-46.67	High cost project - QpcN	30.00
9	Low quality of detailed design drawings - QetN	-46.67	Task is highly repetitive - QtsmN	33.33
10	More than one language spoken on construction site-QcN	-46.67	Very high quality of work required-QpcN	53.33

Positive Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	RII
1	Experienced crew - QpmP	83.33	Well-defined organizational structure - QccP	40.00
2	Equipment and tools are of good quality -QmtsP	80.00	Regular performance reviews -QccP	40.00
3	Materials are of good quality -QmtsP	80.00	Task is not repetitive - QtsmP	40.00
4	Familiar with equipment used for task-QmtsP	76.67	Slow pace of work -QpcP	36.67
5	Pre-fabrication is of good quality -QmtsP	76.67	Project is not unique -QpcP	36.67
6	Experienced crew - QpmP	83.33	Lower than typical productivity required- QccP	33.33
7	Equipment and tools are of good quality -QmtsP	80.00	Remote project - location -QpcP	30.00
8	Materials are of good quality -QmtsP	80.00	Low cost project -QpcP	26.67
9	Familiar with equipment used for task-QmtsP	76.67	Low amount of paperwork involved-QetP	20.00
10	Pre-fabrication is of good quality -QmtsP	76.67	Low quality of work required -QpcP	-23.33

7.5.2. Appendix C2- Foreman

Safety

Negative Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Poor quality of equipment and tools-SmteN	-87.50	Use of advanced technologies -SetN	25.00
2	Poor attitude towards safety- SccN	-75.00	Very high quality of work required-SpcN	16.67
3	Competing company priorities take precedence over safety - SccN	-75.00	High amount of paperwork involved- SetN	8.33
4	Lack of personal protective equipment (PPE) and safety resources- SpmN	-75.00	Assigned task is very complex -StsmN	4.17
5	Congested site- SpmN	-70.83	High cost project- SpcN	0.00
6	Inexperienced (unqualified) supervisor-SpmN	-70.83	Task is highly repetitive - StsmN	-4.17
7	Inexperienced crew - SpmN	-70.83	Look-ahead (bi-weekly) schedule not available- SpmN	-4.17
8	Poor material, tools, and equipment storage-SmteN	-66.67	Lack of regular performance reviews- SccN	-4.17
9	Lack of adequate communication within site management-ScN	-62.50	Large project (physical size)- SpcN	-8.33
10	Lack of familiarity with equipment -SmteN	-58.33	Very unique work- SpcN	-8.33

Positive Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Good attitude towards safety- SccP	83.33	Low quality of work required -SpcP	-25.00
2	Safety takes precedence over other companies priorities - SccP	79.17	Remote project - location -SpcP	-8.33
3	High retention rate of skilled craftsmen - SccP	75.00	Low cost project -SpcP	8.33
4	Excellent personal protective equipment (PPE) and safety resources available - SpmP	75.00	Low amount of paperwork involved-SetP	12.50

5	Worker tasks are not long and monotonous (dull)- StsmP	75.00	Slow pace of work-SpcP	20.83
6	Excellent working relationships and cohesiveness with co-workers- ScP	75.00	Small project -SpcP	25.00
7	Experienced supervisor - SpmP	70.83	Task is not repetitive- StsmP	25.00
8	Familiar with equipment used for task-SmtsP	70.83	Relaxed atmosphere within company - SccP	29.17
9	Equipment and tools are of good quality - SmtsP	70.83	Day shifts only - SpmP	29.17
10	Experienced crew - SpmP	66.67	Regular performance reviews - SccP	33.33

Quality

Negative Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Poor quality of equipment and tools-QmteN	-79.17	Very high quality of work required-QpcN	75.00
2	Low quality of instruction provided for work tasks - QpmN	-70.83	Use of advanced technologies - QetN	45.83
3	Unpredictability of the work tasks due to unknown information- QtsmN	-66.67	Task is highly repetitive - QtsmN	37.50
4	Poor quality materials-QmteN	-66.67	Very unique work- QpcN	20.83
5	Slow response to Requests for Information (RFIs)- QetN	-66.67	High level of competition within company- QccN	16.67
6	Construction drawings not readily available - QpmN	-62.50	Task is long and continuous - QtsmN	12.50
7	Poor material, tools, and equipment storage-QmteN	-62.50	Using complex equipment (requires advanced skills)-QmteN	12.50
8	Poor quality of pre-fabrication -QmteN	-62.50	High cost project - QpcN	4.17
9	Low quality of detailed design drawings - QetN	-62.50	Assigned task is very complex - QtsmN	4.17
10	Inexperienced crew - QpmN	-58.33	High amount of paperwork involved- QetN	4.17

Positive Description				
Ranking	Most Impactful Components	RII	Least Impactful Components	RII
1	High retention rate of skilled craftsmen - QccP	87.50	Low cost project -QpcP	-4.17
2	Materials are of good quality -QmtsP	83.33	Low quality of work required - QpcP	-4.17
3	Experienced supervisor - QpmP	79.17	Remote project - location -QpcP	8.33
4	Construction drawings available when needed - QpmP	79.17	Small project -QpcP	16.67
5	Work tasks very predictable due to adequate information- QtsmP	79.17	Relaxed atmosphere within company - QccP	20.83
6	Material, tools, and equipment is readily available -QmtsP	79.17	Project-based safety incentive - QpmP	20.83
7	Excellent working relationships and cohesiveness with co-workers- QcP	79.17	Safety takes precedence over other companies priorities - QccP	25.00
8	Experienced crew - QpmP	75.00	Task is not repetitive - QtsmP	25.00
9	No interruption/interferences - QtsmP	75.00	Low amount of paperwork involved-QetP	29.17
10	Very organized material, tools, and equipment storage- QmtsP	75.00	Project is not unique -QpcP	33.33

7.5.3. Appendix C3- Superintendent

Safety

Negative Description				
Ranking	Most Impactful Components	RII	Least Impactful Components	RII
1	Poor attitude towards safety- SccN	-85.71	Very high quality of work required- SpcN	23.81
2	Lack of personal protective equipment (PPE) and safety resources- SpmN	-85.71	Large project (physical size)- SpcN	14.29
3	More than one language spoken on construction site-ScN	-85.71	High cost project- SpcN	14.29

4	Lack of adequate communication within site management-ScN	-85.71	Lack of regular performance reviews- SccN	9.52
5	Lack of familiarity with equipment - SmteN	-80.95	Task is highly repetitive - StsmN	4.76
6	Poor working relationships and cohesiveness with co-workers-ScN	-80.95	Very unique work- SpcN	-4.76
7	Inexperienced (unqualified) supervisor- SpmN	-76.19	Design-Bid-Build contract (hard-bid)- SpmN	-4.76
8	Inability to retain skilled craftsmen-SccN	-71.42	Task is long and continuous - StsmN	-4.76
9	Competing company priorities take precedence over safety - SccN	-71.42	You are given new tasks very frequently- StsmN	-4.76
10	Congested site- SpmN	-66.67	Using complex equipment (requires advanced skills)-SmteN	-4.76

Positive Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Experienced supervisor - SpmP	80.95	Low quality of work required -SpcP	-14.29
2	Experienced crew - SpmP	80.95	Task is not repetitive- StsmP	-9.52
3	High retention rate of skilled craftsmen - SccP	76.19	Remote project - location -SpcP	0.00
4	Good attitude towards safety- SccP	76.19	Low cost project -SpcP	9.52
5	Safety takes precedence over other companies priorities - SccP	76.19	Lower than typical productivity required- SccP	19.05
6	Non-congested site - SpmP	71.43	Slow pace of work-SpcP	19.05
7	Excellent personal protective equipment (PPE) and safety resources available - SpmP	71.43	Design-Build contract - SpmP	19.05
8	Acceptable quality of instruction provided for work tasks - SpmP	66.67	High quality of detailed design drawings -SetP	23.81
9	Familiar with equipment used for task-SmtsP	66.67	Small project -SpcP	28.57
10	Excellent working relationships and cohesiveness with co-workers- ScP	66.67	Look-ahead (bi-weekly) schedule available - SpmP	28.57

Quality

Negative Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Inability to retain skilled craftsmen-QccN	-90.48	Very high quality of work required-QpcN	47.62
2	Poor material, tools, and equipment storage-QmteN	-80.95	High cost project - QpcN	23.81
3	Poor quality materials-QmteN	-80.95	Task is highly repetitive - QtsmN	19.05
4	Poor quality of equipment and tools-QmteN	-76.19	Task is long and continuous - QtsmN	14.29
5	More than one language spoken on construction site-QcN	-76.19	Large project (physical size)- QpcN	4.76
6	Lack of adequate communication within site management-QcN	-76.19	Lack of regular performance reviews- QccN	0.00
7	Poorly or non-defined organizational structure-QccN	-71.43	Using complex equipment (requires advanced skills)-QmteN	-4.76
8	Lack of familiarity with equipment - QmteN	-71.43	Very unique work- QpcN	-9.52
9	Low quality of detailed design drawings - QetN	-71.43	Use of advanced technologies - QetN	-9.52
10	Slow response to Requests for Information (RFIs)- QetN	-71.43	Design-Bid-Build contract (hard-bid) - QpmN	-14.3

Positive Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	High retention rate of skilled craftsmen - QccP	85.71	Low quality of work required - QpcP	-19.05
2	Construction drawings available when needed - QpmP	80.95	Task is not repetitive - QtsmP	4.76
3	Experienced crew - QpmP	80.95	Low cost project -QpcP	9.52

4	Experienced supervisor - QpmP	71.43	Remote project - location -QpcP	9.52
5	No or minimal overlapping of different crews/trades on site - QpmP	66.67	Small project -QpcP	23.81
6	Acceptable quality of instruction provided for work tasks - QpmP	66.67	Slow pace of work -QpcP	28.57
7	Pre-fabrication is of good quality - QmtsP	66.67	Project-based safety incentive - QpmP	28.57
8	High quality of detailed design drawings -QetP	66.67	Subcontractors not on-site at same time - QpmP	28.57
9	Only one language spoken on construction site- QcP	66.67	Project is not unique -QpcP	33.33
10	Well-defined organizational structure - QccP	61.90	Look-ahead (bi-weekly) schedule available - QpmP	33.33

7.5.4. Appendix C4- Project Engineer

Safety

Negative Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Poor attitude towards safety- SccN	-95.83	High cost project- SpcN	29.17
2	Inexperienced crew - SpmN	-83.33	Very high quality of work required- SpcN	20.83
3	Lack of personal protective equipment (PPE) and safety resources- SpmN	-79.17	Use of advanced technologies - SetN	12.50
4	Inexperienced (unqualified) supervisor- SpmN	-70.83	High level of competition within company- SccN	8.33
5	Lack of familiarity with equipment - SmteN	-70.83	High amount of paperwork involved- SetN	8.33
6	Poor quality of equipment and tools- SmteN	-70.83	Design-Bid-Build contract (hard-bid)- SpmN	-4.17
7	Poorly or non-defined organizational structure- SccN	-66.67	Large project (physical size)- SpcN	-8.33
8	Adverse weather condition- SpcN	-66.67	Task is long and continuous - StsmN	-8.33

9	Task involves high risk of injury- StsmN	-66.67	Task is highly repetitive - StsmN	-12.50
10	Competing company priorities take precedence over safety - SccN	-62.50	High number of sub-tasks within one task- StsmN	-12.50

Positive Description				
Ranking	Most Impactful Components	RII	Least Impactful Components	RII
1	Safety takes precedence over other companies priorities - SccP	95.83	Remote project - location -SpcP	-25.00
2	Good attitude towards safety- SccP	91.67	Low quality of work required -SpcP	-25.00
3	Experienced crew - SpmP	91.67	Low cost project -SpcP	-8.33
4	Excellent personal protective equipment (PPE) and safety resources available - SpmP	91.67	Lower than typical productivity required- SccP	4.17
5	Experienced supervisor - SpmP	87.50	Low amount of paperwork involved-SetP	4.17
6	High retention rate of skilled craftsmen - SccP	83.33	Small project -SpcP	16.67
7	Familiar with equipment used for task- SmtsP	83.33	Task is not repetitive- StsmP	16.67
8	Project is not unique -SpcP	75.00	Quick response to Requests for Information (RFIs)-SetP	16.67
9	Non-congested site - SpmP	70.83	High quality of detailed design drawings -SetP	20.83
10	Very organized material, tools, and equipment storage- SmtsP	70.83	Slow pace of work-SpcP	25.00

Quality

Negative Description				
Ranking	Most Impactful Components	RII	Least Impactful Components	RII
1	Poor quality materials-QmteN	-83.33	Very high quality of work required- QpcN	58.33

2	Poorly or non-defined organizational structure-QccN	-79.17	High cost project - QpcN	33.33
3	Poor quality of pre-fabrication -QmteN	-79.17	Use of advanced technologies - QetN	33.33
4	Inability to retain skilled craftsmen-QccN	-75.00	High level of competition within company- QccN	25.00
5	Construction drawings not readily available - QpmN	-70.83	Project located in densely populated (urban) area- QpcN	16.67
6	Poor quality of equipment and tools-QmteN	-70.83	Task is highly repetitive - QtsmN	16.67
7	Low quality of detailed design drawings - QetN	-70.83	Large project (physical size)- QpcN	12.50
8	Low quality of instruction provided for work tasks - QpmN	-66.67	Task is long and continuous - QtsmN	12.50
9	Slow response to Requests for Information (RFIs)- QetN	-66.67	Very unique work- QpcN	8.33
10	Inexperienced (unqualified) supervisor - QpmN	-62.50	Design-Bid-Build contract (hard-bid) - QpmN	-8.33

Positive Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Experienced supervisor - QpmP	87.50	Low quality of work required - QpcP	-45.83
2	Excellent working relationships and cohesiveness with co-workers- QcP	87.50	Remote project - location -QpcP	-8.33
3	Experienced crew - QpmP	79.17	Low cost project -QpcP	-4.17
4	High retention rate of skilled craftsmen - QccP	75.00	Small project -QpcP	12.50
5	Construction drawings available when needed - QpmP	75.00	Slow pace of work -QpcP	20.83
6	Materials are of good quality -QmtsP	75.00	Subcontractors not on-site at same time - QpmP	20.83
7	Good communication within site management- QcP	75.00	Few different tasks/activities being worked on by different	20.83

			crews at the same time - QpmP	
8	Very organized material, tools, and equipment storage- QmtsP	70.83	Task is not repetitive - QtsmP	20.83
9	Familiar with equipment used for task- QmtsP	70.83	Lower than typical productivity required- QccP	25.00
10	Equipment and tools are of good quality -QmtsP	70.83	Relaxed atmosphere within company - QccP	25.00

7.5.5. Appendix C5- Project Manger

Safety

Negative Description				
Ranking	Most Impactful Components	RII	Least Impactful Components	RII
1	Poor attitude towards safety- SccN	-83.33	Very unique work- SpcN	33.33
2	Competing company priorities take precedence over safety - SccN	-75.00	Using complex equipment (requires advanced skills)-SmteN	33.33
3	Lack of personal protective equipment (PPE) and safety resources- SpmN	-75.00	Task involves high risk of injury- StsmN	25.00
4	Inability to retain skilled craftsmen- SccN	-66.67	Use of advanced technologies - SetN	25.00
5	Night shifts- SpmN	-66.67	High level of competition within company- SccN	16.67
6	Inexperienced (unqualified) supervisor- SpmN	-66.67	Large project (physical size)- SpcN	16.67
7	Poorly or non-defined organizational structure- SccN	-58.33	Assigned task is very complex - StsmN	16.67
8	Inexperienced crew - SpmN	-58.33	High cost project- SpcN	8.33
9	Lack of familiarity with equipment - SmteN	-58.33	Very high quality of work required- SpcN	8.33
10	More than one language spoken on construction site-ScN	-58.33	Project located in densely populated (urban) area- SpcN	0.00

Positive Description				
Ranking	Most Impactful Components	RII	Least Impactful Components	RII
1	Experienced crew - SpmP	83.33	More time allowed in project schedule than typical - SccP	-16.67
2	Excellent personal protective equipment (PPE) and safety resources available - SpmP	75.00	Slow pace of work-SpcP	-16.67
3	Good attitude towards safety- SccP	66.67	Remote project - location -SpcP	-16.67
4	Safety takes precedence over other companies priorities - SccP	66.67	Low quality of work required -SpcP	-16.67
5	Experienced supervisor - SpmP	66.67	Lower than typical productivity required- SccP	-8.33
6	Familiar with equipment used for task-SmtsP	66.67	Relaxed atmosphere within company - SccP	0.00
7	Well-defined organizational structure-SccP	58.33	Project is not unique -SpcP	0.00
8	Good communication within site management- ScP	58.33	Low cost project -SpcP	0.00
9	High retention rate of skilled craftsmen - SccP	50.00	Assigned task requires little or no calculation, mental stress, remembering, etc- StsmP	0.00
10	Task involves low risk of injury - StsmP	50.00	Low amount of paperwork involved-SetP	0.00

Quality

Negative Description				
Ranking	Most Impactful Components	RII	Least Impactful Components	RII
1	Inability to retain skilled craftsmen-QccN	-75.00	Very high quality of work required-QpcN	83.33
2	Inexperienced (unqualified) supervisor - QpmN	-75.00	High level of competition within company- QccN	58.33
3	Poor quality materials-QmteN	-75.00	Very unique work- QpcN	58.33
4	Inexperienced crew - QpmN	-66.67	Using complex equipment (requires advanced skills)-QmteN	58.33

5	Construction drawings not readily available - QpmN	-58.33	Task is highly repetitive - QtsmN	25.00
6	Poor quality of pre-fabrication -QmteN	-58.33	Task is long and continuous - QtsmN	25.00
7	Poorly or non-defined organizational structure-QccN	-50.00	Assigned task is very complex - QtsmN	25.00
8	High number of project scope changes during construction - QpmN	-50.00	High cost project - QpcN	8.33
9	Poor material, tools, and equipment storage-QmteN	-50.00	Project located in densely populated (urban) area- QpcN	8.33
10	Poor quality of equipment and tools- QmteN	-50.00	Use of advanced technologies - QetN	8.33

Positive Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	High retention rate of skilled craftsmen - QccP	75.00	Lower than typical productivity required- QccP	-25.00
2	Experienced supervisor - QpmP	75.00	Relaxed atmosphere within company - QccP	-25.00
3	Pre-fabrication is of good quality - QmtsP	75.00	Remote project - location -QpcP	-25.00
4	Materials are of good quality -QmtsP	75.00	More time allowed in project schedule than typical - QccP	-16.67
5	Well-defined organizational structure - QccP	66.67	Project is not unique -QpcP	-8.33
6	Experienced crew - QpmP	66.67	Low quality of work required - QpcP	-8.33
7	Equipment and tools are of good quality -QmtsP	66.67	No or minimal overlapping of different crews/trades on site - QpmP	-8.33
8	High quality of detailed design drawings -QetP	58.33	Assigned task requires little or no calculation, mental stress, remembering, etc- QtsmP	-8.33
9	Good communication within site management- QcP	58.33	Good attitude towards safety- QccP	0.00
10	Acceptable quality of instruction provided for work tasks - QpmP	50.00	Safety takes precedence over other companies priorities - QccP	0.00

7.5.6. Appendix C6- Safety Professional

Safety

Negative Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Poor attitude towards safety- SccN	-93.33	Very high quality of work required- SpcN	40.00
2	Competing company priorities take precedence over safety - SccN	-83.33	Use of advanced technologies - SetN	23.33
3	Inexperienced (unqualified) supervisor- SpmN	-73.33	High cost project- SpcN	13.33
4	Congested site- SpmN	-70.00	High amount of paperwork involved- SetN	10.00
5	Poorly or non-defined organizational structure- SccN	-66.67	Large project (physical size)- SpcN	3.33
6	Inexperienced crew - SpmN	-66.67	High level of competition within company- SccN	0.00
7	Lack of personal protective equipment (PPE) and safety resources- SpmN	-66.67	No safety incentive- SpmN	-3.33
8	Inability to retain skilled craftsmen- SccN	-63.33	Using complex equipment (requires advanced skills)-SmteN	-6.67
9	Poor working relationships and cohesiveness with co-workers-ScN	-60.00	Very unique work- SpcN	-10.00
10	Lack of familiarity with equipment - SmteN	-56.67	Low quality of detailed design drawings - SetN	-10.00

Positive Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Good attitude towards safety- SccP	93.33	Low quality of work required -SpcP	-20.00
2	Safety takes precedence over other companies priorities - SccP	73.33	Remote project - location -SpcP	-16.67
3	Non-congested site - SpmP	73.33	Low cost project -SpcP	-3.33

4	High retention rate of skilled craftsmen - SccP	70.00	Slow pace of work-SpcP	10.00
5	Excellent personal protective equipment (PPE) and safety resources available - SpmP	70.00	Small project -SpcP	10.00
6	Good communication within site management- ScP	70.00	Low amount of paperwork involved-SetP	10.00
7	Positive feedback (compliments) is regularly communicated to deserving workers- ScP	70.00	Lower than typical productivity required- SccP	16.67
8	Well-defined organizational structure-SccP	66.67	Project-based safety incentive - SpmP	16.67
9	Experienced supervisor - SpmP	66.67	Quick response to Requests for Information (RFIs)-SetP	23.33
10	Familiar with equipment used for task-SmtsP	66.67	Task is not repetitive- StsmP	26.67

Quality

Negative Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Inability to retain skilled craftsmen-QccN	-70.00	Very high quality of work required-QpcN	46.67
2	Poor attitude towards safety- QccN	-70.00	Use of advanced technologies - QetN	33.33
3	Poorly or non-defined organizational structure-QccN	-66.67	Task is highly repetitive - QtsmN	13.33
4	Competing company priorities take precedence over safety- QccN	-66.67	High cost project - QpcN	10.00
5	Inexperienced (unqualified) supervisor - QpmN	-66.67	High level of competition within company- QccN	6.67
6	Inexperienced crew - QpmN	-66.67	Large project (physical size)- QpcN	6.67
7	Poor quality materials-QmteN	-66.67	Task is long and continuous - QtsmN	3.33
8	Poor quality of pre-fabrication -QmteN	-60.00	High amount of paperwork involved- QetN	0.00

9	Poor working relationships and cohesiveness with co-workers-QcN	-56.67	No safety incentive - QpmN	-3.33
10	Low quality of instruction provided for work tasks - QpmN	-53.33	Very unique work- QpcN	- 10.00

Positive Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	High retention rate of skilled craftsmen - QccP	73.33	Low quality of work required - QpcP	-30.00
2	Very organized material, tools, and equipment storage- QmtsP	66.67	Low cost project -QpcP	3.33
3	Familiar with equipment used for task- QmtsP	66.67	Remote project - location -QpcP	3.33
4	Material, tools, and equipment is readily available -QmtsP	66.67	Project-based safety incentive - QpmP	13.33
5	Pre-fabrication is of good quality - QmtsP	66.67	Task is not repetitive - QtsmP	13.33
6	High quality of detailed design drawings -QetP	66.67	Working on weekdays only - QpmP	23.33
7	Positive feedback (compliments) is regularly communicated to deserving workers- QcP	66.67	Subcontractors not on-site at same time - QpmP	26.67
8	Excellent working relationships and cohesiveness with co-workers- QcP	66.67	Few different tasks/activities being worked on by different crews at the same time - QpmP	26.67
9	Well-defined organizational structure - QccP	63.33	Lower than typical productivity required- QccP	30.00
10	Experienced supervisor - QpmP	63.33	Small project -QpcP	30.00

7.5.7. Appendix C7- Owners Representative

Safety

Negative Description

Ranking	Most Impactful Components	RII	Least Impactful Components	RII
1	Poor attitude towards safety- SccN	-66.67	Very high quality of work required-SpcN	33.33
2	Lack of personal protective equipment (PPE) and safety resources- SpmN	-61.11	High cost project- SpcN	27.78
3	Lack of familiarity with equipment - SmteN	-61.11	Large project (physical size)- SpcN	22.22
4	Poor quality of equipment and tools-SmteN	-61.11	Project located in densely populated (urban) area- SpcN	11.11
5	Poorly or non-defined organizational structure- SccN	-50.00	Use of advanced technologies - SetN	5.56
6	Congested site- SpmN	-50.00	Low quality of detailed design drawings - SetN	0.00
7	In addition to weekdays, working on weekends and holidays- SpmN	-50.00	Slow response to Requests for Information (RFIs)- SetN	0.00
8	Poor material, tools, and equipment storage-SmteN	-50.00	High level of competition within company- SccN	-5.56
9	Inability to retain skilled craftsmen-SccN	-44.44	Very unique work- SpcN	-5.56
10	Inexperienced (unqualified) supervisor-SpmN	-44.44	No safety incentive- SpmN	-5.56

Positive Description				
Ranking	Most Impactful Components	RII	Least Impactful Components	RII
1	Safety takes precedence over other companies priorities - SccP	61.11	Slow pace of work-SpcP	-16.67
2	High retention rate of skilled craftsmen - SccP	55.56	Remote project - location -SpcP	-16.67
3	Good attitude towards safety- SccP	55.56	Low quality of work required -SpcP	-16.67
4	Equipment and tools are of good quality - SmtsP	55.56	Assigned task requires little or no calculation, mental stress, remembering, etc- StsmP	-16.67
5	Good communication within site management- ScP	55.56	Lower than typical productivity required- SccP	-11.11
6	Excellent working relationships and cohesiveness with co-workers- ScP	55.56	Low cost project -SpcP	-11.11

7	Excellent personal protective equipment (PPE) and safety resources available - SpmP	50.00	Small project -SpcP	-5.56
8	Well-defined organizational structure-SccP	44.44	Project is not unique -SpcP	0.00
9	Experienced supervisor - SpmP	44.44	More time allowed in project schedule than typical - SccP	5.56
10	Very organized material, tools, and equipment storage- SmtsP	44.44	Task is not repetitive- StsmP	5.56

Quality

Negative Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	Construction drawings not readily available - QpmN	-77.78	Very high quality of work required- QpcN	66.67
2	Poor working relationships and cohesiveness with co-workers-QcN	-72.22	Use of advanced technologies - QetN	50.00
3	Frequent interruption/interferences-QtsmN	-66.67	Task is highly repetitive - QtsmN	44.44
4	Unpredictability of the work tasks due to unknown information- QtsmN	-61.11	High level of competition within company- QccN	38.89
5	Lack of adequate communication within site management-QcN	-61.11	High cost project - QpcN	27.78
6	Poorly or non-defined organizational structure-QccN	-55.56	Very unique work- QpcN	22.22
7	Inability to retain skilled craftsmen-QccN	-55.56	Large project (physical size)- QpcN	22.22
8	Inexperienced (unqualified) supervisor - QpmN	-55.56	Project located in densely populated (urban) area- QpcN	22.22
9	Frequent switching between tasks required- QtsmN	-55.56	Using complex equipment (requires advanced skills)-QmteN	22.22
10	Poor quality of equipment and tools-QmteN	-55.56	Fast pace of work- QpcN	5.56

Positive Description				
Ranking	**Most Impactful Components**	**RII**	**Least Impactful Components**	**RII**
1	High quality of detailed design drawings -QetP	77.78	Low quality of work required - QpcP	-44.44
2	Excellent working relationships and cohesiveness with co-workers- QcP	77.78	Low cost project -QpcP	-22.22
3	Quick response to Requests for Information (RFIs)-QetP	72.22	Lower than typical productivity required- QccP	-11.11
4	Good communication within site management- QcP	72.22	Slow pace of work -QpcP	-11.11
5	High retention rate of skilled craftsmen - QccP	66.67	Remote project - location -QpcP	-11.11
6	Experienced supervisor - QpmP	66.67	Subcontractors not on-site at same time - QpmP	-5.56
7	Construction drawings available when needed - QpmP	66.67	Task is not repetitive - QtsmP	-5.56
8	No interruption/interferences - QtsmP	61.11	Foreman's method of supervision is conventional- QtsmP	0.00
9	Familiar with equipment used for task- QmtsP	61.11	More time allowed in project schedule than typical - QccP	5.56
10	Equipment and tools are of good quality -QmtsP	61.11	Relaxed atmosphere within company - QccP	5.56

7.6.

7.7. Appendix F- Composition of Energy Constituent

7.7.1. Appendix F1- Fieldworker

	Component	SAFETY		Quality		Range			
		Nve Impact	Pve Impact	Nve Impact	Pve Impact	Safety		Quality	
Uniqueness	Work is Unique	-0.1	0.8	0.1	1.1	-0.1	0.8	0.1	1.1
Predictability	Task predictability	-1.1	1.2	-1.6	2	-1.1	1.2	-1.6	2
Repetitiveness	Task is Highly repetitive	0.3	1.2	1	1.2				
	Task is long and continuous	0	0.7	0.8	1.4	0.15	0.95	0.9	1.3
Complexity	Large Project	0.8	0.9	0.7	1.4				
	High risk of injury	-0.11111111	1.7	-0.9	1.5				
	Complex task	0.5	1.3	-0.4	1.4				
	High number of sub task within 1 task	-0.6	1.7	-0.1	1.666666667	0.147222	1.4	-0.175	1.491667
Availability of needed resources	Inability to retain skilled men	-1	1.7	-1.1	1.8				
	poor material and tool storage	-1.5	2	-1.5	2				
	Complex equipment	-0.6	2.1	-0.3	2				

	lack of familiarity with tools	-1.8	2.2	-1.3	2.3				
	Tools not readily available	-0.9	2	-1.6	2.1				
	Poor quality of tools and equipment	-1.4	2.1	-1.6	2.4				
	poor quality of pre fabs	-1.4	1.9	-1.9	2.3				
	Poor quality of material	-1.4	2.2	-1.7	2.4				
						-1.25	2.025	-1.375	2.1625
Crowding	Congested Site	-1	1.4	-0.5	1.6				
	Manyn different crews	-0.4	1.7	-0.2	2				
	Many sub contractors	-0.6	1.5	-0.6	1.6				
	Many different task/activity	-0.6	1.5	-0.6	1.7				
	Paperwork	0.3	0.5	-0.2	0.6				
						0	1.32	-0.42	1.5
Interruptions	unavailable construction drawing	-0.6	1.6	-0.9	2.2				
	inexperienced crew	-1.1	2.1	-0.777777778	2.5				
	Low quality of information	-0.7	2	-1	2.1				

Switching	High number of overlapping crew work activities	-0.5	1.777777778	-0.6	1.888888889					
	Interruptions	-1.4	1.6	-1.4	1.7					
	RFI response	-0.2	1.3	-1.6	1.5		-0.75	1.72963	-1.0463	1.981481
	switching btwn task	-0.4	1.7	-0.3	1.6					
	Given new task regularly	-0.4	1.6	-1.1	2.1		-0.4	1.65	-0.7	1.85

7.7.2.

7.7.3. Appendix F2- Foreman

	Component	SAFETY		Quality			Range			
		Nve Impact	Pve Impact	Nve Impact	Pve Impact		Safety		Quality	
Uniqueness	Work is Unique	-0.25	1.125	0.625	1		-0.25	1.125	0.625	1
Predictability	Task predictability	-1.5	2	-2	2.375		-1.5	2	-2	2.375
Repetitiveness	Task is Highly repetitive	-0.14286	0.75	1.285714	0.75					
	Task is long and continuous	-0.375	2.25	0.375	1.25					

						-0.25893	1.5	0.830357	1
Complexity	Large Project	-0.25	0.75	-0.25	0.5				
	High risk of injury	-0.125	1.875	-1.25	1.5				
	Complex task	0.125	1.375	-0.875	1.25				
	High number of sub task within 1 task	-0.875	1.75	-0.5	1.75				
						-0.28125	1.4375	-0.71875	1.25
Availability of needed resources	Inability to retain skilled men	-0.75	2.25	-1.25	2.625				
	poor material and tool storage	-2	2	-1.875	2.25				
	Complex equipment	-0.5	1.75	0.375	1.75				
	lack of familiarity with tools	-1.75	2.125	-1	2.125				
	Tools not readily available	-0.625	1.625	-1.5	2.375				
	Poor quality of tools and equipment	-2.625	2.125	-2.375	2.25				
	poor quality of pre fabs	-1.375	1.75	-1.875	2.25				
	Poor quality of material	-1.375	1.75	-2	2.5				
						-1.375	1.921875	-1.4375	2.265625
Crowding	Congested Site	-2.125	1.75	-1.5	1.625				
	Many different crews	-1.375	1.875	-1	1.75				

	Many sub contractors	-1.25	1.25	-0.375	1.25						
	Many different task/activity	-1.375	1.25	-1	1.125						
	Paperwork	0.25	0.375	0.125	0.875		0	1.3		-0.75	1.325
Interruptions	unavailable construction drawing	-0.625	1.625	-1.875	2.375						
	inexperienced crew	-2.125	2	-2	2.25						
	Low quality of information	-1.375	1.625	-2.125	1.875						
	High number of overlapping crew work activities	-1.5	1.5	-1.375	1.25						
	Interruptions	-1.625	1.5	-1.5	2.25						
	RFI response	-0.5	1	-2	2.125		-1.29167	1.541667		-1.8125	2.020833
Switching	switching btwn task	-0.875	1.875	-0.75	1.875						
	Given new task regularly	-0.625	1.75	-0.375	1.625		-0.75	1.8125		-0.5625	1.75

Appendix F3- Superintendent

	Component	SAFETY		Quality		Range			
						Safety		Quality	
		Nve Impact	Pve Impact	Nve Impact	Pve Impact				
Uniqueness	Work is Unique	-0.14286	1.142857	-0.28571	1	-0.14286	1.142857	-0.28571	1
Predictability	Task predictability	-1.42857	1.666667	-1.85714	2.166667	-1.42857	1.666667	-1.85714	2.166667
Repetitiveness	Task is Highly repetitive	0.142857	-0.33333	0.571429	0.166667				
	Task is long and continuous	-0.14286	1.166667	0.428571	1.333333	0	0.416667	0.5	0.75
Complexity	Large Project	0.428571	0.857143	0.142857	0.714286				
	High risk of injury	-0.42857	1.833333	-1.42857	1.833333				
	Complex task	-0.71429	1	-0.57143	1.333333				
	High number of sub task within 1 task	-0.71429	1.166667	-0.28571	2	-0.35714	1.214286	-0.53571	1.470238
Availability of needed resources	Inability to retain skilled men	-2.14286	2.285714	-2.71429	2.571429				
	poor material and tool storage	-1.57143	2	-2.42857	2				
	Complex equipment	-0.14286	2	-0.14286	2				
	lack of familiarity with tools	-2.42857	2.333333	-2.14286	2				

	Tools not readily available	-1.28571	2.166667	-2.16667	1.833333				
	Poor quality of tools and equipment	-1.57143	2	-2.28571	2				
	poor quality of pre fabs	-0.5	2	-2	2.333333				
	Poor quality of material	-1.14286	2	-2.42857	2.166667				
						-1.34821	2.098214	-2.03869	2.113095
Crowding	Congested Site	-2	2.142857	-1.42857	1.714286				
	Manyn different crews	-2	1.857143	-1.42857	2				
	Many sub contractors	-1.42857	0.857143	-1.14286	0.857143				
	Many different task/activity	-1	1	-0.85714	1.142857				
	Paperwork	-0.28571	1	-0.71429	1.333333				
						0	1.371429	-1.11429	1.409524
Interruptions	unavailable construction drawing	-0.71429	1.571429	-1.71429	2.428571				
	inexperienced crew	-2.16667	2.428571	-1.83333	2.428571				
	Low quality of information	-1.28571	2	-1.85714	2				
	High number of overlapping crew work activities	-1.28571	1.285714	-1.28571	1.428571				
	Interruptions	-1.14286	1.5	-1.28571	2.166667				
	RFI response	-1.14286	1.166667	-2.14286	2.166667				

						-1.28968	1.65873	-1.68651	2.103175
Switching	switching btwn task	-0.57143	1.666667	-0.42857	1.666667				
	Given new task regularly	-0.14286	1.5	-0.57143	1.833333	-0.35714	1.583333	-0.5	1.75

7.7.4. Appendix F4- Project Engineer

	Component	SAFETY		Quality		Range			
		Nve Impact	Pve Impact	Nve Impact	Pve Impact	Safety		Quality	
Uniqueness	Work is Unique	-0.5	2.25	0.25	1	-0.5	2.25	0.25	1
Predictability	Task predictability	-1.75	1.625	-1.875	1.75	-1.75	1.625	-1.875	1.75
Repetitiveness	Task is Highly repetitive	-0.375	0.5	0.5	0.625				
	Task is long and continuous	-0.25	1.125	0.375	1.125	-0.3125	0.8125	0.4375	0.875
Complexity	Large Project	-0.25	0.5	0.375	0.375				
	High risk of injury	-0.875	2	-2	1.25				

	Complex task	-0.375	0.75	-1.125	1.25				
	High number of sub task within 1 task	-1	1.125	-0.375	1.375	-0.625	1.09375	-0.78125	1.0625
Availability of needed resources	Inability to retain skilled men	-1.625	2.5	-2.25	2.25				
	poor material and tool storage	-1.875	2.125	-1.375	2.125				
	Complex equipment	-0.75	1.875	-0.5	1.625				
	lack of familiarity with tools	-2.125	2.5	-1.75	2.125				
	Tools not readily available	-1.125	1.625	-1.75	1.875				
	Poor quality of tools and equipment	-2.125	2	-2.125	2.125				
	poor quality of pre fabs	-1.75	1.25	-2.375	1.5				
	Poor quality of material	-1.625	1.5	-2.5	2.25	-1.625	1.921875	-1.82813	1.984375
Value of all tasks	High cost of project	0.875	-0.25	1	-0.125				

	Quality of work demanded	0.625	-0.75	1.75	-1.375				
						0.75	-0.5	1.375	-0.75
Time to complete all task	project schedule	-1	0.875	-2.25	1.25				
	daily work hours	-1.25	2	-1	1.75				
	working weekends	-1.25	1.25	-1	1.125				
						-1.16667	1.375	-1.41667	1.375
Pace	Productivity	0.25	0.125	0.75	0.75				
	Pace of work	-0.75	0.75	-0.625	0.625				
						-0.25	0.4375	0.0625	0.6875
Crowding	Congested Site	-1.5	2.125	-0.875	1.5				
	Manyn different crews	-1.375	1.75	-0.5	1.5				
	Many sub contractors	-0.875	1.125	-0.5	0.625				
	Many different task/activity	-1.25	1	-1	0.625				
	Paperwork	0.25	0.125	-0.5	0.75				
						0	1.225	-0.675	1
Interruptions	unavailable construction drawing	-0.625	1	-2.125	2.25				

						Range Safety Nve	Range Safety Pve	Range Quality Nve	Range Quality Pve
	inexperienced crew	-2.5	2.75	-1.875	2.375				
	Low quality of information	-1.625	1.625	-2	1.875				
	High number of overlapping crew work activities	-1.375	1.625	-1.125	1				
	Interruptions	-1.125	1.375	-1.5	1.875				
	RFI response	-0.375	0.5	-2	2				
						-1.27083	1.479167	-1.77083	1.895833
Switching	switching btwn task	-1.125	1.125	-1.375	1.25				
	Given new task regularly	-0.625	1.125	-0.75	1.25				
						-0.875	1.125	-1.0625	1.25

7.7.5. Appendix F5- Project Manager

	Component	SAFETY		Quality		Range			
		Nve Impact	Pve Impact	Nve Impact	Pve Impact	Safety		Quality	
Uniqueness	Work is Unique	1	0	1.75	-0.25	1	0	1.75	-0.25
Predictability	Task predictability	-0.75	0.75	-0.25	0.25	-0.75	0.75	-0.25	0.25
Repetitiveness	Task is Highly repetitive	-0.25	0.25	0.75	0.25				

	Task is long and continuous	0	0.5	0.75	0.75	-0.125	0.375	0.75	0.5
Complexity	Large Project	0.5	0.25	0	0.25				
	High risk of injury	0	1.5	0.75	0.5				
	Complex task	0.75	0	-1	-0.25				
	High number of sub task within 1 task	0	0.25	0	0	0.3125	0.5	-0.0625	0.125
Availability of needed resources	Inability to retain skilled men	-2	1.5	-2.25	2.25				
	poor material and tool storage	-1.25	1.5	-1.5	1.5				
	Complex equipment	1	1.5	1.75	1.25				
	lack of familiarity with tools	-1.75	2	-1.25	1.25				
	Tools not readily available	-0.5	1	-1.25	1.5				
	Poor quality of tools and equipment	-1.25	1.25	-1.5	2				
	poor quality of pre fabs	-0.75	1	-1.75	2.25				
	Poor quality of material	-1	1	-2.25	2.25	-0.9375	1.34375	-1.25	1.78125
Crowding	Congested Site	-1	1.25	-0.75	1				

	Manyn different crews	-1	0.5	-0.25	-0.25						
	Many sub contractors	-0.5	0.75	-0.25	0.25						
	Many different task/activity	-0.25	0.5	-0.75	0						
	Paperwork	0	0	-0.5	0.5						
							0	0.6		-0.5	0.3
Interruptions	unavailable construction drawing	0	0.25	-1.75	1.25						
	inexperienced crew	-1.75	2.5	-2	2						
	Low quality of information	-0.25	1	-1	1.5						
	High number of overlapping crew work activities	-0.25	0.25	-0.75	0.25						
	Interruptions	-1.25	1	-1	1						
	RFI response	0	0	-1.25	1.5						
							-0.58333	0.833333		-1.29167	1.25
Switching	switching btwn task	-1	0.75	-0.5	0.75						
	Given new task regularly	-0.75	0.75	-0.25	0.25						
							-0.875	0.75		-0.375	0.5

7.7.6. Appendix F6- Safety Professional

		SAFETY	Quality	**Range**

	Component	Nve Impact	Pve Impact	Nve Impact	Pve Impact
Uniqueness	Work is Unique	-0.3	0.9	-0.3	1.2
Predictability	Task predictability	-1.4	1.9	-1.4	1.8
Repetitiveness	Task is Highly repetitive	-0.6	0.8	0.4	0.4
	Task is long and continuous	-1.2	1.1	0.1	1
Complexity	Large Project	0.1	0.3	0.2	0.9
	High risk of injury	-0.5	1.8	-1.2	1.4
	Complex task	-0.5	0.9	-1.2	1
	High number of sub task within 1 task	-0.6	1.1	-0.7	1.3
Availability of needed resources	Inability to retain skilled men	-1.9	2.1	-2.1	2.2
	poor material and tool storage	-1.6	1.8	-1.2	2
	Complex equipment	-0.2	1.4	-0.3	1.5
	lack of familiarity with tools	-1.7	2	-1.3	2
	Tools not readily available	-1.4	1.8	-1.2	2

Safety			Quality	
-0.3	0.9		-0.3	1.2
-1.4	1.9		-1.4	1.8
-0.9	0.95		0.25	0.7
-0.375	1.025		-0.725	1.15

	Poor quality of tools and equipment	-1.3	1.7	-1.6	1.8				
	poor quality of pre fabs	-1.1	1.9	-1.8	2.222222				
	Poor quality of material	-1	1.3	-2	1.9				
						-1.275	1.75	-1.4375	1.952778
Crowding	Congested Site	-2.1	2.2	-1.5	1.8				
	Manyn different crews	-1.6	1.8	-1.3	1.3				
	Many sub contractors	-1.2	0.9	-1	0.8				
	Many different task/activity	-0.9	0.9	-0.9	0.888889				
	Paperwork	0.3	0.3	0	0.9				
						0	1.22	-0.94	1.137778
Interruptions	unavailable construction drawing	-0.8	1	-1.1	1.7				
	inexperienced crew	-2	1.8	-2	1.9				
	Low quality of information	-1.6	1.7	-1.6	1.6				
	High number of overlapping crew work activities	-1.4	1	-1.22222	1.2				
	Interruptions	-1.4	1.5	-1.3	1.7				
	RFI response	-0.4	0.7	-1.4	1.9				
						-1.26667	1.283333	-1.43704	1.666667
Switching	switching btwn task	-1.2	1.2	-1	1.5				

	Given new task regularly	-1	1.4	-0.8	1.2		-1.1	1.3		-0.9	1.35

Appendix F7- Owner's Representative

	Component	SAFETY		Quality		Range				
		Nve Impact	Pve Impact	Nve Impact	Pve Impact	Safety			Quality	
Uniqueness	Work is Unique	-0.17	0.00	0.67	0.33	-0.17	0.00		0.67	0.33
Predictability	Task predictability	-1.17	1.00	-1.83	1.67	-1.17	1.00		-1.83	1.67
Repetitiveness	Task is Highly repetitive	-0.33	0.17	1.33	-0.17					
	Task is long and continuous	-0.80	0.67	0.17	1.17	-0.57	0.42		0.75	0.50
Complexity	Large Project	0.67	-0.17	0.67	0.33					
	High risk of injury	-1.00	0.67	-1.00	0.67					
	Complex task	-0.17	-0.50	-1.00	0.17					
	High number of sub task within 1 task	-0.67	0.33	-0.50	1.17	-0.29	0.08		-0.46	0.58
Availability of needed resources	Inability to retain skilled men	-1.33	1.67	-1.67	2.00					

	poor material and tool storage	-1.50	1.33	-1.17	1.67						
	Complex equipment	-0.33	1.00	0.67	1.17						
	lack of familiarity with tools	-1.83	1.33	-1.33	1.83						
	Tools not readily available	-1.17	1.33	-1.33	1.67						
	Poor quality of tools and equipment	-1.83	1.67	-1.67	1.83						
	poor quality of pre fabs	-0.83	1.33	-1.33	1.83						
	Poor quality of material	-1.00	1.33	-1.67	1.83						
							-1.23	1.38		-1.19	1.73
Crowding	Congested Site	-1.50	1.17	-0.83	1.00						
	Manyn different crews	-0.67	0.67	-0.17	1.17						
	Many sub contractors	-0.50	0.50	-0.67	-0.17						
	Many different task/activity	-1.33	0.83	-1.33	0.83						
	Paperwork	-0.33	0.67	-0.50	0.83						
							0.00	0.77		-0.70	0.73
Interruptions	unavailable construction drawing	-0.33	0.83	-2.33	2.00						
	inexperienced crew	-1.33	1.17	-1.17	1.50						
	Low quality of information	-0.83	0.67	-1.50	1.33						
	High number of overlapping crew work activities	-1.00	1.00	-1.33	1.17						
	Interruptions	-1.17	0.83	-2.00	1.83						
	RFI response	0.00	0.83	-1.50	2.17						
							-0.78	0.89		-1.64	1.67
Switching	switching btwn task	-1.00	0.83	-1.67	1.33						
	Given new task regularly	-0.83	0.83	-1.00	1.00						
							-0.92	0.83		-1.33	1.17

7.8.

7.9. Appendix G- Welch Test ANOVA

7.9.1. Appendix G1- Fieldworker vs Groups- Safety

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Foreman	Between Groups	26.709	28	.954	3.443	.001
	Within Groups	7.757	28	.277		
	Total	34.466	56			
Superintendent	Between Groups	33.487	28	1.196	5.087	.000
	Within Groups	6.582	28	.235		
	Total	40.069	56			
Project Engineer	Between Groups	30.798	28	1.100	5.257	.000
	Within Groups	5.859	28	.209		
	Total	36.657	56			
Project Manger	Between Groups	28.519	28	1.019	2.359	.013
	Within Groups	12.089	28	.432		
	Total	40.607	56			
Owner's Rep	Between Groups	19.226	28	.687	4.332	.000
	Within Groups	4.438	28	.159		
	Total	23.664	56			
Safety Professional	Between Groups	27.577	28	.985	4.025	.000
	Within Groups	6.852	28	.245		
	Total	34.429	56			

7.9.2. Appendix G2- Foreman vs Groups- Safety

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Project Engineer	Between Groups	30.346	24	1.264	6.411	.000
	Within Groups	6.311	32	.197		
	Total	36.657	56			
Project Manger	Between Groups	33.050	24	1.377	5.831	.000
	Within Groups	7.558	32	.236		
	Total	40.607	56			
Owner's Rep	Between Groups	19.780	24	.824	6.791	.000
	Within Groups	3.884	32	.121		

	Total	23.664	56			
Safety Professional	Between Groups	30.134	24	1.256	9.355	.000
	Within Groups	4.295	32	.134		
	Total	34.429	56			
Field Worker	Between Groups	22.606	24	.942	5.046	.000
	Within Groups	5.974	32	.187		
	Total	28.579	56			
Superintendent	Between Groups	34.770	24	1.449	8.749	.000
	Within Groups	5.299	32	.166		
	Total	40.069	56			

7.9.3. Appendix G3- Superintendent Vs Groups- Safety

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Foreman	Between Groups	26.752	22	1.216	5.359	.000
	Within Groups	7.714	34	.227		
	Total	34.466	56			
Project Engineer	Between Groups	27.494	22	1.250	4.637	.000
	Within Groups	9.163	34	.269		
	Total	36.657	56			
Project Manger	Between Groups	28.135	22	1.279	3.486	.001
	Within Groups	12.472	34	.367		
	Total	40.607	56			
Owner's Rep	Between Groups	17.691	22	.804	4.578	.000
	Within Groups	5.972	34	.176		
	Total	23.664	56			
Safety Professional	Between Groups	25.604	22	1.164	4.484	.000
	Within Groups	8.825	34	.260		
	Total	34.429	56			
Field Worker	Between Groups	22.732	22	1.033	6.008	.000
	Within Groups	5.847	34	.172		
	Total	28.579	56			

7.9.4. Appendix G4- Project Engineer vs Groups- Safety

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Project Manger	Between Groups	27.555	23	1.198	3.029	.002
	Within Groups	13.052	33	.396		
	Total	40.607	56			
Owner's Rep	Between Groups	18.223	23	.792	4.805	.000
	Within Groups	5.441	33	.165		
	Total	23.664	56			
Safety Professional	Between Groups	27.598	23	1.200	5.797	.000
	Within Groups	6.831	33	.207		
	Total	34.429	56			
Field Worker	Between Groups	23.475	23	1.021	6.599	.000
	Within Groups	5.104	33	.155		
	Total	28.579	56			
Superintendent	Between Groups	30.234	23	1.315	4.410	.000
	Within Groups	9.835	33	.298		
	Total	40.069	56			
Foreman	Between Groups	29.677	23	1.290	8.890	.000
	Within Groups	4.790	33	.145		
	Total	34.466	56			

7.9.5. Appendix G5- Project Manager vs Groups- Safety

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Owner's Rep	Between Groups	17.472	13	1.344	9.334	.000
	Within Groups	6.192	43	.144		
	Total	23.664	56			
Safety Professional	Between Groups	26.344	13	2.026	10.779	.000
	Within Groups	8.084	43	.188		
	Total	34.429	56			
Field Worker	Between Groups	18.349	13	1.411	5.932	.000
	Within Groups	10.231	43	.238		
	Total	28.579	56			
Superintendent	Between Groups	25.846	13	1.988	6.010	.000
	Within Groups	14.223	43	.331		
	Total	40.069	56			

Foreman	Between Groups	23.715	13	1.824	7.296	.000
	Within Groups	10.752	43	.250		
	Total	34.466	56			
Project Engineer	Between Groups	25.657	13	1.974	7.715	.000
	Within Groups	11.000	43	.256		
	Total	36.657	56			

7.9.6. Appendix G6- Owner's Representative vs Groups- Safety

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Safety Professional	Between Groups	28.772	17	1.692	11.668	.000
	Within Groups	5.657	39	.145		
	Total	34.429	56			
Field Worker	Between Groups	19.863	17	1.168	5.228	.000
	Within Groups	8.716	39	.223		
	Total	28.579	56			
Superintendent	Between Groups	27.622	17	1.625	5.091	.000
	Within Groups	12.447	39	.319		
	Total	40.069	56			
Foreman	Between Groups	25.559	17	1.503	6.583	.000
	Within Groups	8.907	39	.228		
	Total	34.466	56			
Project Engineer	Between Groups	29.843	17	1.755	10.047	.000
	Within Groups	6.814	39	.175		
	Total	36.657	56			
Project Manger	Between Groups	24.657	17	1.450	3.546	.001
	Within Groups	15.951	39	.409		
	Total	40.607	56			

7.9.7. Appendix G7- Safety Professional vs Groups- Safety

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Field Worker	Between Groups	21.817	29	.752	3.004	.003
	Within Groups	6.763	27	.250		
	Total	28.579	56			

Foreman	Between Groups	27.549	29	.950	3.708	.000
	Within Groups	6.917	27	.256		
	Total	34.466	56			
Superintendent	Between Groups	31.484	29	1.086	3.414	.001
	Within Groups	8.585	27	.318		
	Total	40.069	56			
Project Engineer	Between Groups	31.622	29	1.090	5.848	.000
	Within Groups	5.035	27	.186		
	Total	36.657	56			
Project Manger	Between Groups	33.820	29	1.166	4.639	.000
	Within Groups	6.787	27	.251		
	Total	40.607	56			
Owner's Rep	Between Groups	21.145	29	.729	7.817	.000
	Within Groups	2.519	27	.093		
	Total	23.664	56			

Quality

7.9.8. Appendix G8- Fieldworker vs Groups- Quality

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Foreman	Between Groups	44.960	28	1.606	6.675	.000
	Within Groups	6.736	28	.241		
	Total	51.696	56			
Superintendent	Between Groups	36.601	28	1.307	4.716	.000
	Within Groups	7.762	28	.277		
	Total	44.362	56			
Project Engineer	Between Groups	43.042	28	1.537	5.235	.000
	Within Groups	8.221	28	.294		
	Total	51.264	56			
Project Manager	Between Groups	43.683	28	1.560	3.278	.001
	Within Groups	13.326	28	.476		
	Total	57.009	56			
Owner Rep	Between Groups	44.126	28	1.576	4.306	.000

	Within Groups	10.248	28	.366		
	Total	54.374	56			
Safety Professional	Between Groups	26.156	28	.934	3.812	.000
	Within Groups	6.862	28	.245		
	Total	33.018	56			

7.9.9. Appendix G9- Foreman vs Groups- Quality

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Superintendent	Between Groups	34.049	25	1.362	4.094	.000
	Within Groups	10.313	31	.333		
	Total	44.362	56			
Project Engineer	Between Groups	42.098	25	1.684	5.695	.000
	Within Groups	9.166	31	.296		
	Total	51.264	56			
Project Manager	Between Groups	46.809	25	1.872	5.690	.000
	Within Groups	10.200	31	.329		
	Total	57.009	56			
Owner Rep	Between Groups	44.467	25	1.779	5.566	.000
	Within Groups	9.907	31	.320		
	Total	54.374	56			
Safety Professional	Between Groups	27.449	25	1.098	6.112	.000
	Within Groups	5.569	31	.180		
	Total	33.018	56			
Fieldworker	Between Groups	24.836	25	.993	4.097	.000
	Within Groups	7.517	31	.242		
	Total	32.354	56			

7.9.10. Appendix G10- Superintendent vs Groups- Quality

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Project Engineer	Between Groups	42.078	26	1.618	5.285	.000
	Within Groups	9.186	30	.306		
	Total	51.264	56			
Project Manager	Between Groups	45.513	26	1.750	4.568	.000

	Within Groups	11.496	30	.383		
	Total	57.009	56			
Owner Rep	Between Groups	42.377	26	1.630	4.076	.000
	Within Groups	11.997	30	.400		
	Total	54.374	56			
Safety Professional	Between Groups	28.020	26	1.078	6.469	.000
	Within Groups	4.998	30	.167		
	Total	33.018	56			
Fieldworker	Between Groups	27.689	26	1.065	6.849	.000
	Within Groups	4.665	30	.155		
	Total	32.354	56			
Foreman	Between Groups	43.902	26	1.689	6.500	.000
	Within Groups	7.794	30	.260		
	Total	51.696	56			

7.9.11. Appendix G11- Project Engineer vs Groups- Quality

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Project Manager	Between Groups	45.811	24	1.909	5.455	.000
	Within Groups	11.198	32	.350		
	Total	57.009	56			
Owner Rep	Between Groups	49.360	24	2.057	13.127	.000
	Within Groups	5.013	32	.157		
	Total	54.374	56			
Safety Professional	Between Groups	27.006	24	1.125	5.990	.000
	Within Groups	6.012	32	.188		
	Total	33.018	56			
Fieldworker	Between Groups	26.870	24	1.120	6.533	.000
	Within Groups	5.484	32	.171		
	Total	32.354	56			
Foreman	Between Groups	43.892	24	1.829	7.499	.000
	Within Groups	7.804	32	.244		
	Total	51.696	56			
Superintendent	Between Groups	34.693	24	1.446	4.784	.000
	Within Groups	9.669	32	.302		
	Total	44.362	56			

7.9.12. Appendix G12- Project Manager vs Groups- Quality

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Owner Rep	Between Groups	43.946	13	3.380	13.940	.000
	Within Groups	10.427	43	.242		
	Total	54.374	56			
Safety Professional	Between Groups	25.280	13	1.945	10.806	.000
	Within Groups	7.738	43	.180		
	Total	33.018	56			
Field worker	Between Groups	22.500	13	1.731	7.552	.000
	Within Groups	9.854	43	.229		
	Total	32.354	56			
Foreman	Between Groups	40.224	13	3.094	11.597	.000
	Within Groups	11.472	43	.267		
	Total	51.696	56			
Superintendent	Between Groups	33.531	13	2.579	10.240	.000
	Within Groups	10.831	43	.252		
	Total	44.362	56			
Project Engineer	Between Groups	41.576	13	3.198	14.195	.000
	Within Groups	9.688	43	.225		
	Total	51.264	56			

7.9.13. Appendix G13- Owner's Representative vs Groups- Quality

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Safety Professional	Between Groups	26.944	20	1.347	7.984	.000
	Within Groups	6.074	36	.169		
	Total	33.018	56			
Fieldworker	Between Groups	22.803	20	1.140	4.297	.000
	Within Groups	9.551	36	.265		
	Total	32.354	56			
Foreman	Between Groups	41.014	20	2.051	6.911	.000
	Within Groups	10.682	36	.297		
	Total	51.696	56			

Superintendent	Between Groups	29.369	20	1.468	3.526	.000
	Within Groups	14.993	36	.416		
	Total	44.362	56			
Project Engineer	Between Groups	45.163	20	2.258	13.326	.000
	Within Groups	6.100	36	.169		
	Total	51.264	56			
Project Manager	Between Groups	45.485	20	2.274	7.105	.000
	Within Groups	11.524	36	.320		
	Total	57.009	56			

7.9.14. Appendix G14- Safety Professional vs Groups- Quality

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fieldworker	Between Groups	26.259	26	1.010	4.972	.000
	Within Groups	6.094	30	.203		
	Total	32.354	56			
Foreman	Between Groups	46.272	26	1.780	9.844	.000
	Within Groups	5.424	30	.181		
	Total	51.696	56			
Superintendent	Between Groups	36.233	26	1.394	5.143	.000
	Within Groups	8.129	30	.271		
	Total	44.362	56			
Project Engineer	Between Groups	42.755	26	1.644	5.798	.000
	Within Groups	8.509	30	.284		
	Total	51.264	56			
Project Manager	Between Groups	45.408	26	1.746	4.517	.000
	Within Groups	11.600	30	.387		
	Total	57.009	56			
Owner Rep	Between Groups	46.340	26	1.782	6.656	.000
	Within Groups	8.034	30	.268		
	Total	54.374	56			