Qualitative Analysis of Lost Labor Productivity in Electrical Construction from the Perspective of Field Personnel

by

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Executive Summary

The stagnant production practices, the decline in experienced workers, and the steep economical labor cost has challenged the construction industry to improve labor production practices. This research study investigates the impact and the influence of labor performance through the perception of electrical construction workers. Electrical construction workers are present throughout the construction phases and acquire substantial understanding, insight, and intuition on factors that impact labor productivity. These electrical construction workers are typically the first on-site: pulling conduit, installing circuit breakers, operating heavy equipment, and ultimately executing the project design. Nonetheless, their expertise and intelligence is unfortunately seldom discussed among academics and industry personnel, thus by considering it this research will convey a more precise understanding of the impact of labor productivity on the construction industry.

This research study is influenced by a previous research study conducted by the Construction Industry Institute (CII), which examined the influence of factors that impede worker labor production of numerous trades. However, this research looks to study the factors that influence labor productivity exclusively for electrical workers.

There are various factors that adversely influence electrical workers’ performances. One being the Electrical construction trade is exceptionally labor-intensive and accounts for nearly 70% of construction project costs. To improve project cost and efficiency, the electrical construction industry continues to aspire for innovative and new methods that impact the industry while developing a more productive workforce.

Technological innovations such as AutoCAD, Building Information Modeling (BIM), Solids Works, and Primavera have significantly influenced the electrical construction industry through advancements in construction methods, designs, planning, and implementation of project scope. However, the industry still faces several challenging factors that impede production including inadequate engineering design, work scheduling, and resource management. These challenges obstruct electrical workers’ labor performance. The wealth of knowledge that electrical workers possess enables this research study to examine which factors have the most significant impact to workers’ performance. The data that is collected can assist owners and contractors in enhancing their knowledge regarding factors that impact worker performance.

To further enhance the research study, electrical workers were surveyed to acquire their perception of factors that impede their labor production. From the 182 workers responded out of the 3000 electrical workers that were emailed in the United States and Canada. This accounted for a response rate of 6.07%. These electrical workers varied in experience, job position, perception of factors that influence labor productivity. The compiled data was examined to determine trends and correlations. Furthermore, the findings from the analyzed data enabled an improved awareness of labor production of electrical construction workers.

Considering the perception of electrical workers allowed this research study to gain significant knowledge on factors that hinder the appropriate labor production of workers. Knowing the factors that impact construction labor production, owners and contractors can better
manage their construction workers. Consequently, this reduces rework, design-plan errors, and omissions, and essentially enables a more productive project work schedule. Additional efforts are recommended to improve company culture, working conditions, and adequate communication amongst project team members. Continuous improvements of labor production practices are essential in the systematic growth of the electrical construction industry.
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Chapter 1 Introduction

1.1 Introduction

The stagnant growth of the construction industry can be associated with the challenges with labor production in both the United States and Canada. In the U.S., construction labor productivity has been progressively declining over the past half century. As shown in Figure 1 the U.S. Department of Labor, while non-farm labor productivity has increased at an average rate of 1.6 percent annually since 1964, construction labor productivity has decreased on average of 0.05 percent annually (Teicholz, Goodrum, and Hass 2001 and 2004). However, the Canadian sector has faced different concerns. According to Statistics Canada, construction productivity in Canada has been improving marginally at a rate of 1.3 percent while the business sector has improved at a rate 2.5 times of 3.28 percent annually. This rate is 2.5 times higher than productivity improvement in the Canadian construction industry.

There are numerous reported reasons for inadequate productivity performance among the construction sector in both the U.S and Canada, such as unavailability of experienced workers, decrease in worker’s morale, and inefficiencies resulting from inadequate working conditions (Gundecha, 2012). The experience of construction workers and their awareness of labor productivity practices within the construction industry enables them to be knowledgeable of inadequate labor practices, which is the fundamental principle of this research.
Figure 1: Productivity Index for Construction and All Non-Farm Manufacturing Industries (Teicholz, Goodrum, and Hass 2001 and 2004)

1.2 Problem Statement

The electrical contracting trade is one of the most critical and labor-intensive trades among the construction sector, which is frequently delayed by other construction trades due to incomplete prerequisite work. These delays ultimately result in inefficiencies and decreased labor productivity. The adverse working conditions and severity of electrical trade significantly impacts the construction industry. This research examines the compelling perception of the electrical workforce’s awareness of inadequate labor production practices.

Construction workers play a vital role in achieving adequate labor practices that essentially progress the development of the project. Without the strong support of the workforce, the construction sector would falter. Inconsistencies in workers’ performances may obstruct the production of other workers and other trades. These trades are influenced by factors that affect workers’ productivity and their work environment, which is crucial to improving industry practices. There has been limited research investigating labor productivity at the worker’s level,
more specifically for the electrical construction industry. To gain a better understanding of the worker’s ability to work efficiently, this research study focuses on filling the gap in construction literature by evaluating the perception of electrical workers with a comprehensive set of factors.

These factors are comprised of core issues that affect labor productivity among electrical workers. To acquire the electrical workers’ knowledge of the factors that impact their labor production practices, an elaborate survey questionnaire was formulated. This was utilized to quantify the workers’ perception of labor production in the construction industry. Furthermore, the findings of this research study will increase the awareness, efficiency, and render suitable recommendations to the electrical construction industry.

1.3 Research Motivation

The ineptitudes and decline in labor production have been occurring erratically throughout the construction industry. The construction industry has faced considerable challenges that impede labor production and profoundly impact the employment of construction workers in the U.S. and Canada. The systematic and adverse impact on the construction workforce can mainly be attributed to the decline in adequate experienced construction workers. Labor production can be calculated as input (work hours) divided by output (completed work) or vice-versa (Hanna 1999). Labor production of the industry’s workforce consumes 40 to 70 percent of a construction project’s overall cost, and is an essential component to analyze to improve construction practices (Figure 3).

The perpetual demand for qualified and experienced construction workers has steadily increased from 1992 to 2005. It peaked in April of 2006 with demand for 7.8 million construction workers (Simonson 2016). Many researchers attribute the rise in demand to new innovations in
computer-aided software and delivery methods. The development of Building Information Modeling (BIM) has enabled construction workers to have a visual representation of what they’re constructing and improves construction quality, time, and cost (Gerber et al. 2010). BIM, along with additional innovations in construction project contracts and delivery systems, such as Design-Bid (DB), Design Bid Build (DBB), Integrated Project Delivery (IPD) have enabled significant advancement in construction industry practices in terms of scheduling, planning, and design.

Figure 2: Construction Labor Cost (AlixPartners 2016)

The rise of construction worker availability between 1992 and 2006 was substantial, as the thriving construction industry enabled significant infrastructural growth. However, from 2007 to 2012, the construction industry suffered devastating losses in economic revenue and qualified construction workforce. The staggering construction decline of 2007-2008 can be attributed to The Great Recession, causing significant economic hardship to construction companies and construction workers. The economy forced construction companies to downsize, and they were unable to retain adequate number of construction workers. The impact of the Great Recession was responsible for a 29% annual decline in the construction workforce, and by 2012 only a mere 5.5 million construction workers remained (Davidson 2012).

To further validate the motivation of this research, recent data from the Bureau of Labor
Statistics showed the monthly employment change from January 2012 through December 2016 with seasonal adjusted rates in thousands. It was revealed that some months displayed negative rates of employment that can be attributed to deficiencies in construction practices and inadequate administrative management. A contributing factor that influenced the employment rate of the construction industry from 2012 through 2016 (Figure 4) was the prominent inflation of the U.S. economy. The construction industry found itself competing in sectors in which they once were ranked highly in annual revenue, and labor production. This enabled owner the opportunity to continue to invest and take on new projects.

![Construction Industry Employment (BLS January 2014-January 2017)](image)

**Figure 3: Construction Industry Employment (BLS January 2014-January 2017)**

The impressive growth of the construction industry could not have occurred without the individuals that labor to sustain the industries advancements. Construction workers hardly receive the appropriate recognition they deserve for the painstaking hours of work they perform. The motivation to investigate the perception of electrical construction workers within this industry originates from the commitment these workers have for their trade. Additionally, being able to transcribe their personal intuition into a platform that the construction industry may utilize to correct labor performance practices are ideal to improving labor productivity.

In general, productivity decline can be attributed to factors occurring at three different
levels: the industry level, the company level (contractors), and the workforce level. In terms of industry-related factors, many researchers related the use of traditional project delivery systems to inefficient labor productivity because of the fragmented nature of the delivery systems (Fernane 2011). Recent research shows improved productivity with the usage of innovation in delivery systems such as IPS and DB (Asmar, Hanna, and Loh 2013).

At the company level, several researchers have cited inadequate management practices as the main cause of labor inefficiency (Caldas 2015). Inadequate management practices include poor and informal preconstruction planning, lack of benchmarking for key productivity indicators, and insufficient training of project managers. These occur in several competency areas such as leadership skills and communication between office operations and field personnel.

At the construction workers’ level, high percentages of absenteeism and turnover was shown to cause a significant decline in labor productivity (Hanna, Menches, Sullivan, and Lackney 2005). Environmental factors such as erratic temperatures, strong wind, and rain, or snow increases fatigue and creates difficult working conditions, thus reducing labor productivity. In addition, poor safety practices were cited as a main cause of declining labor productivity.

Many researchers have concluded that the construction industry is significantly influenced by complications in the construction schedule. Two nearly identical projects may progress differently due to inadequate construction design and planning. Furthermore, the construction industry’s labor production continues to decline due to inadequate front-end planning and scheduling at the preliminary phase of design (Sarde 2016). Delays that stem from construction scheduling complication significantly contribute to the decline in construction worker labor performance. Many researchers site schedule compression and acceleration as one of the key causes of labor inefficiency. Labor acceleration techniques include overtime, overmanning, and
the use of a second shift to accelerate project baseline (Hanna, Chang, Sullivan, and Lackney 2005). Researchers identified a strong correlation between the loss of labor efficiency and the extensive use of overtime (Hanna et. al. 2005), increasing hours worked weekly as well as the amount of allotted overtime. An additional research study examined schedule compression practices and found that over-time, overmanning, and increase in crew size has an adverse influence on construction workers’ labor productivity (Chang, Hanna, Lackney, and Sullivan 2007). A correlation between loss of productivity and the use of second shift was also proven, however, it was found that productivity loss under the second shift scheduling technique was less than that of overtime and overmanning (Hanna et al. 2005).

1.4 Research Objectives

This research study displays a methodical evaluation of the perception of electrical workers on labor productivity practices in the construction industry. The objectives of this research are to:

1 Survey and quantify the perception of electrical workers in the construction industry to better study how inadequate engineering practices alter electrical worker labor production, how frequent electrical workers are delayed due to inadequate acquisition of resources, and how project managerial personnel may influence labor production.

2 Analyze the influence of inadequate labor production on electrical workers, and investigate the impact of labor production on cost, schedule, safety, and quality of constructional development.

3 To evaluate and correlate the significance in agreement amongst electrical worker job positions regarding performance factors that affect labor productivity.
4 Recommend appropriate labor production practices for the electrical construction industry:

Generate a comprehensive selection of adequate labor production practices for the industry.

1.5 Methodology

1.5.1 Literature review

The initial phase of this research was to consider previous literatures pertaining to labor production in the construction industry especially, as it relates to electrical workers. Previous literature was reviewed to understand the parameters in which labor production practices have been investigated and to correlate literature to formulate preliminary research focal points. The majority of the literature review includes construction labor practice concerns such as project scheduling, adequate engineering design, and proper allocation of resources which includes tools, information, materials and environment. Previous literature associated with labor productivity mainly focused on determining the essential factors affecting labor productivity at the project level but fell short in addressing the factors that impact labor productivity at the worker’s level. The full literature review can be found in Chapter 2.

1.5.2 Development of Survey Questionnaire

To further validate the intent of this paper as well as past literature, an intricate survey questionnaire was developed to inquire the perception of electrical workers and their awareness of labor productivity inefficacies. This paper was influenced by previous research executed through the Construction Industry Institute (CII) Research Team in (2006). However, the CII study focused on several construction trades, while this paper references specifically the electrical contracting trade. The development of the survey questionnaire was influenced by
academics and industry personnel. They assisted in developing sophisticated survey questions that enabled for a more thorough understanding of the knowledge that electrical workers possess regarding labor productivity practices. Data was collected from various types of personnel; mainly field-level electrical workers as well as working and non-working foremen. The survey questionnaire was distributed electronically and manually to electrical workers in both the U.S. and Canada. Qualtrics, an electronic data collection software company used throughout the academia for scientific and technical surveys was used to distribute the survey.

The survey questionnaire progressed with the service of the University of Wisconsin-Madison Survey Center (UWMSC). They assisted with framing proper structure and development of the survey questionnaire to ensure the most reliable data response for analysis. In addition, the UWMSC rendered substantial assistance on how to condense the survey so that the questions are comprehensible and not repetitive. A preliminary draft of the survey was administered to 48 electrical workers. It functioned as a pilot survey test used to refine the survey and make appropriate alteration to the content and delivery objective of the survey questionnaire. The preliminary survey results indicated that electrical workers have an immense wealth of knowledge pertaining to labor practice ineptitudes within the construction industry. In addition, the preliminary survey could acquire knowledge that confirmed the integrity of the survey. This allowed for limited variations to the survey questionnaire post-pilot test.

1.5.3 Distribution of Survey Questionnaire

The research goal advanced through the pilot test, after which the survey questionnaire was distributed to more than 3000 electrical workers from various states and providences in U.S and Canada. A cover letter accompanied the survey questionnaire, serving to provide knowledge
and information pertaining to the survey and the purpose of the research. Workers were asked to complete the survey questionnaire with information from their current construction project. This was done to increase accuracy and validation of the responses.

To acquire a large number of responses, the survey was distributed to workers from various electrical organizations and associations including, the National Electrical Contractors Association (NECA), the Saskatoon Construction Association (SCA), the Electrical Contractor Association of British Columbia (ECA-BC), and the Winnipeg Construction Association (WCA). Of the 3000 survey questionnaires, 182 electrical workers were able to complete or partially complete the survey. Of the partially completed responses, the average was calculated utilizing the 5-Point Likert Scale. The average was then used in place of the absence of responses.

1.6 Scope of Research

This research study identified three limitations that formulated the scope of the intended research. The initial scope of this research was to gain insight into electrical workers’ awareness of inadequate labor production practices within the electrical construction industry. Secondly, the data was limited by not inquiring information regarding the construction projects and contractual delivery methods but rather the survey focused on engineering design practices that impede labor production. Lastly, the study exclusively examines the electrical construction workforce rather than project managerial personnel. Electrical workers are tasked with performing painstaking work and are in a principal position to observe labor production practices, thus, adding value to the research scope.
1.7 Summary and Report Organization

Emerging innovations and technologies have allowed for the construction industry to evolve over past decades. The construction industry has drastically improved in past years, but construction productivity is still facing difficult challenges. The influence of labor performance is pertinent to understand; it enables conducive awareness of construction labor inefficiency that may halt the advancement of the construction industry.

This research study is intended to acquire the awareness of the electrical workers’ knowledge regarding labor production practices. Chapter 2 will review literatures relating to previous research published on construction labor production. Chapter 3 will quantify the demographics of the surveyed electrical workers, while Chapter 4 will illustrate and analyze statistical methodologies, correlations, and trends found through the development of the research. Chapter 5 will detail recommendations for industry personnel, and Chapter 6 will offer conclusion to the findings of this research study. Finally, the Appendices will be attached to further validate the research findings.
Chapter 2 Literature Review

2.1 Introduction

In order to validate the purpose of this research study, a comprehensive review of previous research was performed. Preceding research identified several factors that impact construction labor methods and practices. These factors include adequate scheduling, proper allocation of resources, appropriate engineering planning and design and adequate communication between project managerial personnel and construction workers. Consequently, these factors influence worker’s daily production on construction projects and are identified to adequately improve construction labor performance. To fully comprehend worker’s performance throughout the progression of the construction project, worker’s perception must be analyzed to cumulate a profound understand of labor productivity. Additionally, the findings of previous literature correspond to the findings of this research study.

2.2 Developmental History of Labor Productivity

Over the past half century, the construction industry has weathered variation to construction practices, methods, and emblematic propensities to which construction companies have grown accustomed. The construction industry has drastically developed overtime; however, it still adheres to the fundamental principles of engineering design and construction. The construction of one of the world’s most astonishing structures, the Leaning Tower of Pisa of Italy, began in 1173. The peculiar soil conditions of the building were unable to sufficiently support the weight of the building, causing the structure to lean. Remarkably, over the 300 years of construction, workers intensely labored to erect the unique structure (Harris 2011). Since the construction of the Leaning Tower of Pisa labor production has considerably progressed. New
innovations in construction practices and methods (in terms of prefabrication and technological advancement) has enabled a development in labor production while maintaining the core principles that govern historical constructions.

2.3 Factors Impacting Electrical Construction Labor Productivity

As alluded to in the previous section, numerous factors impede the production of electrical construction workers. In order to discern labor production, this section outlines previous literature on factors that influence the fluctuation of electrical construction workers’ labor performance.

2.3.1 Labor Productivity Factors

“Understanding productivity in the construction industry is a complex and elusive task…made more difficult by the very nature of the industry” (Bernstein 2003). The construction industry has been complacent with the standards that have systematically influenced production growth of the industry. Leading construction industry pioneers understand the current position of the industry and are eager to discover new innovations, metrics, and models that can impact labor production. These new innovations may be able to drastically improve labor performance within the electrical construction trade.

Preceding research conducted by (Vereen, Rasdorf, and Hummer 2016) developed an intricate metrics to quantify the progression of labor productivity within the construction industry was formulated. The data was collected through RS Means, a construction building cost database. The database is widely used in the construction industry; contractors, sub-contractors and suppliers employ RS Means to provide precise estimates to their clients. The metric revealed a continuous decline in labor production. Vereen quantified two types of factors that impede labor production
(single and multi-factors). Single labor productivity (SLP) factor indicates an output from one input source, whereas multi-factors productivity (MFP) numerous input sources, such as tools, materials, and information. Vereen verified the decline in production in (Figure 5), which represents the combined inputs, outputs, and MFP from 1990-2010. A significant decline in labor output occurred during the economic recessions of 1990, 2001, and 2007, which left the construction sector in disarray. The industry has continued to endure the reduction in labor performance in both input and output factors of the construction workforce.

![Graph showing multifactor productivity index over time](image)

**Figure 4: Multifactor Productivity Index (Vereen 2016)**

The arduous task of quantifying worker’s labor performance has compelled the construction industry to acquire sufficient labor production measuring metrics. Vereen identified that changes due to a single input factor may directly or indirectly hinder preceding work, causing additional rework. Additionally, the study acknowledged that project modifications because of MFP factors may delay the completion date of the project. Table 1 shows construction production input-output relationship pertinent to time, cost, and unit hourly work. The correlation of input-output is inversely proportional, (that is time/unit is equivalent to unit/time). Labor efficiency measures input (that is 0.1 hr/sf per brick) to output which is the
number of bricks assembled, thus calculating construction worker’s production performance. The industry has developed considerable metrics to quantify labor production, however a standard productivity measuring system has not yet been implemented (Park, Thomas, and Tucker 2005).

Table 1: Labor Productivity Measurement Metrics

<table>
<thead>
<tr>
<th>Input-output relationship</th>
<th>Measure</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input/output</td>
<td>Time/unit</td>
<td>0.1 h/SF (SM) brick</td>
</tr>
<tr>
<td></td>
<td>Cost/unit</td>
<td>$12/SF (SM) brick</td>
</tr>
<tr>
<td>Output/input</td>
<td>Unit/time</td>
<td>10 SF (0.929 SM) of brick/hour</td>
</tr>
<tr>
<td></td>
<td>Unit/cost</td>
<td>10 SF (0.929 SM) of brick/$120</td>
</tr>
</tbody>
</table>

Tsehayae, and Fayek (2014) identified 169 critical factors that impact the labor production of construction workers. These factors were utilized to measure the appropriate labor performance of workers. Data was collected through a comprehensive data-driven model that quantified the labor production of industry personnel. The study participants included Project Managers and Tradesmen such as Foremen and Craft Workers. This was done to quantify and correlate the perception of Project Managers and Tradesmen’s labor methods on a construction project. The model was implemented to investigate labor production of construction workers and rank the factors that hinder their work performance. It was revealed that weather and working conditions were among the highest correlated factors of inconsistent labor production. Table 2 illustrates the evaluation score and evaluation difference of Project Managers and Tradesmen’s perspective on disparate factors that impact their labor production. Calculations of index metrics are as follows:
In examining the responses of the Project Managers and Tradesmen, the agreement-frequency and impact-influence scale value for each respondent statement was calculated and examined to determine their evaluation score. Calibrating the weighted percent ($R_A$) of positively worded agreements was examined along with the positive weighted percent impact ($I_p$) (Tsehayae et al. 2014). The evaluation scores indicated that working conditions and weather conditions were of the most concern for Project Managers. However, Craft Laborer concerns were driven toward the motivation and flexibility of their trade. There are still several lingering concerns Tradesmen have regarding productivity ineptitude in the construction industry. Scheduling factors were still major concern of construction workers, being that schedule may dictate the allocated time workers labor on the construction project.

Table 2: Labor Production Parameters (Data Drive Model)
2.3.2 Scheduling Factors

Construction delays that emanate from scheduling inaccuracies may severely influence the labor performance of electrical workers. Construction front-end planning and scheduling are pivotal in the timely success of a project. Typically, the construction completion date is fixed and any deviation from the construction schedule results in contractors using different methods to accelerate the progression of the project. Using schedule accelerators ultimately adds cost overrun to the project.

Previous studies reported three vital factors that often reduce worker’s labor productivity, which includes excessive use of shift workers, inefficient crew size, and excessive use of overtime (Hanna 2003). Earlier studies have shown shift work to be beneficial when used in moderation. In fact, productivity losses associated with excessive shiftwork use can reach up to 11% of cost overrun (Hanna, Chang, Sullivan, and Lackney 2008). In addition, many studies reported that overmanning and inefficient crew sizes constitute major source dilution of site supervision and site congestions. This ultimately reduces labor productivity and value added work to the project. Figure 6 illustrates cumulative and individual electrical labor practices measured in percent of labor consumed (Horman, Orosz, and Riley 2006). These projects typically peak at two-thirds to three-quarters of the project baseline. Furthermore, a 15% loss of efficiency due to overtime usage was reported by (Hanna, Taylor, and Sullivan 2005). Moreover, (Hanna, Chang, Sullivan, and Lackney 2005) reported 50-60 hours/week work schedule results in lower crew productivity levels as compared to 40-hours work schedule. A U.S. Labor Department study also determined that prolonged work hours result in an increase in absenteeism, thus reducing labor productivity among workers (BRT 1983).
Horman et al (2006) investigated the significance of adequate sequence planning on the electrical construction industry. The data analyzed labor production through the developmental phase of the construction projects (front-end planning, procurement, construction and post construction), but it lacked the appropriate planning for adequate labor performance of the electrical workers. Variations to the initial project plan system were implemented and Horman recorded a resounding 1,176 saved work hours over the 23-week study, which resulted in a 58% performance marginal gain. This was done by improving the reliability of the initial schedule planning system and involving electrical workers in the planning of project activities.

In general, the electrical construction trade involves the performance of work through a systematical sequence that spans from the preliminary phase of construction and concludes at the completion of the project. The majority of electrical work performed occurred in the electrical room that housed generators, switchgear and controls boards. Figure 7 depicts the correlation among project-planning-performance and project-performance-factors measured by percent of planned projects completed, earned and actual performance of project. The project planning performance indicator normalized near the 50% construction completion but thereafter it continued to fluctuate. Additionally, compressed work schedule, stacking of trades, and out-of-sequence
work was also attributed to destitute scheduling practices (Horman et al. 2006).

Sveikauskas, Rowe, Mildenberger, and Proce (2015) revealed through an extensive research study that labor production in the construction sector (including single-family housing, multiple-family housing, highways, and industrial construction) is experiencing meager production growth. Consequently, it was also reported that additional labor shifts reduce labor production growth by 0.4% a year. The Census of Construction (U.S. Census Bureau) provided the study with precise and adequate data regarding construction input and output. However, the current data did not exemplify the integrated construction industry which includes institutional, industrial, and commercial. Subsequently, the concluding interpretation of the findings were inconclusive, thus the current data shows that the construction industry is still experiencing inadequate labor production performance (Pekuri, Haapasalo, Herrala 2011).

Hanna, Chang, Sullivan and Lackney (2008) recognized that implementation of 2nd shift may be beneficial to the completion of the project, but also may be detrimental to the sequence and the development of project activities. The use of 2nd shift is widespread within the construction industry but is difficult to quantify. In quantifying the impact of 2nd shift in the construction industry, Hanna et al. (2008) devised a linear model that correlates the relation between loss of
production and percent shift-work (Figure 8). The models signify that 2\textsuperscript{nd} shift efficiency level typically peaks around the 50\% project completion level. 2\textsuperscript{nd} shift work is often preferred over overtime and overmanning to accelerate project schedule (Hanna et al. 2008). However, additive cost may be accrued due to the utilization of 2\textsuperscript{nd} shift work (e.g. additional managerial personnel, labor cost, and facility management). Figure 9 illustrates factors including influencing factors, controlling factors, input, and output that occur due to loss of production resulting from the utilization of 2\textsuperscript{nd} shift. Among the influencing factors that impact workers labor performance was the availability of equipment that is needed to effectively perform their work. Adequate resources such as tools, materials, equipment, and information are essential in the daily activity of workers.

![Figure 7. Shift Work Impact on Labor Productivity](image-url)
2.3.3 Resources Factors

Workers’ inability to obtain adequate resources (like tools, information, materials, and environment) may significantly hinder the systematic sequence of work. This lack of ability to perform construction activities in appropriate sequence disrupts construction baseline schedule, ultimately causing delays to the construction project. In addition, the unavailability of project resources causes the construction workforce to be idle, resulting in workers’ inability to add value to the progression of the project. Moreover, inquiring and searching for tools and equipment also hinders labor production. Rather than construction workers being engaged in value added engineering, their focus and time will be preoccupied acquiring tools to complete their work. This section investigates previous research pertaining to construction workers’ awareness of proper resource procurement management.

Grau, Caldas, Hass, Goodrum, and Gong (2009) conceded that automation in project site
tracking methods will immensely improve construction project performance of the construction industry. Implementation of Radio Frequency Identification (RFID) and Global Positioning System (GPS) was utilized to identify, locate, and automate various construction components (Grau et al. 2009). RFID technology was used to track components such as tools, materials, and also used to store operational data (Goodrum, Dai, and Maloney 2006). They were also used to quantify the impact of material tracking methods on a $750 million power plant project. This enabled an eight-to-one reduction of labor time spent commuting to the material laydown area (Table 3). Additionally, as denoted in Table 3, the average time spent utilizing the traditional tracking method was 36.80 minutes as opposed to 4.56 minutes which is the average time utilized with the automated tracking method system.

Table 3: Laborer Average Time Spent at Project

<table>
<thead>
<tr>
<th>Activity</th>
<th>Traditional Tracking Method</th>
<th>Automated Tracking Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mark Component</td>
<td>1.09</td>
<td>0.73</td>
</tr>
<tr>
<td>Record Grid Position</td>
<td>0.41</td>
<td>2.20</td>
</tr>
<tr>
<td>Locate and Flag</td>
<td>6.73</td>
<td>1.63</td>
</tr>
<tr>
<td>Extended Searches</td>
<td>28.57</td>
<td>4.56</td>
</tr>
<tr>
<td>Average Time</td>
<td>36.80</td>
<td>4.56</td>
</tr>
</tbody>
</table>

Previous studies indicated that improper material management approaches were among the major factors affecting productivity at the worker level (CII 1986). More specifically, material quality, delivery, distribution, and handling, has significant effects on workers’ on-site performance. The 1986 CII research also revealed that an adequate material management system can improve productivity among workers by up to 6%.

More recent research revealed that adequate resource management may yield significant time and cost saving over the progression of construction design and implementation (Shehata,
Project managerial personnel are responsible for resource management such as purchasing equipment, location of material storage, and ensuring that the construction project has the adequate number of tools and equipment, while construction workers are charged with the responsibility of transferring materials from the laydown area and properly installing the material utilizing the appropriate tools and equipment. The ability to conduct these sequences of events efficiently ultimately increases labor production among construction workers.

The study distinguished between these three resource-related factors that impede construction industry labor performance: industry factors, management factors, and labor factors. The availability of materials, the quality of material, and the cost fluctuation of materials are a few industry factors that impacts workers’ ability to complete their work efficiently. Construction planning, scheduling, and availability of skilled workers are management factors that influence labor production. This leaves motivational, moral, and worker experience level as labor factors that affect labor performance. These factors hinder production in a multitude of ways. In certain circumstance, multiple factors may converge on a project. A project can have weather delays (industry related factor), thus causing the project scheduling (management related factor) to be altered. Shehata et al (2012) concluded that the industry should maintain the ability to predict accurate work sequence of laborers to better coordinate project scheduling and production. Maintaining adequate work hours minimizes the usage of overtime, thus maximizing on workers’ labor productivity.

Hendrickson (2008) detailed that efficient utilization of resources are vital to appropriate project management and project production. Inadequate utilization of resources halts construction development, delays project schedule and increases workers’ idleness. Additionally, insufficient resource management and inactive workforce diminishes value added engineering,
thus increases construction cost. The increase of value added engineering and material handling methods may strengthen the performance of construction workers. Adequate material handling systems include appropriate procurement methods, inventory stockpile, and prefabrication (Hendrickson 2008). Material delivery methods were classified by bulk materials (materials in their nature state), standard off-the-shelf materials (stockpiled materials), and fabricated units (manufactured/assembled in shop). Adequate material storage and delivery methods can vastly influence construction production.

The efficiency of construction labor performance relies heavily on worker’s ability to transfer labor, equipment, and materials into favorable output components. The inefficient transformation of construction input to output leads to cost overrun and schedule delays. Hendrickson characterized several labor factors that indirectly impact workers’ performance, that includes; (1) rework, (2) stoppage of work (e.g. strikes, holidays, inclement weather), and (3) workers’ absenteeism and turnover ratio. Furthermore, additional factors such as inadequate engineering design methods influence the production of workers on a construction project.

2.3.4 Engineering Design Factors

The emanating principles of construction are based on the accuracy and constructability of engineering design. Engineers certify that their engineering designs, plans, and drawings are reliable, constructible, and precise for construction. Inadequate engineering design may cause construction delays. Delays may occur due to errors and omissions in engineering designs, a show response to Request-For-Information (RFI), and inaccurate engineering drawings. Methodical developments in construction project schedule rely heavily on the production of construction workers. Inadequate engineering design interferes in the progression of construction production,
thus hindering labor productivity.

Efficient and effective engineering project management is essential for company growth and development. Kronenberg (2016) conceded that engineering performance management adheres to three components which includes: (1) emphasizing quality production output that is system diagram, bills of materials, drawings, designs, and specifications, (2) adequate management of resources and project schedule and (3) augmenting engineering cost. It was noted that obstructions from these three engineering management components may result in construction project delays and significant reduction in workers’ labor productivity. In most cases, design engineers spend majority of their day in meetings, on the phone, and sending emails; allocating only 20%-30% of their time on actual engineering production (Figure 10). Improving organizational management, company structure and standards may increase engineering production by 15%-20% through the projects design cycle (Kronenberg 2016). Notably, technological advancements in the construction industry have enabled a progression on engineering design methods that has influenced labor productivity.

![Table](image)

**Figure 9: Engineering Design Labor Production Rate (Kronenberg 2016)**

### 2.3.5 Technological Factors

Advancements in technological software, databases, and metrics have enabled a significant progression in construction engineering procurement, design, and implementation. Nowadays
supervisors evaluate plans, permits, and project documents through the comfort of tablets and laptops. Suppliers and Sub-Contractors typically use material database metrics like RSMeans to accurately deliver precise pricing to their clients. Researchers have continued to investigate the conceptual components of technological advancements within the industry, and have alluded to an increase in labor production. Initial reaction to technological advancements in the construction industry was opposition by many construction workers (O’Connor and Li-Ren 2004). More experienced workers were content with customary construction practices of their trade and failed to initially accept practical progression in technology. As technology improvements became more prevalent in the industry, construction personnel must become cognizant of the benefits of technology which includes more efficient scheduling, planning, designing, installation (Hendrickson 2008). The contemporary advancement of technology has enabled improved performance of construction workers and has propelled the systematic progression of the construction industry.

Zhai, Goodrum, Hass, and Cardas (2009) investigated the appropriate use of Information Technology (IT) in the construction industry and the influence it has on labor production. More importantly, the research study examined the implementation of automation and integration of information systems and how they may benefit the progression of the construction industry. Data was collected from 86 projects through the CII Benchmarking and Metrics (BM&M) Productivity Database, that measure project performance in the industry (Zhai et al. 2009). The results indicated that there was a positive correlation between proper implementation of automation and integration on labor performance. Table 4 reports descriptive statistics of four construction trades which are concrete, structural steel, electrical, piping and the activities normalized productivity mean, ranging from 3.50-4.18 (Zhai et al. 2009). Table 5 represent the IT automation of the trades, and
all were statistically significant at 0.05 confidence level. Table 6 indicates the IT integration of the trades, and the electrical trade was statistically significant at the 0.15 confidence level. Though construction workers typically do not administer IT methods, they acquire substantial assistance from their usage. A large portion of construction imperfections such as rework is reduced, thus reducing delays in construction.

**Table 4: Construction Trades Descriptive Statistic**

<table>
<thead>
<tr>
<th>Trade</th>
<th>N (activities)</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>Std.Dev</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>81</td>
<td>3.50</td>
<td>1</td>
<td>10</td>
<td>2.33</td>
<td>2.99</td>
<td>4.02</td>
</tr>
<tr>
<td>Structural Steel</td>
<td>75</td>
<td>4.15</td>
<td>1</td>
<td>10</td>
<td>2.46</td>
<td>3.58</td>
<td>4.72</td>
</tr>
<tr>
<td>Electrical</td>
<td>85</td>
<td>3.88</td>
<td>1</td>
<td>10</td>
<td>2.85</td>
<td>3.27</td>
<td>4.50</td>
</tr>
<tr>
<td>Piping</td>
<td>98</td>
<td>4.18</td>
<td>1</td>
<td>10</td>
<td>2.98</td>
<td>3.58</td>
<td>4.78</td>
</tr>
</tbody>
</table>

**Table 5: Construction Trades Automation t-Test**

<table>
<thead>
<tr>
<th>Trade</th>
<th>High level automation</th>
<th>Low level automation</th>
<th>Difference</th>
<th>Levene’s test for equality of variances</th>
<th>Equal variances assumed</th>
<th>Equal variances not assumed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>3.48 (33)</td>
<td>3.89 (37)</td>
<td>-0.40</td>
<td>4.98</td>
<td>0.03</td>
<td>-3.69</td>
</tr>
<tr>
<td>Structural Steel</td>
<td>3.74 (40)</td>
<td>5.24 (24)</td>
<td>1.50</td>
<td>16.91</td>
<td>0.00</td>
<td>-2.42</td>
</tr>
<tr>
<td>Electrical</td>
<td>3.65 (52)</td>
<td>5.21 (19)</td>
<td>-1.55</td>
<td>1.51</td>
<td>0.22</td>
<td>-2.04</td>
</tr>
<tr>
<td>Piping</td>
<td>3.96 (53)</td>
<td>4.40 (37)</td>
<td>-0.45</td>
<td>3.97</td>
<td>0.05</td>
<td>-3.71</td>
</tr>
<tr>
<td>All trades</td>
<td>3.68 (176)</td>
<td>4.54 (117)</td>
<td>-0.86</td>
<td>20.62</td>
<td>0.00</td>
<td>-2.72</td>
</tr>
</tbody>
</table>

Note: ***=significance at 0.05. The numbers in the parentheses are the sample sizes (activity productivities).

**Table 6: Construction Trades Integrated t-Test**

<table>
<thead>
<tr>
<th>Trade</th>
<th>High level integration</th>
<th>Low level integration</th>
<th>Difference</th>
<th>Levene’s test for equality of variances</th>
<th>Equal variances assumed</th>
<th>Equal variances not assumed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete **</td>
<td>2.91 (33)</td>
<td>4.71 (19)</td>
<td>-1.81</td>
<td>19.90</td>
<td>0.00</td>
<td>-3.12</td>
</tr>
<tr>
<td>Structural Steel</td>
<td>3.48 (39)</td>
<td>5.30 (10)</td>
<td>-1.82</td>
<td>3.28</td>
<td>0.04</td>
<td>-2.58</td>
</tr>
<tr>
<td>Electrical</td>
<td>3.28 (48)</td>
<td>5.66 (6)</td>
<td>-2.38</td>
<td>8.15</td>
<td>0.01</td>
<td>-2.36</td>
</tr>
<tr>
<td>Piping</td>
<td>3.82 (52)</td>
<td>5.02 (15)</td>
<td>-1.20</td>
<td>10.59</td>
<td>0.00</td>
<td>-1.39</td>
</tr>
<tr>
<td>All trades **</td>
<td>3.57 (172)</td>
<td>5.06 (52)</td>
<td>-1.49</td>
<td>28.89</td>
<td>0.00</td>
<td>-4.41</td>
</tr>
</tbody>
</table>

Note: **=significance at 0.05; *=significance at 0.15. The numbers in the parentheses are the sample sizes (activity productivities).

Eastman and Sacks (2008) explained the systematic improvements of the construction industry as it relates to prefabricated components, which he referred to as “off-site fabrication”.

Prefabrication is defined as a manufacturing process of materials that are formulated together in a closed facility to maximize productivity and schedule (Mikhail 2014). The enhancement of performance of the construction workforce may be attributed to the manufacturing of construction components in a controlled environment. Eastman 2008 concluded that off-site manufacture of construction components such as junction boxes, underground power distribution stub-up, pull box assembly. These components enabled productivity to grow 46% over the last 10 years against the on-site components. Figure 11 demonstrates a 2.32% annual growth in off-site fabrication, and 1.43% annual growth in on-site fabrication; indicating 1.6 times production growth rate of off-site fabrication than on-site fabrication (Eastman et al. 2008). Production growth of off-site fabrication can be attributed to the efforts of project managerial personnel ability to acquire and maintain adequate construction practices.

![Figure 10: Production Growth Off-Site Fabrication and On-Site Fabrication](image)

### 2.3.6 Project Managerial Factors

The risk associated with inadequate construction and project management may be associated to components that influence workers’ performance during construction project development. Electrical construction workers have alluded to poor project management as an essential component that obstructs their labor performance. The Project Management Institute
(PMI) elucidated that project management are the components that direct, coordinate, and manage project workforce, resources, and information through the life cycle of the construction project (Project Smart Sheets). This is achieved through innovative managerial techniques utilized to optimize project objective and scope. These techniques ultimately improve cost, schedule, and quality of the construction project.

This research examined project management risk process in several complex projects, using the methods of Delphi analysis (Cano and Cruz 2002). Cano revealed through the execution of Delphi analysis, in order for the project risk management analysis to be most efficient the construction company have to be entirely committed to the initiative. The companies approach in implementing appropriate project risk management essential alleviates additive risk associated with project management. Moreover, company’s temperament is pivotal in influencing the behavior and performance of construction workers. Therefore, project managers should be aware that they share a substantial influence on construction worker performance.

In addition, a past benchmarking study revealed that average man-power, peak man-power, man-power loading curve and S-curve serves as adequate project indicators in measuring labor production on a construction project (Hanna, Peterson, and Lee 2002). The study utilized several linear regression models to estimate and quantify the correlation between 59 project performance indicators, which were measuring “well-executed projects”. These projects were based on project size, project percent completed, cumulative work hours, and project duration. Figure 12 displays project completion level against the total man-power loading of the electrical construction projects. Man-power percentage peaks at 155% of the average total labor of the electrical projects. They peaked near the 75% project completion level. Therefore, adequately measuring labor production of electrical workers is pivotal to improving labor performance and practices in the construction
industry.

Figure 11: Manpower Loading Curve

More recent research has found that projects with steady craft availability perform at a more exceptional rate as compared to projects with excessive absenteeism, turnover ratio and Craft Labor unavailability (Karimi 2016). The research study could develop a cost change metrics that quantified staffing availability among workers. Projects that exhibited minimum staffing issues generally resulted in a higher rate compared to those projects that had significant worker staffing concerns. The completion of any construction project is closely related to the daily production of the construction workers, and at times may cause additive safety concerns for the project.

2.3.7 Safety Factors

The incremental surge of the correlation between deficient construction labor practices and construction safety practices are a momentous source of risk accompanying construction workers. Minimizing risk associated with construction such as injuries, fatalities, and accidents is pivotal in optimizing construction worker’s performance. There are numerous safety components that may impede construction workers labor performance such as their age, working experience, safety training, and working environment.

Previous research has shown that these components listed above have a substantial influence on construction workers’ safety, thus inhibiting them from adequately perform their task.
effectively (Albert, Hallowell, and Kleiner 2014). Understanding the parallel relation of construction worker’s attitude and their performance while conducting their construction activity has been studied extensively. Short job tenure, increase interpersonal conflict and decrease in the quality of worker leadership all displayed a significant correlation to inadequate construction safety (McCabe, and Lougnlin, Munteanu, Tucker, and Lam 2008). The research study was able to generate two models; a regression model that displayed a significant $R^2$ value of 0.284, 0.230, and 0.234 for physical symptoms, accidents, and psychological symptoms respectively, represented in the Bayesian network model (Figure 13). The Bayesian model contained 21 variables and 36 connections constructed on the strengths of the correlations used to measure the probability of inadequate safety performance (McCabe et al. 2008). Additionally, the study investigated the frequency in which accidents occur and the factors that influence construction accidents (Table 7). It is important to note that accidents and injuries of Supervisors were significantly lower than those of Journeyman and Apprentice. This may be attributed to the intensity of the work, the continuous pressure to complete the work, and the experience level of Journeymen and Apprentice workers.

![Bayesian Network Model](image)

Figure 12: Bayesian Network Model
McCabe (2013) It was characterized that the construction industry’s efforts to improve safety practices on construction project alludes from increase worker compensation cost and an increase in medical expenses. The study surveyed 911 construction workers from 84 non-residential construction projects in Ontario Canada and revealed a significant disparity among younger and more experienced workers (Table 8). Additional factors which includes physical injury, psychological injury, and accidents (Table 9) were examined. In each instance, the less experienced workers rate was significantly higher than that of more experienced workers. Furthermore, rapid project turnover has substantially contributed to construction worker’s inadequate safety practices. Continuous change in construction projects hinders workers’ progression. This regulates them to learn different project and company standards, thus impeding the holistic labor performance of the construction workers.

Table 8: Safety Factors

<table>
<thead>
<tr>
<th>Age</th>
<th>Physical Injuries</th>
<th>Psychological Injuries</th>
<th>Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-29</td>
<td>7.7</td>
<td>4.4</td>
<td>4.4</td>
</tr>
<tr>
<td>30-38</td>
<td>6.1</td>
<td>3.6</td>
<td>3.5</td>
</tr>
<tr>
<td>39-45</td>
<td>4.9</td>
<td>3.4</td>
<td>2.5</td>
</tr>
<tr>
<td>46-69</td>
<td>3.5</td>
<td>2.2</td>
<td>2.3</td>
</tr>
</tbody>
</table>
Table 9: Safety Definition

<table>
<thead>
<tr>
<th>Physical injuries</th>
<th>Psychological injuries</th>
<th>Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache or dizziness</td>
<td>Eye injury</td>
<td>Slipped, tripped or fell on the same level</td>
</tr>
<tr>
<td>Persistent fatigue</td>
<td>Electrical shock</td>
<td>Was struck by a moving vehicle</td>
</tr>
<tr>
<td>Respiratory injuries (e.g., difficulty breathing)</td>
<td>Dislocated / fractured bone</td>
<td>Was struck by flying/falling object(s)</td>
</tr>
<tr>
<td>Strain or sprain (e.g., back pain)</td>
<td>Skin rash / burn</td>
<td>Fell from height</td>
</tr>
<tr>
<td>Cut or puncture (open wound)</td>
<td>Hernia</td>
<td>Contacted moving machinery</td>
</tr>
<tr>
<td>Temporary loss of hearing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lost much sleep due to work related worries</td>
<td>Felt constantly under strain</td>
<td></td>
</tr>
<tr>
<td>Been unable to concentrate on work related tasks</td>
<td>Been losing confidence in myself</td>
<td></td>
</tr>
<tr>
<td>Been unable to enjoy my normal day-to-day activities</td>
<td>Felt incapable of making decisions</td>
<td></td>
</tr>
<tr>
<td>Was exposed to chemicals such as gases &amp; fumes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over exerted myself while handling, lifting or carrying</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trapped by something collapsing, caving in or overturning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Struck against something fixed or stationary</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.4.0 Conclusion

The electrical construction industry must be ready to tackle and face the challenges of poor labor practices. The challenges concerning the electrical construction industry include low labor productivity levels, inadequate engineering and design practices, and schedule compressions due to project delays. Insufficient on-site communication between workers, lack of tools, inefficient flow of information between workers and supervisors, and unsafe working environment are additional factors that frequently impede workers’ ability to perform their task efficiently. This research study supplements the previous literature cited above with an extensive understanding of 182 electrical workers’ perception on the comprehensive set of factors that may impede their labor performance.
3.0 Data Characteristics

3.1 Introduction

The data was collected to understand the concerns of productivity at the crew level perspective. A comprehensive survey questionnaire was formulated with the following objectives:

- To ascertain the opinion of electrical construction workers, foremen, and supervisors on labor productivity;
- To quantify the impact of inadequate construction labor practices and methods, and
- To recommend appropriate labor production practices and methods to the construction industry.

This chapter will expand on the development and distribution of the survey to electrical construction workers in both the U.S. and Canada and discuss the demographics of the electrical workers surveyed along with their construction companies.

3.2 Methodology

The research began with the implementation of a pilot survey questionnaire that studied 21 performance factors that impact electrical workers’ labor production. The pilot study was used to generate a contemporary understanding of how electrical workers would respond to the survey, before the survey is nationally distributed through the electrical construction industry. The pilot study was also utilized to identify and correct any errors or ambiguities of the survey questionnaire.

To improve the quality of the survey questionnaire, it was reviewed by the University of
Wisconsin-Madison Writing Center (UWMWC), construction industry personnel, and academic institutional personnel. The pilot survey was administered to 48 electrical construction workers. The pilot survey responses were collected and analyzed. From the analysis, the electrical workers found the survey understandable, thus minimal changes were made to the pilot survey. This enabled a mass distribution of the survey questionnaire via Qualtrics, an online survey database. The survey questionnaire was distributed to over 3000 electrical workers, and there were 182 respondents, which gave a response percentage of 6.07%. The fundamental goal of this survey questionnaire was met by acquiring adequate information to analyze labor production from the perspective of the crew level employees.

### 3.3 Survey Questionnaire Characteristics

The survey asked the electrical workers to rate several productivity factors that may impact their performance on their current construction project. The survey questionnaire was divided into eight distinct sections: demographics, work schedule, availability of resources, safety, engineering design, project management, supervision, and labor. A copy of the survey cover letter can be found in Appendix A, along with the survey questionnaire in Appendix B. In addition, the survey asked specific characteristics of electrical workers and their perspective on labor productivity within the electrical construction industry, such as Electrical Worker Information, Company Information, and Project Information.

#### 3.3.1 Electrical Worker Information

The initial analysis enabled a more precise understanding of quantitative variables that represent the surveyed electrical construction workers. Table 10 shows that the average electrical worker was 41.2 years old with 24.06 years of construction industry experience, and 14.67 years of company experience. The average age of electrical workers that were surveyed coincides with
the 2006 CII study that looked to examine factors affecting workers’ ability to perform their tasks effectively.

Additionally, the average age of electrical workers has remained stagnant for the past few decades. This concerning trend will remain at the forefront of the construction industry until adequate attention is devoted to hiring, training, and retaining more able-bodied construction personnel. Companies must be willing to attract the new wave of workers and should be amenable in developing them to becoming great workers and leaders of the industry. Figure 14 shows 20% of electrical workers age ranged between “25-30 years”, 14% were “31-35 years”, and 15% were “36-40 years.” Additionally, 19% of electrical workers ranged between “41-45 years,” 11% were “46-50 years,” 13% were “51-55 years” and a notable 8% were “56-65 years.” The youngest electrical worker surveyed was 25 years old, and the eldest was 62 years old.

**Table 10: Electrical Workers Experience**

<table>
<thead>
<tr>
<th>Experience Factors</th>
<th>Mean Average (Years)</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Age of Electrical Worker</td>
<td>41.2</td>
<td>12.27</td>
</tr>
<tr>
<td>How long have you been working in the construction industry?</td>
<td>24.06</td>
<td>12.47</td>
</tr>
<tr>
<td>How long have you been working with your current construction company?</td>
<td>14.67</td>
<td>11.67</td>
</tr>
</tbody>
</table>

**Figure 13: Age of Electrical Workers**
Among those surveyed, (39%) were “Working Foreman,” (38%) were “General Foreman,” (15%) were “Non-Working Foreman,” and (8%) were “Journeyman” (Figure 15). Industry and company experience echelons were also measured. The electrical workers, foremen, and supervisors averaged roughly 20 years of construction industry work experience and 15 years of company work experience. Table 10 displays the breakdown of the electrical construction workers’ industry and company experiences, quantified in years.

Table 11: Electrical Construction Work Experience

<table>
<thead>
<tr>
<th>Construction Experience (Years)</th>
<th>Percent of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5 years</td>
<td>6%</td>
</tr>
<tr>
<td>6-10 years</td>
<td>17%</td>
</tr>
<tr>
<td>11-15 years</td>
<td>17%</td>
</tr>
<tr>
<td>16-20 years</td>
<td>15%</td>
</tr>
<tr>
<td>21-25 years</td>
<td>17%</td>
</tr>
<tr>
<td>26-30 years</td>
<td>12%</td>
</tr>
<tr>
<td>31-35 years</td>
<td>9%</td>
</tr>
<tr>
<td>36-40 years</td>
<td>7%</td>
</tr>
</tbody>
</table>

Table 12: Electrical Company Work Experience

<table>
<thead>
<tr>
<th>Company Work Experience (Years)</th>
<th>Percent of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2 years</td>
<td>17%</td>
</tr>
<tr>
<td>3-5 years</td>
<td>16%</td>
</tr>
<tr>
<td>6-10 years</td>
<td>23%</td>
</tr>
<tr>
<td>11-15 years</td>
<td>13%</td>
</tr>
<tr>
<td>16-20 years</td>
<td>18%</td>
</tr>
<tr>
<td>20-25 years</td>
<td>13%</td>
</tr>
</tbody>
</table>
3.3.2 Company Information

The electrical workers that were surveyed worked for numerous companies with diverse attributes and company working cultures. Electrical construction companies had various characteristics regarding number of employees, annual projects completed, and annual labor cost. Figure 16 shows the geographical distribution of the electrical workers’ companies in both the U.S. and Canada. Several projects were completed in the Midwestern Region, (Wisconsin, Illinois, Ohio, Minnesota, and Michigan), and a substantial portion of projects were completed in Toronto and Ontario (Canada).
Figure 15: Geographical Distribution of Project

Figure 17 shows the distribution of the companies’ annual revenue. Twenty-one percent of the company’s revenue were between $20- $50 million of annual revenues, while 37% of the companies had annual revenue greater than $50 million. Figure 18 indicates that only 2% of the companies executed less than 10 projects per year, while 53% of the companies executed more than 40 projects per year. According to Figure 19 companies varied in terms of the total number of employees; 27% of companies had 0 to 40 employees, 22% of companies had 41 to 100 employees, and 17% had more than 1,000 people employed.
Figure 16: Construction Company Annual Revenue

Figure 17: Construction Projects performed Annually

Figure 18: Number of Employees
3.3.3 Project Information

The dataset included projects of various types. As illustrated in Figure 20, 50% of the projects were commercial, 43% were industrial, and only 7% were residential. Figure 21 illustrates the distribution of daily commute times of electrical workers. The distribution shows that 29% of the workers were less than 10 miles away from their construction project site, 56% were 10 to 30 miles away, and 26% were 30 to 60 miles away from their job site. A considerable amount 17% had a daily commute time of more than 60 miles to their job site, which is quite inefficient. Workers with high commute times are prone to higher absenteeism rates, which negatively affects labor productivity and increases worker turnover.

**Figure 19: Project Type**

**Figure 20: Electrical Workers Commute Time**
3.4 Conclusion

The electrical workers surveyed were an exceptional representation of the electrical construction industry workforce. Varying in education, experience level, and job position, the electrical workers could give incredible insight to the root cause of labor production inadequacies in the electrical construction industry.

After examining the data, it can be concluded that the electrical workers have significant knowledge of construction practices. The level of experience, expertise and knowledge of the electrical trade has enabled them to have thorough understanding pertaining to the factors that impede their labor productivity. Additionally, the workers inspire the continued development and acquisition of information to improving labor production of the construction industry.
Chapter 4 Data Analysis

4.1 Introduction
The next phase of the research was the analysis of the data that was collected through the responses of the survey questionnaire. The data collected concerned the opinion of the electrical workers, which was presented on a scale of perception (Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree), frequency (Not at All, A Little, Somewhat, Quite a Bit, A Great Deal), and impact (Never, Rarely, Sometimes, Most of the Time, Always) of their labor performance. The perception, frequency and impact scales were converted to a 5-point Likert Scale, where the range is 1-5, with 1 being least likely to occur or least impactful and 5 being most likely to occur or most impactful. The factors were analyzed independently to isolate specific correlations and trends pertaining to the electrical workers’ labor productivity.

4.1.1 Electrical Workers Intuition on Labor Productivity
The factors that influence labor productivity in the electrical construction industry are profuse. These factors encourage mutually constructive and adverse actions of electrical workers, thus influencing their performance level. This research study analyzes the importance of scheduling, adequate resources, and engineering design practices on electrical workers’ labor performance. Moreover, this study acquires sufficient knowledge on the awareness of electrical workers of numerous factors that influence their labor productivity.

4.1.2 Impact of Scheduling on Labor Productivity
Timely completion of construction projects is pivotal so that contractors and owners may continue to foster a relationship grounded on trust and principle. Through history the construction industry has utilized an immense array of scheduling practices such as, 4-10 Work Schedule, 5-8 Work Schedule, and 2nd Shift (Hanna 2003). Researchers can measure labor
production by the construction schedule loss or gain (Hanna 2008). This research study examines scheduling practices of electrical workers within the industry and its impact on labor productivity.

There has been an enormous amount of research done on scheduling and ways to improve scheduling practices. An essential factor to analyze was overtime. The use of overtime to accelerate the progression of projects is notorious in the construction industry. Figure 22 shows 15% of electrical workers surveyed responded to working overtime to meet project schedule. Only 16% worked “Less than 40 hours/week”.

Table 13 presents the responses of the electrical workers concerning the frequency in which 4-10 work schedule, 5-8 work schedule, and 2\textsuperscript{nd} shift was used on their construction project. Seventy-five percent of workers responded that they “Never” or “Rarely” worked a “4-10 Work Schedule”, while 86% of those surveyed reported working “5-8 Work Schedule”. Interestingly, 68% of electrical workers surveyed preferred working longer days and enjoying a three-day weekend. Within the construction industry it is common to utilize multiple shifts to improve work schedule. However, 76% of electrical workers responded that their company “never” or “rarely” used 2\textsuperscript{nd} shift to meet project baseline.

Figure 21: Scheduling Practices: Overtime
Table 13: Project Schedule (Frequency)

<table>
<thead>
<tr>
<th></th>
<th>4-10 Work Shift</th>
<th>5-8 Work Shift</th>
<th>2\textsuperscript{nd} Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>36%</td>
<td>2%</td>
<td>16%</td>
</tr>
<tr>
<td>Rarely</td>
<td>39%</td>
<td>4%</td>
<td>50%</td>
</tr>
<tr>
<td>Sometimes</td>
<td>15%</td>
<td>8%</td>
<td>31%</td>
</tr>
<tr>
<td>Most of the Time</td>
<td>9%</td>
<td>71%</td>
<td>3%</td>
</tr>
<tr>
<td>Always</td>
<td>1%</td>
<td>15%</td>
<td>0%</td>
</tr>
</tbody>
</table>

4.2 Impact of Resources on Labor Productivity

Improving the availability of resources on project sites improves the production of electrical workers and the projects schedule. With adequate resources, electrical workers can perform task more efficiently and effectively, thus reducing rework and time spent on rework. This study investigates the perspectives of electrical workers and their awareness of the impact of adequate resource which includes tools, information, material, and environmental that influence labor production.

4.2.1 Tools

The construction industry has faced several challenges regarding adequate resources and appropriate time management. Among those surveyed 18\% of electrical workers await adequate tools for completion of their current work. Table 14 shows that 70\% of workers’ waste “1-2 hours/week” awaiting tools, 25\% waste “3-4 hours/week,” and 5\% of electrical workers’ waste “5 or more hours/week” awaiting tools. Additionally, the mean rating for time wasted awaiting tools were 1.35, which was calculated using the response percentage of the electrical workers. In addition, the increase in power, energy, and complexity of tools has improved labor productivity among construction workers (Hendrickson 2008). However, 48\% of electrical workers
responded that there are inadequate cordless drills on their construction project.

4.2.2 Information

Inadequate allocation of information is a core element in having appropriate engineering design, engineering design practices, safety, and project management. Bid proposals, design documents, Request for Information (RFI’s), design plans, specifications, schedules, and permits are all forms of information in the construction industry. If information is not properly communicated by the project stakeholders, delays will occur, and will cause a reduction in labor productivity.

This research analyzed the perception of electrical workers and their awareness of the impact of inadequate information sharing among owners, contractors, sub-contractors, and suppliers. The response of electrical workers concerning the impact of adequate allocation of information sharing was that 17% were delayed in completing their work. Table 14 shows 77% were delayed “1-2 hours/week,” 15% were delayed “3-4 hours/week,” and 8% were delayed “5 or more hours/week” due to awaiting adequate information from their direct supervisor. Furthermore, the average mean rating for time wasted awaiting information were 1.31 which is slightly less than the availability of tools in the previous section.

4.2.3 Materials

When managing a construction project, supervisors should be cognizant of materials and equipment entering the site, the amount of materials being consumed through the development of the project and where on the project site the material will be stored. The availability, delivery, installation, prefabrication, and quality of materials are components that impact the production rate of a construction project (CII 2006). Previous research has shown that the adequate usage of the Material Management System improves labor productivity by 6% of the overall project cost.
This research study observes the perception of workers and their knowledge pertaining to material management concerns of the electrical contracting industry. Furthermore, 27% of electrical workers were delayed in the progression of their work due to lack of adequate materials. Additionally, 64% of electrical workers surveyed were delayed “1-2 hours/week,” 24% were delayed “3-4 hours/week” and 12% were delayed “5 or more hours/week” awaiting materials (Table 14). Additionally, the mean rating for time wasted awaiting adequate material was 1.48. Moreover, only 44% of electrical workers responded that materials are stored in appropriate “Laydown Areas” on the project site. Forty-three percent of workers specified material are stockpiled in close proximity to their work area and 13% of workers responded that materials were stored off-site at a warehouse facility (Figure 23).

![Figure 22: Material Handling](image)

**4.2.4 Work Environment**

Moreover, this study investigated the availability of appropriate work environment, including the horizontal and vertical space to perform work. Among those surveyed, 40% of electrical workers did not have sufficient space required to perform their work, while 64% of electrical workers responded that the construction project lacked adequate temporary facilities such as toilets and break rooms. Table 14 also shows that 46% of electrical workers were
delayed “1-2 hours/week,” 36% were delayed “3-4 hours/week,” and 18% were delayed “5 or more hours/week” due to inadequate work environment on the construction project. Lastly, the average mean rating for time wasted awaiting appropriate environment was 1.72 which is the highest ranking among the available resources.

Finally, the success of a project can be impacted by the ability of contractors to receive material and the period it takes for electrical contractors to install the material. The innovation of prefabricated components has improved construction through in terms of cost, quality, safety, scheduling, and productivity (Mikhail 2014).

**Table 14: Delay Time of Inadequate Allocation of Resources**

<table>
<thead>
<tr>
<th>Tools</th>
<th>Information</th>
<th>Material</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 hours/week</td>
<td>70%</td>
<td>77%</td>
<td>64%</td>
</tr>
<tr>
<td>3-4 hours/week</td>
<td>25%</td>
<td>15%</td>
<td>24%</td>
</tr>
<tr>
<td>5+ hours/week</td>
<td>5%</td>
<td>8%</td>
<td>12%</td>
</tr>
</tbody>
</table>

4.3 **Impact of Adequate Engineering Design**

Documents that are required for adequate engineering design may cause an incredible amount of rework, delay, and cost overrun. Errors and omissions, inadequate design plans and specification, and slow responses to RFIs delay project schedule substantially and reduce the productivity of the project and electrical construction workers. This research study investigates the knowledge of electrical workers and their insight of engineering design and the impact on labor productivity.

Delays that occur from errors and omissions in design documents are becoming less
prevalent in the construction industry due to new innovations in digital software such as AutoCAD, Building Information Modeling (BIM), SolidWorks, and Primavera. Figure 24 shows 34% of electrical workers “Most of the Time” or “Always” observed an adverse impact on their production from inaccurate design documents. Figure 25 goes on to show 35% of electrical workers who found inconsistencies in design documents. A resounding 62% of electrical workers were delayed in their work due to slow response to RFIs (Figure 26).

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**Figure 23: Impact of Errors and Omission on Labor Productivity**

**Figure 24: Frequency of Errors and Omissions**
4.4 Engineering Practice Impact- Project Management & Supervision

Construction design practices influence electrical workers’ productivity. These practices are implemented by the Project Management team to maximize construction cost and quality as well as reduce construction delay times. Appropriate construction management practices alleviate poor planning and scheduling techniques, thus increasing productivity of the workforce. Inadequate design practices lead to cost overrun, and increase worker turnover and absenteeism. This research study examines several engineering practices that impede the production of electrical workers in the construction industry.

Minimizing construction delays is key to improving workers performance on construction project. Delays are frequently caused by various factors including incomplete prerequisite work, absenteeism, and inadequate electrical crew sizes. Figure 27 shows that 14% of workers observed delays due to incomplete prerequisite work “Most of the Time” or “Always”. Additionally, Figure 28 shows that 60% “Never” or “Rarely” were delayed due to worker absenteeism. While, Figure 29 reveals that majority of electrical workers, 62% “Agree” or “Strongly Agree” that there are adequate crew sizes on their construction project.
Figure 26: Frequency-Delay due to Incomplete Prerequisite Work

Figure 27: Frequency-Delays Due to Absenteeism

Figure 28: Adequate Crew Size
4.5 Impact Performance Factors

There are innumerable factors that play a vital role in influencing how electrical workers perform through the execution of their construction projects. The top 10 performance factors that positively impact labor production are shown in Table 15. A comprehensive list of these positive factors can be found in Appendix C. The mean scale value is measured on 5-point Likert Scale ranging from 1-5, with 1 being least impactful and 5 being most impactful.

<table>
<thead>
<tr>
<th>Factors that Impact Labor Production</th>
<th>Impact</th>
<th>Mean Rating</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are the craft workers from your trade qualified to do the work</td>
<td>Positive</td>
<td>4.03</td>
<td>0.61</td>
</tr>
<tr>
<td>Your Relationship with your supervisor positively impacts your productivity on this job</td>
<td>Positive</td>
<td>3.96</td>
<td>0.91</td>
</tr>
<tr>
<td>Does prefabricated components positively impact the overall productivity of the project?</td>
<td>Positive</td>
<td>3.92</td>
<td>0.79</td>
</tr>
<tr>
<td>My direct Supervisor receives support he needs from administration</td>
<td>Positive</td>
<td>3.81</td>
<td>0.59</td>
</tr>
<tr>
<td>Are there mutual trust between craft workers, foremen, and supervisors</td>
<td>Positive</td>
<td>3.80</td>
<td>0.58</td>
</tr>
<tr>
<td>Enough attention is paid to protecting the workers from the weather</td>
<td>Positive</td>
<td>3.78</td>
<td>0.57</td>
</tr>
<tr>
<td>Has apprenticeship training program impact your labor productivity</td>
<td>Positive</td>
<td>3.72</td>
<td>1.79</td>
</tr>
<tr>
<td>Are the craft workers from other trades on this project qualified to do the work.</td>
<td>Positive</td>
<td>3.71</td>
<td>0.61</td>
</tr>
<tr>
<td>Does daily huddle meetings positively impact your productivity</td>
<td>Positive</td>
<td>3.66</td>
<td>0.85</td>
</tr>
<tr>
<td>Are vehicle traffic routes on this project are laid out well</td>
<td>Positive</td>
<td>3.55</td>
<td>0.76</td>
</tr>
</tbody>
</table>

The performance factors were demarcated in 8 different categories to better assess the perception of the electrical construction workers. The categories are Labor, Supervision, Project Management, Engineering, Safety, Work Schedule, Resources, and Prefabrication. The mean and standard deviation of each performance factor was tabulated and ranked accordingly in
descending order. The factors that positively influence electrical workers’ ability to perform their task were more directional and empathetic components such as, electrical workers’ relationships with their direct supervisor, supervisors’ acquisition of adequate support from administrative personnel, and trust level among electrical worker and supervisor. Additional positive performance factors were noted as being labor-intensive traits, such as the quality of electrical workers and the utilization of prefabricated components impacting labor production.

Conversely, there are variations of factors that adversely impact electrical construction workers’ performance. These factors are listed in Table 16 and are mainly related to inadequate engineering practices and lackadaisical managerial support such as; delay in work due to incomplete prerequisite work, inadequate design documents, and absenteeism. Proper sequencing of workers’ tasks is essential in maintaining stable and punctual completion of the construction project. Inadequate prerequisite work and construction worker absenteeism has been shown to significantly delay construction projects. To combat these concerns, the managerial administrative team must adequately plan and coordinate projects at the earliest stage of construction. Appropriate communication between the administrative team and the construction team is necessary to enable a more comprehensive awareness of construction issues as they arise in both the construction field and field office. This ultimately allows for team members to work together to better coordinate and complete the construction project, thus increasing labor productivity.
### Table 16: Performance Factors that Influence Labor Productivity (Negative)

<table>
<thead>
<tr>
<th>Factors that Impact Labor Production</th>
<th>Impact</th>
<th>Mean Rating</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you been delayed in your work due to incomplete prerequisite work</td>
<td>Negative</td>
<td>3.00</td>
<td>0.65</td>
</tr>
<tr>
<td>How often do errors and omissions in plans and specifications negatively impact your productivity</td>
<td>Negative</td>
<td>3.31</td>
<td>0.75</td>
</tr>
<tr>
<td>Is there a lack of communication between management personnel on this project</td>
<td>Negative</td>
<td>2.39</td>
<td>0.79</td>
</tr>
<tr>
<td>Is there a lack of communication between your supervisor and the craft workers on the project</td>
<td>Negative</td>
<td>2.39</td>
<td>0.74</td>
</tr>
<tr>
<td>Have you been delayed in your work due to the absence of other workers.</td>
<td>Negative</td>
<td>2.34</td>
<td>0.61</td>
</tr>
<tr>
<td>How often do safety conditions negatively impact your productivity</td>
<td>Negative</td>
<td>2.28</td>
<td>0.70</td>
</tr>
</tbody>
</table>

#### 4.6 Frequency Factors

Adequate and substantial completion of a construction project is widely determined by appropriate scheduling and planning within the scope of the project. The proper sequencing of trades, resources, and manpower is pivotal to the success of the project. Electrical workers reported that adequate response time for RFI’s, availability of adequate design drawings, and errors in engineering design documents are influential in causing construction delays. This obstructs value-added engineering, in turn reducing project labor production. Furthermore, the surveyed electrical workers responded that 2\textsuperscript{nd} shift was rarely used to expedite construction development with a 2.19 mean scale value (Table 17). Effective communication and experienced engineers can alleviate such industry concerns.
Table 17: Frequency of Performance Factors that influence Labor Productivity

<table>
<thead>
<tr>
<th>Frequency of Factors that Impact Labor Production</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>How often is 5-8 work schedule used</td>
<td>3.91</td>
<td>0.77</td>
</tr>
<tr>
<td>Are engineers slow to respond to Request for Information (RFI)</td>
<td>3.72</td>
<td>0.87</td>
</tr>
<tr>
<td>How often are the drawings you need to do your job readily available</td>
<td>3.48</td>
<td>0.83</td>
</tr>
<tr>
<td>How often are there errors in the drawings</td>
<td>3.35</td>
<td>0.79</td>
</tr>
<tr>
<td>How often is 2nd shifts used to meet baseline schedule deadlines</td>
<td>2.19</td>
<td>0.73</td>
</tr>
<tr>
<td>How often is 4-10 work schedule used</td>
<td>2.00</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Supplementary analysis was conducted to examine the perception of electrical workers on matters pertaining to adequate resources, work schedules, safety, labor, and prefabrication. For this analysis, the mean scale was not used as a measuring tool. Instead, percentages were used to measure these findings. Table 18 shows that 86% of workers responded not having to wait for adequate tools. Eighty-two percent responded that they did not have to wait for adequate information, while 73% of workers received adequate materials. Lastly, 59% responded that there were adequate work environment spacing on the construction project. However, it should be noted that nearly two-fifths 41% of respondents were delayed due to an inadequate working environment. It was also revealed that 77% of supervisors use daily huddle meetings to begin their work day, and 95% of supervisors held toolbox meetings to re-emphasize safety precautions and practices. It is also interesting to note that a considerable number 62% of projects used some form of prefabrication, however, 74% of the workforce still resists the use of prefabricated components.
Table 18: Percentage of Performance Factors

<table>
<thead>
<tr>
<th>Frequency of Factors that Impact Labor Production</th>
<th>Percentage (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did you often have to stop work because you did not have adequate tools</td>
<td>(14%, 86%)</td>
</tr>
<tr>
<td>Did you often have to stop work because you did not have adequate information</td>
<td>(18%, 82%)</td>
</tr>
<tr>
<td>Did you often have to stop work because you did not have adequate materials</td>
<td>(27%, 73%)</td>
</tr>
<tr>
<td>Did you often have to stop work because you did not have adequate environment</td>
<td>(41%, 59%)</td>
</tr>
<tr>
<td>There is enough room on the site for material storage</td>
<td>(80%, 20%)</td>
</tr>
<tr>
<td>There are not enough temporary facilities (toilets, break areas)</td>
<td>(36%, 64%)</td>
</tr>
<tr>
<td>Does your supervisor use daily huddle each morning before work begins to explain what needs to be done</td>
<td>(77%, 23%)</td>
</tr>
<tr>
<td>Does your supervisor hold toolbox meeting to re-emphasize safety</td>
<td>(95%, 5%)</td>
</tr>
<tr>
<td>Have you completed any formal apprenticeship training</td>
<td>(76%, 24%)</td>
</tr>
<tr>
<td>Do you attend job site orientation programs</td>
<td>(84%, 16%)</td>
</tr>
<tr>
<td>Does your trade perform any prefabricated work</td>
<td>(62%, 38%)</td>
</tr>
<tr>
<td>Does the workforce resist the use of prefabricated components</td>
<td>(74%, 26%)</td>
</tr>
</tbody>
</table>

4.7 Quantification Metrics

The electrical workforce consists of Supervisors, Foremen, and Electrical Workers. So, to gain further awareness regarding the concerns of electrical construction workers, the mean scale ratings was further utilized to rank the labor productivity performance factors. Furthermore, the factors influencing the performance of the electrical workers were ranked on a scale from 1 to 21 and were independent of each performance factor. As shown in Table 18, the mean scale was tabulated according to the variation of job positions which includes (Supervisor, Forman, Electrical Craft Worker), and will be analyzed thoroughly in this section.

4.7.1 Labor Performance Factors: -Frequency

This research reveals that suitable response to RFI’s, or the availability of engineering design drawings, continue to impede the systematic development of construction projects, and hinders the methodical progression of electrical workers’ labor productivity. This research study reveals that Craft Workers are more capable to accurately assess the inaccuracies of engineering design drawings. This is initiated from the drawings being thoroughly evaluated and
implemented by Craft Workers, giving them a significant awareness of errors in engineering drawings. However, Supervisors and Foreman also play an essential role in the project development and adequate sequencing and planning of trade work. Table 19 shows the correlation between construction Supervisors, Foremen, and Electrical Craft Workers.

**Table 19. Frequency Factors – Workers by Group**

<table>
<thead>
<tr>
<th>Labor Productivity Survey Question</th>
<th>Supervisors</th>
<th></th>
<th></th>
<th>Foremen</th>
<th></th>
<th></th>
<th>Electrical Craft Workers</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Rate</td>
<td>Rank</td>
<td>Mean Rate</td>
<td>Rank</td>
<td>Mean Rate</td>
<td>Rank</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are engineers slow to respond to (RFI)</td>
<td>3.622</td>
<td>6</td>
<td>3.771</td>
<td>4</td>
<td>4.000</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How often are the drawings you need to do your job available</td>
<td>3.622</td>
<td>6</td>
<td>3.323</td>
<td>10</td>
<td>3.818</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are vehicle traffic routes on this project are laid out well</td>
<td>3.608</td>
<td>7</td>
<td>3.562</td>
<td>7</td>
<td>3.182</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There is good coordination between the trades</td>
<td>3.554</td>
<td>8</td>
<td>3.552</td>
<td>8</td>
<td>3.091</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There are adequate work crew sizes of all trades on this job</td>
<td>3.527</td>
<td>9</td>
<td>3.615</td>
<td>6</td>
<td>2.818</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How often do errors and omissions in plans and specifications negatively impact your productivity on your current job</td>
<td>3.419</td>
<td>6</td>
<td>3.198</td>
<td>6</td>
<td>3.545</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How often are there errors in the drawings</td>
<td>3.257</td>
<td>10</td>
<td>3.458</td>
<td>9</td>
<td>3.091</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you been delayed in your work due to incomplete prerequisite work</td>
<td>2.932</td>
<td>12</td>
<td>3.031</td>
<td>12</td>
<td>3.273</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How often are 2nd shifts used to meet baseline schedule deadlines</td>
<td>2.378</td>
<td>14</td>
<td>2.052</td>
<td>16</td>
<td>2.237</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There is a lack of communication between management personnel on this project</td>
<td>2.324</td>
<td>16</td>
<td>2.479</td>
<td>13</td>
<td>2.182</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How often a 4-10 work schedule is used</td>
<td>1.905</td>
<td>18</td>
<td>2.021</td>
<td>17</td>
<td>2.455</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Moreover, engineering design inaccuracies have forced workers to remain idle while awaiting corrections from errors and omissions in plans and specifications. Idle time doesn’t add value to the project scope and essentially delays the electrical workers’ completion of the construction project. When asked, “How often do errors and omissions in plans and specifications negatively impact your productivity on your current job?” the mean rating was significant. This coincides with substantial delays in waiting for errors and omissions in
engineering design documents. Lastly, delays’ arising from inadequate sequencing of trade work was another significant issue that stems from the research findings. However, in these circumstances, both Foremen and Electrical Craft Workers were highly correlated, and Supervisors had a subsidiary correlation as it relates to the performance factors that were measured through the survey.

In addition to measuring and examining the mean rating of the performance factors against Electrical Trade job positions, a Spearman Rank Order Correlation test was used to analyzes and rank the directional strength of the association between two variables. Table 20-22 shows the Spearman Rank Test measuring the correlation between Supervisors and Foremen, Supervisors and Electrical Craft Workers, and Foremen and Electrical Craft Workers. They all have significant correlations, of 0.969, 0.9301, and 0.87 respectively, with significant p-values < 0.05 significance level, showing strong evidence of agreement between construction work groups.

### Table 20. Spearman Correlation between Supervisors and Foremen – Frequency Factors

<table>
<thead>
<tr>
<th>Spearman’s rho</th>
<th>Supervisors Correlation Coefficient</th>
<th>Supervisors P-value</th>
<th>Foremen Correlation Coefficient</th>
<th>Foremen P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisors</td>
<td>1</td>
<td>0.969774</td>
<td>1</td>
<td>1.014e-13***</td>
</tr>
<tr>
<td>Foremen</td>
<td>0.969774</td>
<td>1</td>
<td>0.969774</td>
<td>1</td>
</tr>
</tbody>
</table>

Correlation is significant at the 0.0001 significance level: Very Strong Evidence

### Table 21. Spearman Correlation between Supervisors and Craftsmen – Frequency Factors

<table>
<thead>
<tr>
<th>Spearman’s rho</th>
<th>Supervisors Correlation Coefficient</th>
<th>Supervisors P-value</th>
<th>Electrical Craft Workers Correlation Coefficient</th>
<th>Electrical Craft Workers P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisors</td>
<td>1</td>
<td>0.9301282</td>
<td>0.9301282</td>
<td>3.744e-10***</td>
</tr>
<tr>
<td>Electrical Craft Workers</td>
<td>0.9301282</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P-value = 3.744e-10***
Correlation is significant at the 0.0001 significance level: Very Strong Evidence

Table 22. Spearman Correlation between Foremen and Craftsmen – Frequency Factors

<table>
<thead>
<tr>
<th>Spearman’s rho</th>
<th>Foremen</th>
<th>Electrical Craft Workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foremen</td>
<td>Correlation Coefficient</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>P-value</td>
<td>5e-08***</td>
</tr>
<tr>
<td>Electrical Craft Workers</td>
<td>Correlation Coefficient</td>
<td>0.883735</td>
</tr>
<tr>
<td></td>
<td>P-value</td>
<td>5e-08***</td>
</tr>
</tbody>
</table>

The intricate correlation between Foremen and Electrical Craft Workers originates through the personal relationships fostered from the initial front-end planning through erection and completion of the construction project. Foremen direct and instruct Electrical Craft Workers; their relationships are imperative to the timely completion and success of the project. Adequate communication between Workers and their Foreman can improve the correlation among the groups. Through this research we could find a significant agreement correlation between the three groups (Supervisor Foremen, Electrical Worker) that engineers are slow to respond to RFI’s. Additionally, the three groups agreed that errors and omissions significantly impacted project performance. Furthermore, the three groups confined seldom using 2nd shift to accelerate project completion, and they also agreed to rarely using 4-10 work schedule. Finally, these findings correspond with the previous research conducted by CII RT-215, which had 83 data points. The findings of this research are derived from a larger sample size of 182 construction workers, which has enhanced the construction literature in labor productivity.

4.7.2 Labor Performance Factors: Impact

Electrical construction workers can be significantly impacted by innumerable factors that
adversely impact their ability to perform at an effective rate. This research study investigates several factors such as the impact of prefabrication and project training programs on the ability to facilitate and complete project tasks, thus enabling schedule and cost savings. As illustrated in Table 23, a comprehensive list of eight factors shows the disparity among electrical construction job positions. When asked, “Do prefabricated components positively impact the overall productivity of construction projects?” each job position ranked the utilization of prefabricated components as a significant method in their construction process that increases labor production.

<table>
<thead>
<tr>
<th>Impact Factor Question</th>
<th>Supervisors</th>
<th>Foremen</th>
<th>Electrical Craftworkers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does Your relationship with your supervisor positively impacts your productivity</td>
<td>4.081</td>
<td>3.823</td>
<td>4.364</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Does the use of prefabricated components positively impact your productivity</td>
<td>3.986</td>
<td>3.844</td>
<td>4.091</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Has training programs affected your productivity</td>
<td>3.932</td>
<td>3.526</td>
<td>3.909</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Does the usage of daily huddle positively impact your productivity</td>
<td>3.703</td>
<td>3.642</td>
<td>3.545</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Does toolbox meetings positively impact your productivity</td>
<td>3.622</td>
<td>3.469</td>
<td>3.545</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Does working a 4-10 work schedule positively impact your productivity</td>
<td>3.419</td>
<td>2.990</td>
<td>2.273</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Did the job site orientation program positively impact your productivity</td>
<td>2.865</td>
<td>2.854</td>
<td>2.909</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>8</td>
<td>5</td>
</tr>
</tbody>
</table>

Moreover, work schedule and job orientation programs substantially contributed to the impact on labor productivity amongst the surveyed electrical trade workers. It is not surprising that Supervisors ranked the usage of a 4-10 work schedule as more significant than both Foremen and Electrical Craft Workers, even though only a small proportion, (25%), of
construction projects surveyed, utilized 4-10 work schedule. Lastly, this research signifies that there is a significant correlation between construction work groups and are shown in Table 24-26.

Table 24. Spearman Correlation between Supervisors and Foremen – Impact Factors

<table>
<thead>
<tr>
<th>Spearman’s rho</th>
<th>Supervisors Correlation Coefficient</th>
<th>Supervisors</th>
<th>1</th>
<th>0.9461247</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-value</td>
<td></td>
<td></td>
<td></td>
<td>0.0003753**</td>
</tr>
<tr>
<td>Foremen</td>
<td>Correlation Coefficient</td>
<td>0.9461247</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td></td>
<td></td>
<td>0.0003753**</td>
</tr>
</tbody>
</table>

Correlation is significant at the 0.001 significance level: Strong Evidence

Table 25. Spearman Correlation between Supervisors and Craftsmen – Impact Factors

<table>
<thead>
<tr>
<th>Spearman’s rho</th>
<th>Supervisors Correlation Coefficient</th>
<th>Supervisors</th>
<th>1</th>
<th>0.9204013</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-value</td>
<td></td>
<td></td>
<td></td>
<td>0.001187*</td>
</tr>
<tr>
<td>Electrical Craft Worker</td>
<td>Correlation Coefficient</td>
<td>0.9204013</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td></td>
<td></td>
<td>0.001187*</td>
</tr>
</tbody>
</table>

Correlation is significant at the 0.005 significance level: Strong Evidence

Table 26. Spearman Correlation between Foremen and Craftsmen – Impact Factors

<table>
<thead>
<tr>
<th>Spearman’s rho</th>
<th>Foremen Correlation Coefficient</th>
<th>Foremen</th>
<th>1</th>
<th>0.8783101</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-value</td>
<td></td>
<td></td>
<td></td>
<td>0.004104***</td>
</tr>
<tr>
<td>Electrical Craft Worker</td>
<td>Correlation Coefficient</td>
<td>0.8783101</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td></td>
<td></td>
<td>0.004104***</td>
</tr>
</tbody>
</table>

Correlation is significant at the 0.005 significance level: Strong Evidence
4.7.3. **Labor Performance Factors: Project Phase**

Preconstruction planning and front-end planning influence the systematic completion of the construction project. The schedule performance of the construction project was measured, and the electrical workers’ responses were quantified. In doing so, the performance factor, “Percentage of Construction Complete,” were divided into two categories “Less than 50% Project Complete” and “More than 50% Project Complete.” The responses measured as “Less than or Equal to 50% Project Complete” ranged from “Under 25%” to “25%-50%,” while the response for “More than 50% Project Complete” were denoted as “50%-75%” and “above 75%” construction complete. Table 27 goes on to indicate the top 10 mean scale rating for both “Less than 50%” and “More than 50%” Construction Complete. It shows the mean ranking of “Less than 50% Project Complete” and “More than 50% Project Complete” have significant agreement correlations among the project phase. Additionally, the remaining performance factors that were measured can be found in Appendix F.
Table 27. Frequency Factors - Project Phase

<table>
<thead>
<tr>
<th>Frequency Factor Question</th>
<th>Less than or equal to 50% Complete</th>
<th>More than 50% Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Rate</td>
<td>Rank</td>
</tr>
<tr>
<td>There is enough attention to protecting the workers from the weather</td>
<td>3.731</td>
<td>4</td>
</tr>
<tr>
<td>The craft workers from other trades are qualified to do the work</td>
<td>3.687</td>
<td>5</td>
</tr>
<tr>
<td>Engineers are slow to respond (RFI)</td>
<td>3.687</td>
<td>5</td>
</tr>
<tr>
<td>There is good coordination between the trades</td>
<td>3.522</td>
<td>6</td>
</tr>
<tr>
<td>There are adequate work crew sizes of all trades</td>
<td>3.478</td>
<td>8</td>
</tr>
<tr>
<td>Vehicle traffic routes on this project are laid out well</td>
<td>3.493</td>
<td>7</td>
</tr>
<tr>
<td>How often are the drawings you need to do your job available</td>
<td>3.478</td>
<td>8</td>
</tr>
<tr>
<td>How often are there errors in the drawings</td>
<td>3.493</td>
<td>7</td>
</tr>
<tr>
<td>Younger craft workers are as motivated as the older ones on this project</td>
<td>3.164</td>
<td>9</td>
</tr>
<tr>
<td>I’ve been delayed in my work due to incomplete prerequisite work</td>
<td>3.090</td>
<td>10</td>
</tr>
</tbody>
</table>

To reiterate, engineering design practices and procedures were measured extremely high in intervening in the electrical workers’ labor production and the timely completion of the construction project. Inadequate response to RFI’s was again a concern of the electrical workers, and was associated to both project phases (“Less than 50%” and “More than 50%” construction complete). It was not surprising to note the disparity between the project completion phase among the project having adequate work crew size and traffic routes. These performance factors can fluctuate depending on the timely progression of the construction project. The construction industry has viewed overmanning as a methodical tool used to accelerate construction development. However, inadequate staffing of construction workers may cause project delays, an apathetic workforce, and site congestions due to inadequate site planning and vehicle mobilization. Additionally, engineering drawing errors and availability of drawings considered to hinder labor performances of electrical workers. Lastly, Table 28 shows a significant correlation
between “Less than 50%” and “More than 50%” project completion, with a p-value less than 0.000001 at 0.05 significance level that shows very strong evidence of agreement between the project phase.

**Table 28. Spearman Rank Order Correlation for Project Phase – Frequency Factors**

<table>
<thead>
<tr>
<th>Spearman’s rho</th>
<th>Less than or = to 50%</th>
<th>More than 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than or = to 50%</td>
<td>Correlation Coefficient</td>
<td>1</td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td>8.295e-15***</td>
</tr>
<tr>
<td>More than 50%</td>
<td>Correlation Coefficient</td>
<td>0.9765338</td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td>8.295e-15***</td>
</tr>
</tbody>
</table>

Correlation is significant at the 0.0001 significance level: Very Strong Evidence

**4.8 Conclusion**

The different characteristics revealed through the survey have enabled a more precise understanding of the performance factors that influence the construction industry workforce. Through the investigation of the experience of the 182 electrical workers, it was revealed that they encompass a knowledge pertaining to labor ineptitudes that influence the progression of the construction project.

The analysis centered on the conceptual framework of electrical trade job positions, and the agreement between Electrical Workers, Foremen, and Supervisors. The construction workforce agreed that inadequate engineering design practices, unavailability of RFI’s, and errors and omission in design documents have significant impact on the performance of workers on a construction project. Additionally, construction project phase was analyzed, and it revealed that majority of the factors have a substantial agreement correlation to project phasing. The project phase had similar factor correlation. For instance, adequate attention being paid to
protecting workers from inclement weather, and the qualification of other trades workers on the project were highly correlated and significant to electrical workers’ labor performance. The correlation of the performance factors has enabled this research to conclude several reputable findings that will be presented in the succeeding chapter.
Chapter 5: Electrical Industry Recommendations

5.1 Introduction

The findings that were quantified in Chapter 4 revealed several statistically significant results that will be able to benefit the labor performance practices of electrical workers. Additionally, the construction industry could utilize the findings of the preceding chapter to enhance industry practices, thus improving the labor production of construction projects. The results exemplified in the previous chapter stem from the perceptions of 182 electrical construction workers from 18 different states and providences in both the U.S. and Canada.

The electrical workers’ awareness of labor-practice has allowed a profound and capacious understanding of the root causes that hinder labor performances within the electrical construction industry. The principal foundation that carries the load of the construction project is the construction workforce. Without their experience, understanding of the project, quality of work, and pure exertion, and the construction project would remain stagnant.

The electrical construction workforce is responsible for implementing the scope of the project in a rapid and appropriate manner to increase the labor productivity of the project. It can be noted that the research findings were not entirely adversely impacting the labor productivity of the electrical workforce. Some conclusive results that were found through the research were the use of orientation programs, prefabrication, and daily huddle meetings. These factors played a critical role in enabling the electrical workers the ability to have clear understanding of their day-to-day work activity on the construction project. Therefore, this chapter will make recommendations that will enable owners, general contractors, and construction companies the ability to enhance the recognition of allying factors that impact labor production.
5.2 Implication of Performance Factors

The research findings were separated into sections to better relate and categorize the research results. The categories were electrical workers’ demography, Work Schedule, Resources, Engineering, Supervision, Project Management, Safety, and Prefabrication. This also serves as the breakdown of the survey questionnaire that was administered to the electrical workers. Their understanding of the conditions and effects on the performance factors was pivotal in acquiring significant results that were found statistically significant at an alpha confidence level of 0.05. The correlations and trends like the disparity among job positions such as Supervisor, Foremen, Electrical Worker and their fundamental understanding of these factors were analyzed in the preceding chapter. This section looks to examine the findings and solicit recommendations for construction industry personnel.

5.2.1 Worker Demographics

The holistic increase in the average working age of electrical construction workers has continued to be problematic for the industry. The findings of this research study revealed that the average age of electrical construction workers was 41.2 years, with 24.06 years of construction work experience, and 14.67 years of current company work experience. The construction workers typically held post high school accolades, with 47% acquiring a college degree, 34% being trained in vocational or trade school, and the remaining 19% held a high school diploma. A staggering 98% of the electrical workers surveyed were employed by a union contractor, and 76% of the workers have completed apprenticeship training either from their union contractors or construction company. The training included leadership, technical, and safety, and the electrical workers responded (62%, 25%, 9% respectively). The research provides recommendations to improve these numerical findings, which are:

- Transcending the construction industry to become a more attractive trade for Millennia’s.
Continuing to improve the utilization of innovative and contemporary devices and software.

Retaining younger and inexperienced workers through mentoring programs.

Rotational system geared towards finding the most suitable position for inexperienced workers.

- Incentivize vocational and trade schooling.
  - Target underprivileged and marginalized high school districts.

- Early engagement with apprenticeship training programs.
  - Improve the awareness of safety training by implementing mandatory training.
  - Extend leadership training to aid in improving inefficient workers’ productivity.

### 5.2.2 Work Schedule

Appropriate construction schedule is pivotal to the timely completion of any construction project. The proper sequencing, planning, and coordination of construction tasks into a comprehensive methodical construction schedule continues to be an enormous challenge for the construction industry. The innovative software and applications that are used in today’s building development have tremendously improved the coordination and sequencing of workers’ task and activities on construction projects. However, the industry can still benefit from additional solutions to combat scheduling inaccuracies.

This research study reported that majority of the construction projects 66% did not utilize 2nd shift work to meet project baseline and were mainly utilizing a 5-8 work schedule 86%. Minimizing the usage of 2nd shift reduces project cost and it also reduces congestion on the project site. For this to occur, the project must be efficiently planned and scheduled, with minimum delays to the critical path of the project. Delays in construction are inevitable,
However, to mitigate construction delays, these solutions are offered:

- Allowing electrical construction workers to assist the construction team during the front-end planning and scheduling.
  - Determining the ideal construction sequence (Critical Path).
- Understand when to properly utilize 2nd shift.
- Substantially decrease overtime usage.
- Proper communication amongst construction team members that includes designers, architects, owners, contractors, subcontractors, suppliers.

5.2.3 Resources

The success of a project can be determined by several factors. Appropriate acquisition of project resources is a primary cause of project success or failure. Availability of tools such as power tools, pliers, cable pullers, equipment like cranes and lifts, and material including but not limited to electrical wires, conduits, and light fixtures are indispensable to the systematic development of the construction project as well as the productivity of the construction workers. The time used in acquiring the right resources can be utilized to add value to the progression of the construction project, rather than delaying and reducing the production of electrical workers on the projects.

According to the findings of this research study, the electrical workers generally waited “1-2 hours a week” on tools, information, and materials (70%, 77%, and 64%, respectively). While 36% of electrical workers wait “3-4 hours a week” and “5 or more hours a week” for adequate environment. Environment pertains to the ability of workers to have suitable horizontal and vertical space to properly perform their work activity. Additionally, 41% of electrical workers surveyed reported that they must stop work occasionally to wait for appropriate environment. So, to combat the concerns of inappropriate allocation of resources on
a construction project, these solutions are acknowledged:

- Utilize technological software to improve trade sequence
- Enhance the relation between different trades with collaborative learning
- Enable electrical workers to be personally responsible for tools and equipment
- Improve tool-loan system by tracking tools with electronic code
- Improve utilization skills of equipment operators
- Improve material storage facility
- Decrease over-stocking of material storage facility
- Maintain adequate lead time for unique materials and equipment
- De-congest working area

5.2.4 Engineering

Appropriate engineering design for plans and specification is essential to the timely completion of the construction project. The construction industry is aware that inaccurate engineering designs can lead to lengthy delays in construction schedules, unproductive workforces, and cost overruns for construction projects. The ability of general contractors to work alongside engineers and architects is pivotal to the success of the project, and the production of electrical workers.

For instance, the notion of adequate engineering design throughout pre-construction planning through substantial completion is pivotal to the success or failure of the construction project. The precise and accurate understanding of this notion is critical in improving labor productivity within the industry. This research has shown that inadequate engineering design practices such as errors and omissions in plans and specifications, design drawing inaccuracies, and slow response to RFI’s has systematically impeded the production of electrical construction
workers. To further validate the research findings, engineering design inaccuracies were seen to have adverse impacts on labor production regarding projects productivity level being “Less and More Productive Projects” and were also shown in projects phase that were “Less than or More than 50% construction completed.” To combat these industry concerns, the following solutions are proposed:

- Enhance the communication amongst project team members.
- Increase the availability of Engineering personnel on-site.
- Consistently examine drawings and plans for errors.
- Continue to foster a lasting relationship with field and office personnel.
- Utilize innovative devices and software to enhance the response time for RFI’s.
- Determine an incentive system for engineers to respond to variation in design documents.

5.2.5 Supervision & Project Management

Construction projects are subject to numerous changes due to the perpetual contrasting variables that delay, prolong or completely halt construction production on site. Supervisors and project management personnel are responsible for accurately executing the scope of the construction project while maintaining a cohesive and productive workforce. Project coordination and sequencing are crucial to the timely completion of the construction project. Project managers are tasked with directing, maintaining, and managing site logistics, manpower availability, and communication amongst construction field and engineering office personnel. Supervisors direct and inform electrical workers on tasks that need to be implemented through the progression of the project. The passable efforts of construction worker supervisors and project managers can severely impact the production of electrical workers while performing their
work activities.

This research initiates the findings from which delays arise. The incomplete prerequisite work of other trades were correlated to have a significant adverse impact on electrical worker labor productivity. However, other factors such as the relationship between supervisor and worker, the supervisor’s ability to receive appropriate support from the project administrative team, adequate work crew size, and appropriate coordination between trades were associated to have an encouraging impact among the electrical workers surveyed. Lastly, the lack of communication between management personnel on site was weighed as having significant impact on labor production of the electrical workforce. To combat these project managerial and supervision concerns, this research shows the following recommendations:

- Improve communication between trade personnel to reduce the lack of incomplete prerequisite work.
- Enhance trade sequencing in order to reduce rework.
- Improve communication amongst trades.
  - Utilize production incentive to improve labor production.
- Decongest construction site.
- Initiate checklist for construction workforce to thoroughly understand what activities that need to performed and when it needs to be completed.
- Improve communication between construction field office and construction workers on site.
- Implement field staffing presence on site to check project development.
5.2.6 Safety

Electrical construction is one of the more labor-intensive trades within the industry. Workers are tasked with the proper distribution of high-powered voltage, and the safety of these workers is the number one priority of the electrical construction industry. Allowing these men and women the ability to return home to their families is essential to those within the industry. The electrical construction industry is subjected to follow rules and regulations governed through the Environmental Protection Agency (EPA), National Electrical Contractors Association (NECA), city and state building codes. These regulations oversee the safety of construction companies granting them an Experience Modification Rate (EMR). A company with an EMR rating less than one signifies a good safety record, while a company with an EMR exceeding one reflects that their safety record may be a bit tarnished due to worker compensation claims or injuries on their construction site.

The findings of this research suggest that safety factors such as supervisors’ usage of toolbox meetings to reiterate proper safety practices on the construction site were viewed to have a positive correlation to the project’s production development. Safety issues are main concern for all industries, more importantly, the electrical construction industry due to workers’ exposure to high voltages. Even while using hard hats, safety glasses, gloves, and Hi-Viz vests, additional precautions can always be implemented to improve safety conditions within the construction industry. In general, the electrical workers’ responses to safety conditions on their job site were positive, so a few recommendations will be stated:

- Encourage electrical worker to be involved in Toolbox Meetings.
- Decongest construction work area (Appropriate material and equipment management)
• Implement incentives for appropriate safety record.

5.2.7 Prefabrication

The development and progression of the construction industry and the ability of the industry to retain project-cost savings is due to proper utilization of prefabricated components. These components which includes electrical rooms, rough-in, conduit, and breaker boxes have significantly improved the holistic production and performance of electrical workers. More importantly, the electrical construction trade has benefited significantly from the application of prefabricated components. The minuscule and intricate electrical components such as screws, wire connectors, electrical tape, and so on can be placed prior to installation accelerates the activity, thus improving the project schedule. The research findings correspond to the notion of prefabrication having a significant positive impact to electrical workers’ labor production. The construction industry should continue to implement prefabricated components in building construction. It has significant improvements to the construction industry by means of quality, time and financial cost savings. There are two recommendations that this research has sought out through its findings:

• Encourage experienced workers to divert to more contemporary construction methods.
• Continue to foster and implement innovative construction practices and methods.

5.3 Conclusion

Thorough analysis has concluded that labor production of electrical workers can be severely influenced by project work schedule, insufficient engineering design practices, and the lack of proper resources on the project site. Additionally, other factors such as safety, managerial team commitment, and the use of prefabricated components can significantly impact
worker labor production. However, sufficient communication was the most recurring recommendation made to industry personnel. A project that uses ample communication can acquire solutions to problems that arise more rapidly. For example, if an outlet needs to be moved to the other side of the door, satisfactory communication between the electrician and the project Supervisor can present a solution to the situation. Proper communication enables an unambiguous project site and increases the labor production of electrical workers. Additionally, insufficient engineering design practices and methods have continued to impact the production of electrical workers. Slow response to RFI’s, errors and omission in engineering drawings, and deficient plans and specifications were shown to impede labor performance. However, this section has made recommendations to the construction industry derived from the factors that impact labor production within the industry. This demonstrates the exceptional insight and knowledge that electrical construction workers possess pertaining to assessing acceptable labor production practices.
Chapter 6 Summary and Conclusion

6.1 Introduction

Labor productivity and labor practices in the electrical construction industry continue to be a leading concern of the construction industry. This is due to the severe risk and the labor intensiveness involved with the electrical construction trade. The electrical workforce is present throughout all developmental phases of construction from installing temporary lighting for construction through the completion of the construction project. In addition, the electrical workers remain a part of the building life-cycle even after the building is constructed. This is done through the maintenance and preservation of the building by replacing and upgrading the building’s electrical components. Enhancing the production of the electrical workforce will improve overall labor performance and ultimately improve labor production practices of the electrical construction trade.

Additionally, the industry has faced various factors that have impacted the systematic production of electrical workers and their ability to sufficiently complete work in a timely manner. Factors such as availability of resources, adequate project scheduling, and accurate engineering drawings plays a vital role in the progression of the construction project. More specifically, the electrical contracting trade has faced numerous challenges relating to construction industry practices, methods, and innovations that impact worker productivity. The electrical workers’ knowledge has enabled this research to gain an essential understanding of construction methods and factors that impede production. This chapter will summarize the findings of this research study and propose summaries for the methodology and results while simultaneously providing research limitations and discussing future research.
6.2 Research Summary

Chapter 1 examines the history of labor productivity in both the U.S and Canada as well as, how the industry has continued to struggle with labor production rates. Additionally, this chapter includes the problem statement, motivation, objectives, and methodology by which the research was formulated and performed as well as the collection of data. The scope of the research is also included in this chapter.

Chapter 2 provides an extensive literature review pertaining to the multiple factors that impact labor production within the electrical construction industry. The literature review provided an in-depth understanding of these factors such as adequate scheduling, proper allocation of resources, appropriate engineering planning and design, and adequate communication between project managerial personnel and construction workers.

Chapter 3 details the methodology that was required to formulate, distribute, and examine the data that was collected from the 182 electrical construction workers. Furthermore, data characteristics such as electrical worker demographics, company information, and project information were revealed and analyzed. The data collected encompasses 18 different states and providences in both the U.S. and Canada.

Chapter 4 contains an extensive statistical analysis of the data. The initial analysis was performed using descriptive statistics to acquire the mean average and standard deviation for the age, construction experience, and work experience of the electrical workers. Additionally, mean scale ratings were utilized to appropriately rank the 21 performance factors. It was revealed that inaccuracies in engineering design and inadequate communication among project teams were the most critical components that impact the progression of electrical workers within the construction industry. Lastly, the Spearman Rank Order Correlation Test was utilized to determine the correlation and rank the directional strength of the factors being analyzed with a
0.05 confidence level.

Chapter 5 makes suitable recommendations to improve the labor performance within the electrical construction industry. These recommendations were based on the results and data analysis performed in the previous chapters. They pertain to the aging electrical workforce, work schedule, availability of resources, adequate engineering practices, appropriate supervisor and management support, safety, and the use of prefabrication.

6.3 Result Summary
Electrical workers continue to face challenges pertaining to their labor production:

1. The electrical workforce continues to endure a significant rise in inexperienced workers. This is due to the inability of these inexperienced workers to learn and implement the labor-intensive task of the electrical construction industry. Developing a mentorship program where experienced workers could mentor and guide inexperienced workers is crucial to the construction industry’s ability to acquire and retain a younger and better-trained workforce.

2. The electrical workers’ responses to the survey questionnaire gave a clear and precise insight of those factors that adversely impacted labor production. Factors such as, delays due to incomplete prerequisite work, errors and omissions in plans and specifications, and lack of communication between managerial personnel were found to unfavorably impact workers’ labor productivity.

3. Additionally, the survey questionnaire determined factors which positively impacted the electrical workers’ ability to perform their work task. The use of prefabricated components, the workers’ relationship with their direct supervisor, and the use of
apprenticeship training were exceedingly significant to cultivating appropriate labor production.

4. Frequency of factors that impacted electrical workers’ labor productivity were also analyzed. The usage of a 5-8 work schedule, the slow response to RFI’s, and the availability of adequate engineering drawings were ranked as the most frequent outcomes on the construction project. Sixty-eight percent of the electrical workers prefer to work a 4-10 work schedules, however, 86% of the companies utilize a 5-8 work schedules.

5. The electrical workers’ responded that the use of 2\textsuperscript{nd} shift to advance project schedule was rarely used on their construction projects.

6. Most electrical workers’ 69% worked 40-50-hour work weeks. Additionally, 15% worked overtime on their construction project, working over 50 hours a week.

7. Electrical workers typically await adequate resources such as tools, information, material and environment approximately for “1-2 hours a week.”

8. Surprisingly, 83% of electrical workers were delayed in their work due to incomplete prerequisite work.

9. The Spearman Rank Correlation Test signified the correlation between job positions like Supervisor, Foreman, and Electrical Worker. Engineering design concerns such as, delays due to RFI’s, availability of engineering designs, and errors in design drawings were decidedly ranked for all job positions. The ranks were significantly correlated at 0.969, 0.9301, and 0.87 respectively, with significant p-values < 0.05 significance level. These results coincide with the findings of the 2006 CII Craft Labor study.

10. It is astonishing to note that 94% of electrical workers surveyed responded to waiting for response to RFI’s.
11. Less productive and more productive jobs were also analyzed. The mean ratings were significant with the performance factors such as qualified electrical workers, utilization of a 5-8 work schedule, and adequate attention towards weather protection of the project. These factors were highly favored to be the most impactful to electrical workers’ labor productivity.

12. Less than 50% construction complete and more than 50% construction complete were also analyzed to determine the factors that impact labor production. The results were similar the job productivity frequency factors. Adequate attention to weather protection, qualification of other trades, and the response to RFI’s were highly correlated to impact electrical worker labor productivity.

6.4 Research Limitation
The scope and objective of the research was limited by the data collected from the 182 electrical construction workers from the U.S. and Canada. The comprehensive survey ascertained credible results from the electrical workers, and was limited to their perception of labor productivity. The contractual document related to professional and contractual agreement such as, Design Bid Build (DBB), Design Build (DB), and Integrated Project Delivery Methods (IPD), were subjectively related to project production and less related to electrical worker performance. This allowed us to exclude contractual documents from the survey. Additionally, contract types such as lump sum, cost reimbursement, unit cost, and guaranteed maximum price were not examined by this research study. Finally, the survey questionnaire was unable to acquire adequate information pertaining to project man hour, which could have significantly enhanced the statistical analysis of the findings. Nonetheless, the results of this research enhanced the industry’s fundamental understanding of labor productivity from the view of
6.5 Future Research

There has been extensive research performed on the shortcomings in labor production within the construction industry. However, there has been limited current research done to acquire the perception of the laborers that perform these labor-intensive work tasks. More specifically, the industry is further limited in acquiring information pertaining to the inaccuracies in labor productivity within the electrical contracting trade. In relation to future research, a methodological comparison can be performed to correlate safety as a significant component of electrical workers’ labor performance. This research study briefly discussed safety as a significant risk of electrical workers. However, future research can expand the breadth of knowledge in the electrical construction industry by examining safety as it relates to the construction of high-powered electrical grids, substations and electrical rooms. A critical component of the construction project sequencing is to have the electrical room built and installed first to have an initial point of contact for the remaining trades.

6.6 Conclusion

The fundamental purpose of this research was to acquire suitable knowledge and understanding of electrical construction workers on their perspective of labor productivity ineptitudes within the construction industry. Additionally, the objectives of this research were to analyze the influence of delayed labor production on electrical workers, and examine future improvements to labor performance within the electrical construction industry. These objectives were fulfilled through the research findings collected through the survey questionnaire. The research findings are intended to be used as a tool to improve and enhance labor productivity of the electrical construction industry. These findings may also be used by other trades to improve
labor productivity.
References


kProject and Phase Level.” Journal of Construction Engineering and Management.


Thomas. Jacqueline. (2009),” Craft Productivity Program-Phase 1.” A Report to the Construction Industry Institute, The Univ. of Texas at Austin, Research Report 252-1


Appendix A-Survey Cover Letter

Dear Craft Worker:

We are writing to request your participation in this survey on labor productivity. This study will benefit the civil, mechanical, plumbing, and electrical industries, and your participation will allow for a more thorough examination of labor productivity. The questionnaire will take approximately 30 minutes to complete. In compensation for your participation, you will receive a free copy of the report.

The information you provide will be held in confidence, and we will not share names of specific individuals, organizations, or projects. To gain the most accurate information, each section should be completed in its entirety. In addition to this questionnaire, we have also included a section for you to write additional comments that can be considered for future research analysis.

Thank you for your time and for your commitment to our research. We will contact you within the next week to make sure you have received the questionnaire. If you have any questions, please feel free to contact either Dr. Awad Hanna or Godwin Offiah at the numbers listed below.

Sincerely,

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Godwin Ashley Dilibe Offiah
Graduate Research Assistant
601-832-0462
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Appendix B-Electrical Worker Survey Questionnaire

Section 1 – Personal Questions

1. How old are you? _______ years old

2. What is your highest level of education?
   o Less than High School Diploma
   o High School Graduate
   o General Education Development (GED)
   o Vocational or Trade School
   o College Graduate
   o Other (please specify) ______________________

3. What is your first language?
   o English
   o Spanish
   o French
   o Other (please specify) ______________________

4. Please describe yourself
   o General foreman
   o Non-working foreman (A Foreman)
   o Working foreman
   o Journeyman
   o Apprentice (what year)_______
   o Pre-apprentice
   o Material Handler
   o Helper
   o Other (please specify) ______________________

5. How long have you been working in the construction industry? ______

6. How long have you been working with your current employer? ______

7. How many construction employers have you worked for over the past (5) years?
   o 1-2
   o 3-4
   o 5+

8. How many miles are you from your jobsite?
   o Less than 10 miles
   o 10-30 miles
   o 30-60 miles
   o 60-100 miles
   o More than 100 miles

9. Where do you work? (City and State, or Province) _________________

10. Please indicate the type of construction most commonly performed by your company?
    o Residential
    o Commercial
    o Manufacturing
11. How many projects are performed by your company in a typical year?  
   - 1-10 projects a year  
   - 11-20 projects a year  
   - 21-30 projects a year  
   - 31-40 projects a year  
   - More than 40 projects a year  
   - I do not know  

12. What is the average dollar value of work performed annually by your company?  
   - $0-$500,000  
   - $500,001-$1,000,000  
   - $1,000,001-$5,000,000  
   - $5,000,001-$20,000,000  
   - $20,000,001-$50,000,000  
   - Greater than $50,000,000  
   - I do not know  

13. How many workers are currently employed full time by your company?  
   - 0-40 employees  
   - 41-100 employees  
   - 101-300 employees  
   - 301-500 employees  
   - 501-1000 employees  
   - Greater than 1000 employees  
   - I do not know  

14. What is your affiliation?  
   - Union  
   - Nonunion  
   - Both  

15. Have you completed any formal apprenticeship training programs (Union Apprenticeship, National Center for Construction Education and Research Apprenticeship, Associated Builders and Contractors Inc. (ABC) Apprenticeship program, or any other)?  
   - Yes  
   - No  

16. How has the program affected your productivity on your current construction project?
17. What type of training have you received as a journeyman or foreman in the last two years?
   - Leadership Development
   - Technical
   - Other______
   - None

18. How frequently did you receive training as a journeyman or foreman?
   - 1-2 per year
   - 3-4 per year
   - 5 or more
   - N/A

Section 2 – Crew Schedule

19. How many hours do you typically work a week for your current construction project?
   - Less than 40 hours/week
   - 40-50 hours/week
   - 50-60 hours/week
   - More than 60 hours/week

20. How often do you work a 4-10 work schedule (working 10 hours a day for 4 straight days)?
   - Never
   - Rarely
   - Sometimes
   - Most of the time
   - Always

21. How often do you work a 5-8 work schedule (working 8 hours a day for 5 straight days)?
   - Never
   - Rarely
   - Sometimes
   - Most of the time
   - Always

22. Which crew schedule do you prefer?
   - 4-10 hours/day
   - 5-8 hours/day
23. Does working a 4-10 work schedule positively impact your productivity?
   - Not at All
   - A Little
   - Somewhat
   - Quite a Bit
   - A Great Deal
   - N/A

24. How often do you work a 2nd shift to meet baseline schedule deadlines?
   - Never
   - Rarely
   - Sometimes
   - Most of the time
   - Always

25. What is the approximate percentage of construction completed at the time of this survey?
   - Under 25%
   - 25%-50%
   - 50%-75%
   - Above 75%
   - Don’t know

26. What is the current schedule performance of this construction project against the baseline plan?
   - Behind Schedule
   - On Schedule
   - Ahead of Schedule
   - I do not know

27. Compared to past jobs, please rate your overall productivity on this job:
   - 1 – least productive job
   - 2 – below average productivity
   - 3 – average productivity
   - 4 – above average productivity
   - 5 – most productive job

28. Does your supervisor hold a daily huddle each morning before work begins to explain what needs to be done by who and where?
   - Yes
   - No

29. Does the daily huddle positively impact your productivity?
   - Not at All
   - A Little
   - Somewhat
   - Quite a Bit
   - A Great Deal
   - N/A
Section 3 – Resources

Tools: Tools include cordless drills, impact drills, chop saws, ladders, dry vacuums, etc.

30. Do you often have to stop work, wait, or move to another area because you do not have adequate tools you need to perform your job?
   - Yes
   - No

31. How many hours per week would you estimate you spend waiting for tools, retrieving tools, or moving to a different area due to lack of tools?
   - 1-2 hours a week
   - 3-4 hours a week
   - 4-5 hours a week
   - More than 5 hours a week
   - N/A

32. Which of the following tools are most often in short supply on the job site?
   - Cord/Cordless Drill
   - Skill Saw
   - Ladders
   - Other (please specify) __________________________

Information

33. Do you often waste time waiting for your supervisor to give you adequate information on what you are supposed to be doing?
   - Yes
   - No

34. How many hours per week would you estimate you spend waiting to get information about what you are supposed to be doing?
   - 1-2 hours a week
   - 3-4 hours a week
   - 4-5 hours a week
   - More than 5 hours a week
   - N/A

Materials

35. Do you often have to stop work, wait, or move to another area because you do not have the materials you need to perform your job?
   - Yes
   - No

36. How many hours per week would you estimate you spend waiting for materials, retrieving materials, or moving to a different area due to lack of materials?
   - 1-2 hours a week
   - 3-4 hours a week
   - 4-5 hours a week
37. In most cases, the material store is:
   - In very close proximity to the work area
   - In a laydown area within the site
   - In a warehouse facility outside the site

38. There is enough room on the site for material storage.
   - Yes
   - No

Environment

Environment indicates the availability of adequate space for you to do your work, adequate horizontal and vertical transportation, and availability of sequential space to perform repetitive work.

39. Do you often have to stop work, wait, or move to another area because you do not have an adequate environment (used by stacking of trades, lack of vertical transportation, space, etc.)?
   - Yes
   - No

40. How often do you stop work, wait, or move to another area because you do not have an adequate environment (used by stacking of trades, lack of vertical transportation, space, etc.)?
   - 1-2 hours a week
   - 3-4 hours a week
   - 4-5 hours a week
   - More than 5 hours a week
   - N/A

41. There are not enough temporary facilities (toilets, break areas, drinking water dispensers, etc.) on the site.
   - Yes
   - No

Section 4 – Supervision

42. Compared to past jobs, please rate the overall safety of this job:
   - 1 – least safe job
   - 2 – poor safety
   - 3 – average safety
   - 4 – good safety
   - 5 – safest job

43. How often do safety conditions negatively impact your productivity on your current job?
o Never
o Rarely
o Sometimes
o Most of the time
o Always

44. Does your supervisor hold toolbox meeting to re-emphasize safety?
   o Yes
   o No

45. Do toolbox meetings positively impact your productivity?
   o Never
   o Rarely
   o Sometimes
   o Most of the time
   o Always
   o N/A

Section 5 – Engineering

46. How often do errors and omissions in plans and specifications negatively impact your productivity on your current job?
   o Never
   o Rarely
   o Sometimes
   o Most of the time
   o Always

47. How often are there errors in the drawings that you use?
   o Never
   o Rarely
   o Sometimes
   o Most of the time
   o Always

48. How often are the drawings you need to do your job readily available?
   o Never
   o Rarely
   o Sometimes
   o Most of the time
   o Always

49. When there is a question or problem with a drawing, the engineers are slow to respond to Request for Information (RFI).
Section 6 – Project Managers for the General Contractors

50. I’ve been delayed in my work because prerequisite work was not done.
   - Never
   - Rarely
   - Sometimes
   - Most of the time
   - Always

51. I’ve been delayed in my work because of the absenteeism of other workers.
   - Never
   - Rarely
   - Sometimes
   - Most of the time
   - Always

52. There is good coordination between the trades.
   - 1-strongly disagree
   - 2-disagree
   - 3-neither agree nor disagree
   - 4-agree
   - 5-strongly agree

53. There are adequate work crew sizes of all trades on this job.
   - 1-strongly disagree
   - 2-disagree
   - 3-neither agree nor disagree
   - 4-agree
   - 5-strongly agree

54. Vehicle traffic routes on this project are laid out well.
   - 1-strongly disagree
   - 2-disagree
   - 3-neither agree nor disagree
   - 4-agree
   - 5-strongly agree

55. Enough attention is paid to protecting the workers from the weather.
   - 1-strongly disagree
   - 2-disagree
   - 3-neither agree nor disagree
   - 4-agree
Section 7 – Supervision

56. Your relationship with your supervisor positively impacts your productivity on this job.
   - Not at All
   - A Little
   - Somewhat
   - Quite a Bit
   - A Great Deal

57. There is a lack of communication between management personnel on this project.
   - 1-strongly disagree
   - 2-disagree
   - 3-neither agree nor disagree
   - 4-agree
   - 5-strongly agree

58. There is a lack of communication between my supervisor and craft workers on this project.
   - 1-strongly disagree
   - 2-disagree
   - 3-neither agree nor disagree
   - 4-agree
   - 5-strongly agree

59. On this project, craft workers trust their supervisors.
   - 1-strongly disagree
   - 2-disagree
   - 3-neither agree nor disagree
   - 4-agree
   - 5-strongly agree

60. My direct supervisor receives the support he needs from administration that allows us to complete our jobs more effectively (warehouse, equipment, supervisors, etc.)
   - 1-strongly disagree
   - 2-disagree
   - 3-neither agree nor disagree
   - 4-agree
   - 5-strongly agree
Section 8 – Labor

61. I attended a jobsite orientation program on this project.
   - Yes
   - No

62. Did the jobsite orientation program positively impact your productivity on this job?
   - Not at All
   - A Little
   - Somewhat
   - Quite a Bit
   - A Great Deal
   - N/A

63. The craft workers from your trade on this project are qualified to do the work.
   - 1-strongly disagree
   - 2-disagree
   - 3-neither agree nor disagree
   - 4-agree
   - 5-strongly agree

64. The craft workers from other trades on this project are qualified to do the work.
   - 1-strongly disagree
   - 2-disagree
   - 3-neither agree nor disagree
   - 4-agree
   - 5-strongly agree

65. Younger craft workers are as motivated as the older ones on this project.
   - 1-strongly disagree
   - 2-disagree
   - 3-neither agree nor disagree
   - 4-agree
   - 5-strongly agree

Section 9 – Prefabrication

66. Does your trade perform any prefabricated work on this construction project?
   - Yes
   - No

67. Which items are prefabricated? (Select all that apply)
   - Rough In Electrical Systems
   - Switches and Outlets
   - Electrical Conduits
   - Light Fixtures
   - Fixtures mounts and braces
   - Breakers
   - Other______________
68. Prefabricated components positively impact the overall productivity of a construction projects.
   o 1-strongly disagree
   o 2-disagree
   o 3-neither agree nor disagree
   o 4-agree
   o 5-strongly agree

69. Does the workforce resist use prefabricated components?
   o Yes
   o No
   o N/A

This is the end of the questionnaire.

Thank you for completing the survey and for your time.
# Appendix C - Performance Factors that Influence Labor Productivity (Positive)

<table>
<thead>
<tr>
<th>Categories</th>
<th>Factors that Impact Labor Production</th>
<th>Positive</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>The craft workers from your trade on this project are qualified to do the work.</td>
<td>Positive</td>
<td>4.03</td>
<td>0.61</td>
</tr>
<tr>
<td>Supervisor</td>
<td>Your Relationship with your supervisor positively impacts your productivity on this job?</td>
<td>Positive</td>
<td>3.96</td>
<td>0.91</td>
</tr>
<tr>
<td>Prefabrication</td>
<td>Prefabricated components positively impact the overall productivity of a construction project?</td>
<td>Positive</td>
<td>3.92</td>
<td>0.79</td>
</tr>
<tr>
<td>Supervisor</td>
<td>My direct Supervisor receives the support he needs from administration that allows us to complete our jobs more effectively?</td>
<td>Positive</td>
<td>3.81</td>
<td>0.59</td>
</tr>
<tr>
<td>Supervisor</td>
<td>Mutual trust between craft workers, foremen, and supervisors.</td>
<td>Positive</td>
<td>3.80</td>
<td>0.58</td>
</tr>
<tr>
<td>Management</td>
<td>Enough attention is paid to protecting the workers from the weather</td>
<td>Positive</td>
<td>3.78</td>
<td>0.57</td>
</tr>
<tr>
<td>Labor</td>
<td>How has apprenticeship training program impact your labor productivity?</td>
<td>Positive</td>
<td>3.72</td>
<td>1.79</td>
</tr>
<tr>
<td>Labor</td>
<td>The craft workers from other trades on this project are qualified to do the work.</td>
<td>Positive</td>
<td>3.71</td>
<td>0.61</td>
</tr>
<tr>
<td>Labor</td>
<td>Does daily huddle meetings positively impact your productivity?</td>
<td>Positive</td>
<td>3.66</td>
<td>0.85</td>
</tr>
<tr>
<td>Management</td>
<td>Vehicle traffic routes on this project are laid out well.</td>
<td>Positive</td>
<td>3.55</td>
<td>0.76</td>
</tr>
<tr>
<td>Safety</td>
<td>Do toolbox meetings positively impact your productivity?</td>
<td>Positive</td>
<td>3.54</td>
<td>0.98</td>
</tr>
<tr>
<td>Management</td>
<td>There are adequate work crew sizes of all trades on this job.</td>
<td>Positive</td>
<td>3.53</td>
<td>0.77</td>
</tr>
<tr>
<td>Management</td>
<td>There is good coordination between the trades.</td>
<td>Positive</td>
<td>3.52</td>
<td>0.77</td>
</tr>
<tr>
<td>Safety</td>
<td>Compared to past jobs, please rate the overall safety of this job?</td>
<td>Positive</td>
<td>3.34</td>
<td>0.91</td>
</tr>
<tr>
<td>Labor</td>
<td>Younger craft workers are motivated to perform activities.</td>
<td>Positive</td>
<td>3.08</td>
<td>0.83</td>
</tr>
<tr>
<td>Labor</td>
<td>Productivity rating of current construction project.</td>
<td>Positive</td>
<td>3.08</td>
<td>0.67</td>
</tr>
<tr>
<td>Labor</td>
<td>Does Jobsite orientation programs positively impact your productivity on this job?</td>
<td>Positive</td>
<td>2.86</td>
<td>0.97</td>
</tr>
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</table>
## Appendix D-Frequency Factors – Workers by Group

<table>
<thead>
<tr>
<th>Frequency Factor Question</th>
<th>Supervisors</th>
<th></th>
<th></th>
<th>Foremen</th>
<th></th>
<th></th>
<th>Craftworkers</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>How often a 4-10 work schedule is used?</td>
<td>1.905</td>
<td>18</td>
<td></td>
<td>2.021</td>
<td>17</td>
<td></td>
<td>2.455</td>
<td>12</td>
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<tr>
<td>How often a 5-8 work schedule is used?</td>
<td>4.000</td>
<td>2</td>
<td>3.884</td>
<td>2</td>
<td>3.545</td>
<td>4</td>
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<td></td>
</tr>
<tr>
<td>How often are 2nd shifts used to meet baseline schedule deadlines?</td>
<td>2.378</td>
<td>14</td>
<td>2.052</td>
<td>16</td>
<td>2.237</td>
<td>14</td>
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<tr>
<td>How often are there errors in the drawings?</td>
<td>3.257</td>
<td>10</td>
<td>3.458</td>
<td>9</td>
<td>3.091</td>
<td>7</td>
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<tr>
<td>How often are the drawings you need to do your job readily available?</td>
<td>3.622</td>
<td>6</td>
<td>3.323</td>
<td>10</td>
<td>3.818</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When there is a question or problem with a drawing, the engineers are slow to respond to Request for Information (RFI).</td>
<td>3.622</td>
<td>6</td>
<td>3.771</td>
<td>4</td>
<td>4.000</td>
<td>2</td>
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<tr>
<td>I’ve been delayed in my work because prerequisite work was not done.</td>
<td>2.932</td>
<td>12</td>
<td>3.031</td>
<td>12</td>
<td>3.273</td>
<td>5</td>
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<tr>
<td>I’ve been delayed in my work because of the absenteeism of other workers.</td>
<td>2.365</td>
<td>15</td>
<td>2.344</td>
<td>15</td>
<td>2.364</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>There is good coordination between the trades.</td>
<td>3.554</td>
<td>8</td>
<td>3.552</td>
<td>8</td>
<td>3.091</td>
<td>7</td>
<td></td>
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<tr>
<td>There are adequate work crew sizes of all trades on this job.</td>
<td>3.527</td>
<td>9</td>
<td>3.615</td>
<td>6</td>
<td>2.818</td>
<td>9</td>
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<tr>
<td>Vehicle traffic routes on this project are laid out well.</td>
<td>3.608</td>
<td>7</td>
<td>3.562</td>
<td>7</td>
<td>3.182</td>
<td>6</td>
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<tr>
<td>Enough attention is paid to protecting the workers from the weather</td>
<td>3.797</td>
<td>4</td>
<td>3.771</td>
<td>4</td>
<td>3.818</td>
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<td>Statement</td>
<td>Mean</td>
<td>SD</td>
<td>Median</td>
<td>Q1</td>
<td>Q3</td>
<td>N</td>
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<tr>
<td>There is a lack of communication between management personnel on this project.</td>
<td>2.324</td>
<td>16</td>
<td>2.479</td>
<td>13</td>
<td>2.182</td>
<td>15</td>
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<tr>
<td>There is a lack of communication between my supervisor and craft workers on this project.</td>
<td>2.405</td>
<td>13</td>
<td>2.365</td>
<td>14</td>
<td>2.545</td>
<td>10</td>
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<td></td>
</tr>
<tr>
<td>Mutual trust between craftworkers, foremen, and supervisors</td>
<td>3.838</td>
<td>3</td>
<td>3.792</td>
<td>3</td>
<td>3.727</td>
<td>3</td>
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</tr>
<tr>
<td>The craft workers from your trade on this project are qualified to do the work.</td>
<td>4.176</td>
<td>1</td>
<td>3.906</td>
<td>1</td>
<td>4.091</td>
<td>1</td>
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<td></td>
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<tr>
<td>The craft workers from other trades on this project are qualified to do the work.</td>
<td>3.703</td>
<td>5</td>
<td>3.729</td>
<td>5</td>
<td>3.545</td>
<td>4</td>
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<tr>
<td>Younger craft workers are as motivated as the older ones on this project.</td>
<td>3.095</td>
<td>11</td>
<td>3.094</td>
<td>11</td>
<td>2.909</td>
<td>8</td>
<td></td>
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</table>
## Frequency Factors – Job Productivity

<table>
<thead>
<tr>
<th>Frequency Factor Question</th>
<th>Less Productive Projects</th>
<th>More Productive Projects</th>
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<tbody>
<tr>
<td></td>
<td>Mean Rating</td>
<td>Ranking</td>
</tr>
<tr>
<td>How often a 4-10 work schedule is used?</td>
<td>2.000</td>
<td>18</td>
</tr>
<tr>
<td>How often a 5-8 work schedule is used?</td>
<td>3.908</td>
<td>2</td>
</tr>
<tr>
<td>How often are 2nd shifts used to meet baseline schedule deadlines?</td>
<td>2.147</td>
<td>17</td>
</tr>
<tr>
<td>How often are there errors in the drawings?</td>
<td>3.343</td>
<td>11</td>
</tr>
<tr>
<td>How often are the drawings you need to do your job readily available?</td>
<td>3.434</td>
<td>10</td>
</tr>
<tr>
<td>When there is a question or problem with a drawing, the engineers are slow to respond to Request for Information (RFI).</td>
<td>3.755</td>
<td>5</td>
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<tr>
<td>I’ve been delayed in my work because prerequisite work was not done.</td>
<td>2.986</td>
<td>13</td>
</tr>
<tr>
<td>I’ve been delayed in my work because of the absenteeism of other workers.</td>
<td>2.357</td>
<td>16</td>
</tr>
<tr>
<td>There is good coordination between the trades.</td>
<td>3.538</td>
<td>8</td>
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<tr>
<td>There are adequate work crew sizes of all trades on this job.</td>
<td>3.517</td>
<td>9</td>
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<tr>
<td>Vehicle traffic routes on this project are laid out well.</td>
<td>3.559</td>
<td>7</td>
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<tr>
<td>Enough attention is paid to protecting the workers from the weather</td>
<td>3.797</td>
<td>3</td>
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<tr>
<td>There is a lack of communication between management personnel on this project.</td>
<td>2.420</td>
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<td>Statement</td>
<td>Mean</td>
<td>SD 1</td>
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<tr>
<td>--------------------------------------------------------------------------</td>
<td>------</td>
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<tr>
<td>There is a lack of communication between my supervisor and craft workers on this project.</td>
<td>2.413</td>
<td>15</td>
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<tr>
<td>Mutual trust between craftworkers, foremen, and supervisors</td>
<td>3.790</td>
<td>4</td>
</tr>
<tr>
<td>The craft workers from your trade on this project are qualified to do the work.</td>
<td>4.007</td>
<td>1</td>
</tr>
<tr>
<td>The craft workers from other trades on this project are qualified to do the work.</td>
<td>3.713</td>
<td>6</td>
</tr>
<tr>
<td>Younger craft workers are as motivated as the older ones on this project.</td>
<td>3.077</td>
<td>12</td>
</tr>
</tbody>
</table>
### Appendix F - Frequency Factors - Project Phase

<table>
<thead>
<tr>
<th>Frequency Factor Question</th>
<th>Less than or equal to 50% Complete</th>
<th>More than 50% Complete</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean Rating</td>
<td>Ranking</td>
</tr>
<tr>
<td>How often a 4-10 work schedule is used?</td>
<td>1.776</td>
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<tr>
<td>How often a 5-8 work schedule is used?</td>
<td>3.833</td>
<td>2</td>
</tr>
<tr>
<td>How often are 2nd shifts used to meet baseline schedule deadlines?</td>
<td>2.134</td>
<td>14</td>
</tr>
<tr>
<td>How often are there errors in the drawings?</td>
<td>3.493</td>
<td>7</td>
</tr>
<tr>
<td>How often are the drawings you need to do your job readily available?</td>
<td>3.478</td>
<td>8</td>
</tr>
<tr>
<td>When there is a question or problem with a drawing, the engineers are slow to respond to Request for Information (RFI).</td>
<td>3.687</td>
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</tr>
<tr>
<td>I’ve been delayed in my work because prerequisite work was not done.</td>
<td>3.090</td>
<td>10</td>
</tr>
<tr>
<td>I’ve been delayed in my work because of the absenteeism of other workers.</td>
<td>2.343</td>
<td>13</td>
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<tr>
<td>There is good coordination between the trades.</td>
<td>3.522</td>
<td>6</td>
</tr>
<tr>
<td>There are adequate work crew sizes of all trades on this job.</td>
<td>3.478</td>
<td>8</td>
</tr>
<tr>
<td>Vehicle traffic routes on this project are laid out well.</td>
<td>3.493</td>
<td>7</td>
</tr>
<tr>
<td>Enough attention is paid to protecting the workers from the weather</td>
<td>3.731</td>
<td>4</td>
</tr>
<tr>
<td>There is a lack of communication between management personnel on this project.</td>
<td>2.388</td>
<td>11</td>
</tr>
<tr>
<td>There is a lack of communication between my supervisor and craft workers on this project.</td>
<td>2.373</td>
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</tr>
<tr>
<td>Statement</td>
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<tr>
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<td>--------</td>
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<tr>
<td>Mutual trust between craftworkers, foremen, and supervisors</td>
<td>3.746</td>
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<tr>
<td>The craft workers from your trade on this project are qualified to do the work.</td>
<td>3.955</td>
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</tr>
<tr>
<td>The craft workers from other trades on this project are qualified to do the work.</td>
<td>3.687</td>
<td>5</td>
</tr>
<tr>
<td>Younger craft workers are as motivated as the older ones on this project.</td>
<td>3.164</td>
<td>9</td>
</tr>
</tbody>
</table>