KEY FACTORS AFFECTING LABOR PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY

By

CASEY JO KUYKENDALL

A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN BUILDING CONSTRUCTION

UNIVERSITY OF FLORIDA

2007
To my family and friends
ACKNOWLEDGMENTS

I would like to thank my family and friends especially my parents, Billy and Selina Kuykendall; and my fiancé, Ryan Kennedy for their continued support. I also thank my professors and peers for their support. I would not be where I am today if I stood alone in my day-to-day endeavors. For that, I am grateful.
5 CONCLUSIONS AND RECOMMENDATIONS .................................................................44

Recap of Objectives............................................................................................................44
Recommendations................................................................................................................45
What Should be Done Differently? .................................................................................45
Future Works ....................................................................................................................45

APPENDIX

A THE SURVEY .................................................................................................................. 46
B THE QUESTIONAIRRE ................................................................................................... 48
C EXAMPLE WORKSHEET APPLICATION OF WEIGHTS ............................................. 49
D EXAMPLE EVALUATION SHEET .................................................................................. 50
E IRB APPROVAL .............................................................................................................. 51
LIST OF REFERENCES ........................................................................................................ 52
BIOGRAPHICAL SKETCH ................................................................................................. 54
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1</td>
<td>A multi-industry comparison of injury cases per 100 full-time employees during 1996, 1997 and 1999 adapted from a book by Chris Hendrickson.</td>
<td>23</td>
</tr>
<tr>
<td>4-1</td>
<td>Mean, median, mode, standard deviation, and variance of the weighted percentages for the top 12 factors affecting labor productivity</td>
<td>35</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>2-1</td>
<td>Labor productivity index for US construction industry and all non-farm industries from 1964 through 2003.</td>
<td>14</td>
</tr>
<tr>
<td>2-2</td>
<td>Time utilization of worker productivity in the United States.</td>
<td>15</td>
</tr>
<tr>
<td>2-3</td>
<td>Problems contributing to unproductive time adapted from a study conducted in the United Kingdom.</td>
<td>17</td>
</tr>
<tr>
<td>2-4</td>
<td>Basic ingredients to successful project management adapted from a book by Chris Hendrickson.</td>
<td>22</td>
</tr>
<tr>
<td>4-1</td>
<td>Current job positions held by survey respondents.</td>
<td>32</td>
</tr>
<tr>
<td>4-2</td>
<td>Gender of survey participants represented as a percentage</td>
<td>33</td>
</tr>
<tr>
<td>4-3</td>
<td>Average years of industry experience compared to average years in current position respondents was 21.1 years in the industry and 18.1 years in their current position.</td>
<td>33</td>
</tr>
<tr>
<td>4-4</td>
<td>Mean weighted percentages for top 12 factors affecting construction labor productivity in ascending order correlation between the data responses.</td>
<td>35</td>
</tr>
<tr>
<td>4-5</td>
<td>Histogram for results from tool management factor comparing responses (as a range of percentages) to the number of responses (falling within each range).</td>
<td>36</td>
</tr>
<tr>
<td>4-6</td>
<td>Histogram for results from equipment management factor comparing responses (as a range of percentages) to the number of responses (falling within each range).</td>
<td>36</td>
</tr>
<tr>
<td>4-7</td>
<td>Histogram for results from access issues factor comparing responses (as a range of percentages) to the number of responses (falling within each range).</td>
<td>37</td>
</tr>
<tr>
<td>4-8</td>
<td>Histogram for results management skills factor comparing responses (as a range of percentages) to the number of responses (falling within each range).</td>
<td>37</td>
</tr>
<tr>
<td>4-9</td>
<td>Histogram for results from safety management factor comparing responses (as a range of percentages) to the number of responses (falling within each range).</td>
<td>38</td>
</tr>
<tr>
<td>4-10</td>
<td>Histogram for results from quality control factor comparing responses (as a range of percentages) to the number of responses (falling within each range).</td>
<td>38</td>
</tr>
<tr>
<td>4-11</td>
<td>Histogram for results from schedule management factor comparing responses (as a range of percentages) to the number of responses (falling within each range).</td>
<td>39</td>
</tr>
<tr>
<td>4-12</td>
<td>Histogram for results from employee training/skills factor comparing responses (as a range of percentages) to the number of responses (falling within each range).</td>
<td>39</td>
</tr>
</tbody>
</table>
4-13 Histogram for results from employee age factor comparing responses (as a range of percentages) to the number of responses (falling within each range). .........................40
4-14 Histogram for results from temperature/humidity factor comparing responses (as a range of percentages) to the number of responses (falling within each range). ..................40
4-15 Histogram for results from employee motivation factor comparing responses (as a range of percentages) to the number of responses (falling within each range). .........................41
4-16 Histogram for results from the degree of bilateral communication factor comparing responses (as a range of percentages) to the number of responses (falling within each range). ...........................................................................................................42
A-1 The survey........................................................................................................................................................................47
B-1 The questionnaire..................................................................................................................................................................48
C-1 Example worksheet for the application of weights...........................................................................................................49
D-1 Final Evaluation Sheet..........................................................................................................................................................50
E-1 IRB approval form.................................................................................................................................................................51
Abstract of Thesis Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Master of Science in Building Construction

KEY FACTORS AFFECTING LABOR PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY

By

Casey Jo Kuykendall

December 2007

Chair:  R. Raymond Issa
Cochair:  Ian Flood
Major: Building Construction

Labor productivity is one of the least studied areas within the construction industry. Productivity improvements achieve high cost savings with minimal investment. Due to the fact that profit margins are small on construction projects, cost savings associated with productivity are crucial to becoming a successful contractor. The chief setback to improving labor productivity is measuring labor productivity. The main objective of this study is to assign a weight of importance to each of the top twelve factors affecting productivity. Experts at the University of Florida Rinker School of Construction compiled a list of the top twelve factors affecting productivity. A survey consisting of the twelve factors and a brief explanation of each was mailed to contractors listed on the ENR Top 400 (2006) in which they were asked to apply a weight to each of the twelve factors, totaling 100%. Results of this survey were then analyzed using the Delphi Method. These weights will be used in a future study to create a tool to help contractor’s grade productivity on their projects in the preplanning stage and plan improvements in the most beneficial areas. This productivity tool will be created by breaking each factor down into a list of activities. The project manager will assign a value to each activity representing how well their current project is achieving this activity. The total for each factor is then multiplied by its respective weight (generated in this study). The outcome of the tool will give a breakdown of
areas for improvement along with values that allow for project managers to focus on the most beneficial areas.
CHAPTER 1
INTRODUCTION

Construction is one of the nation’s largest industries. Construction accounted for 7% of the nation’s GDP in 1997 (Tucker 1999). In 2004, the construction industry provided 7 million wage and salary jobs including 1.9 million self-employed and unpaid family workers (Bureau of Labor Statistics 2006). In 1999, the construction industry provided 6.4 million jobs and the total value of new construction for the same year was $764 billion (Langsford 2006).

A successful construction project is one that is completed on time, within budget, meets specified standards of quality, and strictly conforms to safety policies and precautions. All of this is feasible only if the premeditated levels of productivity can be achieved. All the same, productivity, or lack there of, is one of the construction industry’s most prevalent problems. Due to the nature of construction projects, its importance to society and the existing economic resources, more emphasis should be given to improving productivity.

Main Goals of This Study

In the end, this study will provide a weight of importance for each of the most common factors affecting productivity. These weights will then be used by a group of experts to compose a questionnaire that will provide construction managers and decision makers with a productivity tool that will enhance project productivity. Unlike other currently existing productivity tools, this tool can be used in the planning stage and serve as a checklist to guarantee a more productive completion of projects. Keep in mind this is not intended to serve as a remedy for all problems that occur on construction projects, but as one of the necessary tools for success. The major intentions of this study are as follows:

- To assemble a list of the most notable factors affecting productivity within the construction industry today.
• To develop a weight for each individual factor based on the Delphi Method, with a total weight of 100%.

• To create an example tool in which the weights derived will be used to help project managers and top decision makers assess the current productivity issues on their projects from the pre-planning stage through the project’s completion.

**Study Objectives**

The initial objective of this study is to identify the main factors associated with lost productivity on construction projects. In order to be aware of the problems associated with each factor, the problems must be completely understood. The top factors were identified by experts within the construction and human factors field of study from the University of Florida. Each of these factors will be thoroughly defined within the literature review section of this study. The next objective is to acquire a weight of importance for each of these factors. In order to ensure that the weights are not discussed between respondents, a survey is distributed to 200 contractors listed on the ENR top 400 (2006), in which they are asked to assign a weight to each of the factors. Once these weights are established, a future study will further break down each factor into its components. These components will enable the project managers to give themselves a score from 1 to 10 for each of the components within each factor. The final score can then be evaluated to serve as a checklist to ensure increased productivity all the way up to the completion of the project. The main objectives of this study are as follows:

1. To expand upon the main factors affecting labor productivity
   a) Definition of the factor, and
   b) common problems associated with each factor.

2. To allocate a weight to each factor based on its importance
   c) Each weight will be derived by surveys distributed to experts, and
   d) the Delphi Method will then be used to compile the survey responses.

3. To compose a sample productivity checklist to serve as an example of how the weights will be used in the future.
CHAPTER 2
LITERATURE REVIEW

Background

Construction requires extensive manual labor. Human performance and productivity are reliant on one another. Therefore, the most commonly used measure of productivity is the constant contract dollars of new construction work per work hour (Hendrickson 1998). A study by Teicholtz (2004) revealed that over 40 years (1964-2003) the construction industry lags compared to all other non-farm industries in developing and applying labor saving techniques and substituting equipment for labor. Figure 2-1 depicts construction labor productivity changes as opposed to all non-farm industries from 1964-2003. A study by

Figure 2-1 Labor productivity index for US construction industry and all non-farm industries from 1964 through 2003 (U.S. Bureau of Labor Statistics 2004).
Hendrickson (1998) addressed the time utilization of the average construction worker. Only 40% of a worker's time is considered to be productive, with 55% unproductive time, and 5% personal time. Figure 2-2 shows a breakdown of the average worker's time utilization.

**Does a Problem Exist?**

From 1966 to 2003 Haskell (2004) conducted research analyzing and reporting long-term trends in construction labor productivity within the US building construction industry. This research uses two distinct methodologies. The first approach is aggregate productivity, which is measured using constant dollars as the input (for both labor and non-labor expenditures) and square feet of building area adjusted for quality changes as the measure of aggregate output. The second approach is task productivity, which is calculated using labor man-hours as input and production units as output (Haskell 2004).

The first approach, the output based approach shows a comparison of the unit costs of buildings constructed in 1966 in dollars per square foot, compared to buildings built in 2003. Using a factor of 5.68, the 2003 costs are then deflated back to 1966 costs. The outcome of this data shows a 12.34% decrease in costs per square foot. The outcome is further adjusted for
qualitative changes in order to be able to make a qualitative comparison. Finally after applying a formula involving the qualitative productivity increase and the quantitative productivity increase, total productivity is found to have increased by 33.2%. The second approach, the input based approach studies two effects. The first one is the effect of observable increases in labor productivity, offset by increases in capital costs (Haskell 2004).

The second effect is the documented decrease in materials costs (Haskell, 2004). The result of this research, 32.4% falls very close to the result of the output based result of 33.2%. The conclusions of this research is that the similarity of the outcomes based on two different approaches, input and output, prove that productivity within the construction industry have in fact increased over the last 37 years by about 33% (Haskell 2004).

Another recent study by Teicholtz (2004), mentioned earlier measured productivity within the construction industry over a 40-year period ranging from 1964 to 2003. This study measured productivity as constant contract dollars of new construction work per work hour (Teicholtz 2004). The results are the opposite of that cited by Haskell. Teicholtz finds that productivity has been decreasing over the last forty years at a rate of about 0.59% per year. Teicholtz summarizes this stating:

The construction industry suffers from structural productivity problems that will not be rapidly cured. The slow erosion of labor productivity, the aging of the construction work force, the slow rate of change in field practice and the current lack of student preference for civil engineering education are serious indications that new approaches are needed to revitalize and bring fresh ideas into this industry (Teicholtz 2004).

By comparing these two studies, it is apparent that measuring productivity and deriving a pattern is dependent on the method of data collection and measurement. Different researchers will inevitably come up with different outcomes until a standard measure of productivity is derived or if a preplanning tool is created to guarantee significant increases in productivity early on in the project.
A study very similar to our study was conducted in Canada known as the “Productivity Improvements on Alberta Major Construction Projects.” Within this, a study conducted in the United Kingdom was cited. The workers were asked to rank a general list of common problems on their construction site and in addition they were asked to estimate the respective lost time per problem area (McTague 2002). The four tables included in Figure 2-3 illustrate the problems and their respective time loss.

<table>
<thead>
<tr>
<th>Order of Factors Influencing Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor Overall Order</td>
</tr>
<tr>
<td>1  Lack of Materials</td>
</tr>
<tr>
<td>2  Crew Interference</td>
</tr>
<tr>
<td>3  Repeat Work</td>
</tr>
<tr>
<td>4  Supervision</td>
</tr>
<tr>
<td>5  Lack of Equipment, Tools</td>
</tr>
<tr>
<td>6  Absenteeism</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated Time loss per Problem in a 40-Hour Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor Estimated Time Loss</td>
</tr>
<tr>
<td>3  Lack of Materials</td>
</tr>
<tr>
<td>2  Crew Interference</td>
</tr>
<tr>
<td>2.5 Repeat Work</td>
</tr>
<tr>
<td>2  Supervision</td>
</tr>
<tr>
<td>2  Lack of Equipment, Tools</td>
</tr>
<tr>
<td>0.5 Absenteeism</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Order of Causes of Lack of Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor Overall Order</td>
</tr>
<tr>
<td>1  Lack of Planning</td>
</tr>
<tr>
<td>2  Transport within Site</td>
</tr>
<tr>
<td>3  Improper Materials</td>
</tr>
<tr>
<td>4  Interference</td>
</tr>
<tr>
<td>5  Unnecessary Paperwork</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Order of Causes of Rework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor Estimated Time Loss</td>
</tr>
<tr>
<td>1  Change of Instructions</td>
</tr>
<tr>
<td>2  Unclear Instructions</td>
</tr>
<tr>
<td>3  Complex Specification</td>
</tr>
<tr>
<td>4  Poor Workmanship</td>
</tr>
</tbody>
</table>

Figure 2-3 Problems contributing to unproductive time adapted from a study conducted in the United Kingdom (McTague 2002).
The construction industry is continuously becoming more complicated, with clients with higher expectations and requirements. More commonly, clients are expecting more complex projects to be completed in a shorter period of time. Moreover, the increased competition is causing contractors to complete day-to-day business with very low profit margins, while taking on more risks (McTague 2002).

In order to survive in such an industry, decision makers and project managers need to be able to ensure that their projects are being completed as productively as possible. In order for this to take place a new tool needs to be developed to ensure maximum productivity from the beginning to the end of each project. The development of such a tool is the main focus of this study.

**Defining Productivity**

Many definitions of the word “productivity” exist. For the basis of this study the Merriam-Webster definition will be used. Merriam-Webster defines productivity as the quality or state of being productive. Labor productivity is typically measured as output per worker or output per labor-hour. Although there are endless definitions for productivity, they all refer to productivity as a comparison of input versus output. \[ \text{Productivity} = \frac{\text{Output}}{\text{Input}} \]

Increased productivity occurs when either

1. Output is constant, while input is reduced, and/or
2. Input is constant, while either the quantity or quality of output has been increased or enhanced.

Productivity serves as a source of competitive advantage. Increasing productivity will increase output or the quality of output and if at a faster rate then competition, benefits will be achieved through the value-added through the products (McTague 2002).
How Does Productivity Relate to the Construction Industry?

Increased productivity in the construction industry can be viewed from two perspectives, the consumer and the contractor. From the consumer’s perspective, increased productivity lowers costs, shortens construction schedules, offers more value for the money, and achieves better returns on investments. From the contractor’s perspective, increased productivity leads to a more satisfied customer, while also providing a competitive advantage, and in return leading to faster turnover and increased profits (Horner 2001).

The definition for productivity with regards to construction is the measurement of the output of construction goods and services per unit of labor (McTague 2002). McTague (2002) of “Productivity Improvements on Alberta Major Construction Projects” compiled the following list of commonly used definitions to measure productivity in the construction industry:

Labor Productivity = Output / Labor Cost or
Labor Productivity = Output / Work Hours

In case the input is a combination of various factors, productivity is termed as
Total Factor Productivity and is measured as

Total Factor Productivity = Total Output / Labor + Material + Equipment + Energy + Capital

Various agencies may modify the definition of productivity as per their requirements by deleting some factors and or adding other factors.

For example, the American Federal Highway Administration may define productivity as:
Productivity = Output / Design + Inspection + Construction + Right of Way
Or
Productivity = Lane Mile / Dollars (McTague 2002).
Top 12 Factors Affecting Construction Labor Productivity

Management of Construction Tools

Materials and tool management are a large part of any construction project. In more recent years, construction firms have allocated more focus on retaining small tools, which in the past were perceived as “disposable”. Numerous technological advances have been made that enable tool tracking to be more efficient. Barcodes and scanners are one of the most common techniques used to track tools today. The problem with implementing this system is the complexity of the process. In the past the tools were just replaced, one simple step. The barcode system requires labeling, tracking, cataloguing, filing, and coordinating a multitude of tools. The process is much more demanding. In an article from the Engineering News Record, it is cited that Kafka, a former electrical contractor, achieved an average savings of $0.40 per employee per hour by implementing the barcode system. This compares to an average loss of $0.80 per hour per employee from lack and loss of tools before the barcode system was in place. Other tool tracking systems being researched include radio-frequency identification and forensic chemical marking (Hampton 2003).

Managing Construction Equipment

The Construction Industry Institute states that material and equipment currently comprise 50-60% of construction project costs (Materials Management Task Force 2007). In addition, lack of proper materials and equipment is the number one cause of construction delays. Over the last 20 years significant gains have been made in the construction industry through the implementation of computers. Along with the continued emergence of computers, equipment and materials management will assume a more important role in the industry. Good equipment management begins at the time the equipment is purchased. Purchasing the proper equipment that matches the need of the job, while achieving the lowest costs is necessary to attain suitable
equipment management. Proper record keeping provides information for planning maintenance and replacement activities, ensuring that they occur at the proper time. Managing construction equipment includes preventative maintenance, planning maintenance, and replacement activities (O’Brien and Zilly 2007).

Access Issues

Very little information is available on access issues on construction sites. Reiterating what was said in the access issues portion of the survey, site drawings should be available indicating where dense areas of labor are working and indicating their route to and from the site. Alternate plans to cut roads should only be made when other acceptable routes are ready. A common problem on construction sites is poor or disrupted access caused by holes and barricades and time spent finding alternate routes.

Management Skills

Construction management is schedule and plan work and materials to make certain that no one is waiting for materials, labor, or the completion of another task. Proper management of construction projects requires knowledge of modern management techniques. Figure 2-4 shows the main ingredients of successful project management. A familiarity with general management knowledge and special knowledge domains are indispensable, while supporting disciplines such as computer based information systems is a plus (Hendrickson 1998). A study at the Center for Construction Industry Studies at the University of Texas at Austin has revealed that poor management was responsible for over half of the time wasted on a jobsite. A construction project is unable to achieve profitability and success
without the presence of good management (Tucker 1999). Good management skills include adopting a performance based management viewpoint. This involves setting priorities for improvements, provide cost efficient and easy to use methods, promote a supportive labor-management relationship, and cut costs while increasing profits (Alfred 1988).

**Safety Issues**

Many benefits as well as losses exist through construction safety management. The construction industry is the leader in injuries and lost workdays due to injuries. Thus these injuries are very costly. Table 2-1 shows a comparison of the number of injury cases between the construction industry and other prevalent industries. In 1996, 1997 and 1998 the construction industry has the highest occurrence of injury cases when compared to agriculture, mining, manufacturing, transportation, wholesale and retail, finance, and services. The more visible benefits of construction safety include cheaper workers’ compensation coverage that’s comes with a lower experience modification rating, also increased quality, and owner satisfaction. The Business Roundtable Booklet even goes as far as stating that a contractor’s safety performance is
an indication of the contractor’s commitment to quality; basically stating that the two go hand in hand. The most prevalent hidden costs include worker replacement time, crew efficiency loss, Table 2-1 a multi-industry comparison of injury cases per 100 full-time employees during 1996, 1997 and 1999 adapted from a book by Chris Hendrickson (Hendrickson 1998).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, forestry, fishing</td>
<td>8.7</td>
<td>8.4</td>
<td>7.3</td>
</tr>
<tr>
<td>Mining</td>
<td>5.4</td>
<td>5.9</td>
<td>4.4</td>
</tr>
<tr>
<td>Construction</td>
<td>9.9</td>
<td>9.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>10.6</td>
<td>10.3</td>
<td>9.2</td>
</tr>
<tr>
<td>Transportation/ public utilities</td>
<td>8.7</td>
<td>8.2</td>
<td>7.3</td>
</tr>
<tr>
<td>Wholesale and retail trade</td>
<td>6.8</td>
<td>6.7</td>
<td>6.1</td>
</tr>
<tr>
<td>Finance, insurance, real estate</td>
<td>2.4</td>
<td>2.2</td>
<td>1.8</td>
</tr>
<tr>
<td>Services</td>
<td>6</td>
<td>5.6</td>
<td>4.9</td>
</tr>
</tbody>
</table>

costs incurred due to delays, costs due to rescheduled work, and safety personnel costs (Levitt and Samelson 2007). A study done in the early 1980’s by the Business Roundtable called the “Construction Industry Cost Effectiveness Project” reported that 6.5% of total construction costs could be attributed to accidents. Recommendations to lower this percentage include placing safety requirements in contracts, using safety records as part of the subcontractor prequalification process, and finally requiring management to take a more active role in onsite safety management (Schneider 2007).

Quality Control

Alfred (1988) states that there are two measures for construction quality, they are accuracy and workmanship. Accuracy is defined as the measurement of “how closely the job conforms to plans, specifications, code requirements, and accepted industry standards for workmanship” (Alfred 1988). Workmanship is defined as the measurement of “significant differences in the worth of the finished job created by master craftsman-ship skills (assuming, of course, that all of the work meets standards of accuracy” (Alfred 1988).
Some benefits associated with quality control are avoided rework, generation of new work methods, and circumventing long term problems. Following is a list of key quality control checkpoints and quality problem areas that should be addressed within a jobsite quality inspection checklist. The list includes:

- Design requirements
- Completed preceding work segments
- Work done by qualified employees
- Accepted materials used
- Appropriate amount of materials
- Scope of work requirements achieved
- Installation specifications met
- Entire work phase complete
- All quality problems have been fixed

Quality control pays for itself by increasing productivity while reducing costs (Hendrickson 1998).

Scheduling

The purpose of scheduling is to organize and allocate the resources of, equipment and labor with the construction project’s tasks over a set period of time. Benefits of good scheduling include, avoiding project bottlenecks, allowing for suitable procurement or necessary materials, and overall ensuring that the project is completed as quickly as possible. Poor scheduling can result in unnecessary waste of time caused by delays as laborers wait for materials of equipment to become available or proceeding tasks to be completed (Hendrickson 1998). In order to successfully schedule a project, there must be some methodology to the process. Many scheduling methods exist. For the basis of this study it will be assumed that computer based scheduling is applied. One of the most common scheduling techniques is the Critical Path Method (CPM) (Hendrickson 1998). CPM is a deterministic technique that uses preset time estimates for each activity. CPM is very easy to understand; yet it lacks consideration for
variations that can have a large impact on the final completion time for more complex projects.

Another scheduling method that allows for randomness in completion times for each activity is known as Program Evaluation and Review Technique (PERT). PERT involves six basic steps:

- Identify activities
- Place all activities in the proper order
- Construct a network diagram
- Make time estimates for each activity
- Determine critical path
- Continually update chart as project progresses

Proper applications of scheduling techniques will help avoid unnecessary delays and in turn reduce cost overruns.

**Employee Training/Skills**

Employee training benefits are much underestimated. Jordan (2006) noted that according to the US Department of Labor, apprenticeship training provides a $54 return for every dollar invested. Despite this large return on investment contractors are hesitant to pull their workers off the job to allocate time for proper training. In addition, contractors are averse to spending money on training. In the same article he states that contractors spend only 1.83% of their payroll on training, compared to the 2% spent by the industrial sector overall. Jordan cites a specific study completed by the University of Florida’s Rinker School of Building Construction, in which one company’s training efforts resulted in a 42% increase in productivity (Cox, Issa and Collins 1998). Overall, investing in employee training programs will increase productivity and reduce costs caused by rework and lost time.

**Employee Age**

Many studies suggest that the “working class” is aging, which is leading to a shortage of young skilled workers. One article in the Sacramento Business Journal states that there has been a decline from 37.5% to 28.5% of skilled construction workers between the ages of 25 to 34.
between 1988 and 1997. The average age determined by The Associated General Contractors of America of the construction worker in 2004 was 47 (LeClaire 2004). Zeiss (2007) predicted that by the year 2010 the number of workers between the ages of 35 to 44 will decrease by 19 %, while the number of workers between the ages of 45 to 54 will increase by 21 %. The shortage is caused by the retirement of the baby boom generation and popularity within the younger working class to opt for office oriented jobs. Current solutions to this growing problem include a strengthening and modernization of the nation’s vocational school system. One particular proposition by the Bush Administration is a program known as “Skills to Build America’s Future”, a plan aimed to attract young people into careers in trade fields. The industry is also filling the void by reaching out to minority groups to fill the positions (LeClaire 2004).

**Temperature/ Humidity**

Weather is to some extent unpredictable. When not scheduled adequately, weather can cause delays due to forced changes in the schedule as well as damages causing rework. Productivity decreases in poor weather conditions for many reasons. Some construction processes are affected poorly by suboptimal weather conditions. For example, mortar and concrete become less efficient. Labor is also affected poorly by unfavorable weather conditions. For instance, when weather apparel such as raincoats or heavy jackets is necessary, labor is hindered (Mincks and Johnston 2003). Hot weather, in particular, has both a physiological and psychological effect on workers. Psychologically workers tend to become restless and irritable. Physiologically they can acquire heat cramps, heat stroke, heat exhaustion, etc. The four factors in a hot environment that cause the increased stress include:

- Humidity
- Air Movement
- Air Temperature
- Heat Radiation (Schwarzkopf 1995).
The most effective solution to curb the effect of inclement weather is planning with a consideration for seasonal conditions. Forecast bad weather and plan weather sensitive activities accordingly. In addition, build some amount of flexibility into the work schedule to allow for weather delays. Strive to keep laborers as comfortable as possible considering the weather conditions. For instance, during periods high temperatures ensure that cold water is always available to the workers at the installation station (Mincks and Johnston 2003). The key to suppress the effects of foul weather on productivity is planning.

**Employee Motivation**

Motivation is defined by Cooper (2004) as “the process that directs your people’s work energy. It is the drive behind your own and your people’s wish to satisfy ‘workplace’ wants and needs.” Most successful leaders consider motivational factors such as praise, recognition, and self-esteem. People’s behavior is affected by motivation, which in turn results in a committed energy throughout the workplace. Some guidelines for increasing motivation within the workplace include:

- Provide a safe work environment.
- Recognize good behavior.
- Show appreciation.
- Set attainable goals.
- Develop a fair pay system.
- Provide adequate training programs (Cooper 2004).

Many motivational theories are used in the construction industry in an effort to increase productivity. Some of these theories include Herzberg’s Two Factor Theory (1959), Maslow’s Hierarchy of Needs (1954), and McGregor’s Theory X and Theory Y (1960) (Lam and Tang 2003). In order to maximize productivity, it is necessary to enlist motivational schemes to maximize each worker’s potential.
Degree of Bilateral Communication

Good communication is necessary to efficiently complete a project. Lack of sufficient communication can lead to lack of worker motivation. With today’s technology many communication tools are available. Some of the more commonly used forms of communication include two-way radios, cellular phones, GPS and mobile wireless internet. Lack of communication can cause delays due to mistakes causing rework, lack of information causing downtime, and misinterpretation. Although endless options for communication are available, technical problems do exist. Many people do not familiarize themselves with the user manuals, and when problems occur, they are left with very little options. To avoid situations such as this, employees should be encouraged to become familiar with their communication tools. Other common problems associated with communication on construction projects include understanding the chain of command and continuously communicating about the project and foreseeing potential problems in the future. This can be avoided by holding regular project management team meetings (Cingoranelli 2007).

Summary

Many methods for measuring productivity exist. Regardless of what measurement of output or input is used on a construction project, increasing productivity will increase a project’s efficiency and therefore increase success. The purpose of this literature review is to expand on the top 12 factors affecting construction productivity.
CHAPTER 3
METHODOLOGY

A survey was administered to the ENR Top 400 Construction Companies (2006). The goal was to identify and assign a weight to the top 12 factors affecting labor productivity in the construction industry. Each factor is defined and the potential problems within each factor are identified and explained within the literature review section of this study. The study was based upon the following 12 major productivity factors:

1. Tool Management
2. Equipment Management
3. Access Planning
4. Management Skills
5. Safety
6. Quality Control
7. Scheduling
8. Employee Training/ Skills
9. Employee Age
10. Temperature/ Humidity
11. Employee Motivation
12. Degree of Bilateral Communication

The survey was distributed to 200 contractors from the ENR Top 400. The survey gives a brief description of each factor and the contractor is asked assign a weight to each of the factors based on his or her knowledge and past experience in the construction industry. A complete copy of the survey can be found in Appendix A. The following are the descriptions as they appear in the survey:

1. Management of Construction Tools: In order to maintain large amounts of tools, tool rooms should be used to store non-permanently used tools. Periodic reports should be performed by tool room supervisors. Tool kits should be issued on the basis of trade and each person should be held accountable. A record should be kept of all tool kit assignments, as well as tools not included in the kits. Periodic site inventories are necessary to control loss, theft, and breakage. Some common problems associated with tool management include lack of tool availability, lack of the proper tools, poor tool maintenance, etc.
2. Managing Construction Equipment: Productivity of construction equipment is directly linked to how the equipment is used and how the crews and operators are assigned. Advanced planning is necessary to establish the length of time the equipment will be utilized. Strong efforts should be made to keep the same crew and operator on the same piece of equipment as much as possible. Some common equipment management problems include lack of equipment usage reports, lack of equipment safety checklists, and lack of proper scheduling of equipment.

3. Access: Site drawings should be available indicating where dense areas of labor are working and indicating their route to and from the site. Alternate plans to cut roads should only be made when other acceptable routes are ready. A common problem on construction sites is poor or disrupted access caused by holes and barricades and time spent finding alternate routes.

4. Management Skills: Management often times obscures progress on a project. Good management is required for profitability and success.

5. Safety Management: Everyone involved with a project should be concerned with the level of safety that is maintained. At a minimum, the level of safety on a project must comply with legislated criteria. Some common safety problems include lack of safety in the design, lack of safety training, lack of management support, lack of preventative maintenance on tools and equipment, etc.

6. Quality: Traditionally, generic quality tolerances are used on most projects. Therefore, experienced operators should be periodically reviewing quality on the project and interpreting the quality expectations on the project. Lack of quality control leads to increased costs associated with rework.

7. Schedule Management: Project schedules should establish guidelines as to when and how the project should be executed. Schedule requirements need to be communicated and properly managed throughout the entire project. Some common scheduling problems include outdated schedules, lack of schedule communication, lack of detail, trade stacking, etc.

8. Employee Training/Skills: Overall, there is a lack of formal training in the construction industry. High employee turnover rates deter investments in employee training. Lack of training causes delays due to rework and overall capability levels among workers.

9. Employee Age: Some studies have claimed that the working age is beginning to decline and impacts are becoming evident within the labor market. As the working age diminishes, new young laborers could become harder to come by.

10. Temperature/Humidity: High temperatures and humidity tend to slow down worker productivity. Jobsites should have appropriate rain gear and inclement weather planning.
11. Employee Motivation: Lack of employee motivation can be caused by many factors. Empowering employees is one way to encourage employee motivation. Unmotivated workers can cause loss of productivity associated with excessive down time and lack of concentration.

12. Degree of Bilateral Communication: Effective communication between all members of a construction project is necessary in order to maximize a project and a team’s potential. Lack of communication can affect worker motivation.

Following this portion of the survey the contractor is asked to fill out a questionnaire. This section of the survey includes questions pertaining to age, gender and industry experience. It also includes question regarding to job title, years in the industry, size of company, and average project size. These questions are multiple choice and fill in the blank. The objective of these questions is to find out the perspective of the surveyed individual with regards to their position within the industry. A copy of this portion of the survey can be found in Appendix A.

The total of all of the weights assigned to each of the factors on each survey should total 100 %. Any survey that does not meet this requirement will not be used. In addition any survey that is not completely filled out will also be discarded from the study.
CHAPTER 4
RESULTS

Feedback Responses

A total of 200 surveys were mailed to construction companies listed on the ENR Top 400 Contractors (2006). The surveys resulted in feedback from 24 companies, approximately a 12 % feedback. The survey was limited to the United States. The participants were asked to fill out a questionnaire about their job title, years in the industry, years at current job, and gender. The results of the demographic portions of the questionnaire are shown in Figures 4-1, 4-2, and 4-3. Figure 4-1 is comparison of the positions currently held by the survey respondents. 50% of the respondents were project managers. The remaining 50% consisted of human resource officers, owners, and company presidents. Figure 4-2 is a gender comparison chart. Of the surveyors, 4 % were female and 96 % were male. Figure 4-3 is a histogram that represents the average number of years the respondents have worked in the construction industry compared to the average number of years they have been at their current job. The average construction experience of the

Figure 4-1 Current job positions held by survey respondents.
Figure 4-2 Gender of survey participants represented as a percentage

Figure 4-3 Average years of industry experience compared to average years in current position respondents was 21.1 years in the industry and 18.1 years in their current position.

**Delphi Method**

The Delphi Method is a method used to gather the opinions of a group of experts without any conversation between the experts, which might sway their initial responses. This is accomplished through the use of a mail survey. The results of the survey are then averaged to find the mean for each question or section of the survey. In this study, the experts (holding
positions within the construction industry) were asked to apply a weight to each of the top 12 factors affecting construction labor productivity, with a final total equal to 100%.

Mean Weights

By taking the average of the 24 responses for each factor, the mean weight for each of the factors is calculated as follows:

- Tool Management: 6.48%
- Equipment Management: 9.30%
- Access Planning: 4.83%
- Management Skills: 3.61%
- Safety: 10.00%
- Quality Control: 13.22%
- Scheduling: 7.78%
- Employee Training/ Skills: 10.35%
- Employee Age: 17.39%
- Temperature/ Humidity: 5.65%
- Employee Motivation: 7.87%
- Degree of Bilateral Communication: 4.43%

Figure 4-4 shows a comparison of the mean weights. Management Skills is the highest weighted factor (17.39%), followed by Schedule Management (13.2%). The lowest weighted factor is Employee Age (3.6%).

Further Statistical Analysis

The data is further analyzed in Table 4-1. The responses for each factor are examined to determine the median, mode, standard deviation, and variance. Notably, six of the twelve factors have a standard deviation higher than 5. Management Skills had the highest standard deviation and variance (11.52 and 32.79). In order to visualize the correlation between the 24 responses for each of the twelve factors, histograms were created as shown in Figures 4.5-4.16. By looking at each of the histograms it is visible that there is very little, if any correlation between the data responses. The histograms show how many responses fell within similar percentages.
Figure 4-4 Mean weighted percentages for top 12 factors affecting construction labor productivity in ascending order correlation between the data responses.

Tool management (Figure 4-5), employee age (Figure 4-13), quality control (Figure 4-10), and access issues (Figure 4-7) all have a common recurrence of “5%”.

Table 4-1 Mean, median, mode, standard deviation, and variance of the weighted percentages for the top 12 factors affecting labor productivity

<table>
<thead>
<tr>
<th>Factor</th>
<th>Tool Management</th>
<th>Equipment Management</th>
<th>Access Issues</th>
<th>Management Skills</th>
<th>Safety Management</th>
<th>Quality Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>4.43</td>
<td>7.87</td>
<td>5.65</td>
<td>17.39</td>
<td>10.35</td>
<td>7.78</td>
</tr>
<tr>
<td>Median</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>15</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Mode</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Std. Dev</td>
<td>2.66</td>
<td>6.49</td>
<td>3.38</td>
<td>11.52</td>
<td>9.17</td>
<td>4.40</td>
</tr>
<tr>
<td>Variance</td>
<td>7.08</td>
<td>42.12</td>
<td>11.42</td>
<td>132.79</td>
<td>84.15</td>
<td>19.36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factor</th>
<th>Schedule Management</th>
<th>Employee Training/Skills</th>
<th>Employee Age</th>
<th>Temperature/Humidity</th>
<th>Employee Motivation</th>
<th>Degree of Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>13.22</td>
<td>10.00</td>
<td>3.61</td>
<td>4.83</td>
<td>9.30</td>
<td>6.48</td>
</tr>
<tr>
<td>Median</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Mode</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Std. Dev</td>
<td>8.41</td>
<td>6.16</td>
<td>2.55</td>
<td>4.42</td>
<td>9.88</td>
<td>4.05</td>
</tr>
<tr>
<td>Variance</td>
<td>70.72</td>
<td>37.91</td>
<td>6.52</td>
<td>19.51</td>
<td>97.68</td>
<td>16.44</td>
</tr>
</tbody>
</table>
Figure 4-5 Histogram for results from tool management factor comparing responses (as a range of percentages) to the number of responses (falling within each range).

Figure 4-6 Histogram for results from equipment management factor comparing responses (as a range of percentages) to the number of responses (falling within each range).
Figure 4-7 Histogram for results from access issues factor comparing responses (as a range of percentages) to the number of responses (falling within each range).

Figure 4-8 Histogram for results from management skills factor comparing responses (as a range of percentages) to the number of responses (falling within each range).
Figure 4-9 Histogram for results from safety management factor comparing responses (as a range of percentages) to the number of responses (falling within each range).

Figure 4-10 Histogram for results from quality control factor comparing responses (as a range of percentages) to the number of responses (falling within each range).
Figure 4-11 Histogram for results from schedule management factor comparing responses (as a range of percentages) to the number of responses (falling within each range).

Figure 4-12 Histogram for results from employee training/skills factor comparing responses (as a range of percentages) to the number of responses (falling within each range).
Further analysis was done to determine if there was any correlation between the responses and the gender of the respondents, as well as the number of years in the industry, and years in the
current position held by the respondents. The correlation coefficient is a number between 1 and -1, which measures the degree to which two variables are linearly related. A correlation of .3 or lower was derived for each of the variables considered. There was no significant correlation between the responses of males compared to females. When comparing years in the industry, the correlation test considered respondents with greater than 15 years of experience compared to those with less than 15 years of experience. The correlation was also determined to be less than .3, an insignificant correlation. The final correlation test considered respondents with greater than 10 years in their current position compared to those with less than 10 years in their current

Figure 4-15 Histogram for results from employee motivation factor comparing responses (as a range of percentages) to the number of responses (falling within each range).
The result from this correlation test was that there is no significant correlation between the number of years the respondents have been in their current position and their respective responses.

**Summary**

In order for the average weights that have resulted from this study to be meaningful, some sort of correlation should exist between the responses. It has become evident that this study’s limitations may be too broad. Covering the entire United States with only 24 responses can in no way be considered an accurate average to represent all construction contractors within such a large region. For example, if the survey had been limited to the county of Alachua, 24 respondents, out of 200 would have resulted in more accurate conclusions. As 24 is a larger percentage of the contractors representing Alachua County compared to the percentage representing the United States. Another deficiency in this study, using one factor as a more specific example, “Temperature and Humidity” has various effects across the United States.
company in Maine would deal with snow and cold weather issues as opposed to Florida, which would deal with more rain and extreme heat issues. The two regions in this example may need to be studied separately. Overall, the study did not result in enough responses to make a truly accurate list of the average weights for the top 12 factors affecting labor productivity within the United States.
CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

Recap of Objectives

The main factors were identified and defined. Each factor was then expanded upon within the literature review. The second objective of the study called for a list of weights for each of the 12 factors. The list and the factors are as follows:

1. Tool Management  4.43%
2. Equipment Management  7.87%
3. Access Planning  5.65%
4. Management Skills  17.39%
5. Safety  10.35%
6. Quality Control  7.78%
7. Scheduling  13.22%
8. Employee Training/ Skills  10%
9. Employee Age  3.61%
10. Temperature/ Humidity  4.83%
11. Employee Motivation  9.30%
12. Degree of Bilateral Communication  6.48%

The third and final objective relates to the future applications of these percentages. In appendix B, a worksheet and summary sheet have been created to serve as an example of how these weights can be applied in the future. In a completed set of worksheets, each of the 12 factors would consist of one work sheet. Each worksheet would contain a list of activities that are involved in obtaining 100% satisfaction within this factor. The contractor is asked to assign a value from 1 to 10 indicating how well they are achieving each particular activity on their current project. The values for all of the activities for each individual factor are summed and then transferred to the evaluation sheet at the end of the workbook. The total value for each factor is then multiplied by the factor’s respective weight. The results can then be used to make very specific plan for improving productivity early on in the project.
Recommendations

What Should be Done Differently?

In the event that this study is to be recreated, some parts of the study would yield more accurate results if done differently. The answers from the different respondents yielded very little correlation for most of the factors. One adjustment to this study that may change the results is to conduct multiple surveys with the same respondents, allowing them to see where their answers differed from other respondents, giving them the opportunity to explain. Another beneficial change would be to increase the number of surveys distributed. These changes would require a large increase in the amount of time allotted for the study.

Future Works

In the future, a similar, but more focused study could be done. Instead of only limiting the survey to upper level construction managers and owners, focus on different levels throughout the construction industry and compare the results between the levels. In addition, this study could also be done focusing on multiple smaller regions across the United States and then checking the correlation between them. In regards to this current study, in order to make the weights useful to the construction industry, checklists must be created that will enable construction managers to apply the weights to the scores they have given themselves and target their productivity weaknesses early on in the project.
APPENDIX A

THE SURVEY

Weighting Key Components Affecting Labor Productivity

The following survey lists the 12 most common factors in the construction industry that affect labor productivity and a short description. Please read the description for each of the 12 factors and allocate a percentage for each factor, with a combined total percentage of 100%. The weights should be based on past industry knowledge and experience. Following the weighting portion of the survey is a short questionnaire.

Instructions: Please allocate a weight to each of the following factors affecting productivity. This weight should be allocated based upon how much this factor affects construction productivity.

3. Management of Construction Tools: In order to maintain large amounts of tools, tool rooms should be used to store non-permanently used tools. Periodic reports should be performed by tool room supervisors. Tool kits should be issued on the basis of trade and each person should be held accountable. A record should be kept of all tool kit assignments, as well as tools not included in the kits. Periodic site inventories are necessary to control loss, theft, and breakage. Some common problems associated with tool management include lack of tool availability, lack of the proper tools, poor tool maintenance, etc.

Weight____%

4. Managing Construction Equipment: Productivity of construction equipment is directly linked to how the equipment is used and how the crews and operators are assigned. Advanced planning is necessary to establish the length of time the equipment will be utilized. Strong efforts should be made to keep the same crew and operator on the same piece of equipment as much as possible. Some common equipment management problems include lack of equipment usage reports, lack of equipments safety checklists, and lack of proper scheduling of equipment.

Weight____%

5. Access: Site drawings should be available indicating where dense areas of labor are working and indicating their route to and from the site. Alternate plans to cut roads should only be made when other acceptable routes are ready. A common problem on construction sites poor or disrupted access caused by holes and barricades and time spent finding alternate routes.

Weight____%


Weight____%

7. Safety Management: Everyone involved with a project should be concerned with the level of safety that is maintained. At a minimum, the level of safety on a project must comply with legislated criteria. Some common safety problems include lack if safety in the design, lack
of safety training, lack of management support, lack of preventative maintenance on tools and equipment, etc.

Weight____%

8. Quality: Traditionally, generic quality tolerances are used on most projects. Therefore, experienced operators should be periodically reviewing quality on the project and interpreting the quality expectations on the project. Lack of quality control leads to increased costs associated with rework.

Weight____%

9. Schedule Management: Project schedules should establish guidelines as to when and how the project should be executed. Schedule requirements need to be communicated and properly managed throughout the entire project. Some common scheduling problems include outdated schedules, lack of schedule communication, lack of detail, trade stacking, etc.

Weight___%

10. Employee Training/Skills: Overall, there is a lack of formal training in the construction industry. High employee turnover rates deter investments in employee training. Lack of training causes delays due to rework and overall capability levels among workers.

Weight ___%

11. Employee Age: Some studies have claimed that the working age is beginning to decline and impacts are becoming evident within the labor market. As the working age diminishes, new young laborers could become harder to come by.

Weight____%

12. Temperature/Humidity: High temperatures and humidity tend to slow down worker productivity. Jobsites should have appropriate rain gear and inclement weather planning.

Weight____%

13. Employee Motivation: Lack of employee motivation can be caused by many factors. Empowering employees is one way to encourage employee motivation. Unmotivated workers can cause loss of productivity associated with excessive down time and lack of concentration.

Weight____%

14. Degree of Bilateral Communication: Effective communication between all members of a construction project is necessary in order to maximize a project and a team’s potential. Lack of communication can affect worker motivation.

Weight____%

(Should be 100%) TOTAL WEIGHT_____%

Figure A-1 The survey
APPENDIX B

THE QUESTIONNAIRE

**Questionnaire:** Please circle the best answer for each of the following questions.

1. What is your current position within the company?
   - e) Project Manager
   - b) Foreman
   - c) Laborer
   - d) Other: __________

2. How long have you worked in the construction industry? _____ Years

3. How long have you been employed at your current job? _____ Years

4. What is your gender? ________Female ________Male

Upon completion, please return this survey via email, fax or standard mail.
Email: caseyjo@ufl.edu
Fax: (352) 846-2772 Attn: Casey Kuykendall
Address:  Casey Kuykendall
          Attn: Dottie
          Box 115703
          Gainesville, FL 32611

**Thank you for your time!** Your efforts will help us complete our productivity program enabling better opportunities for management to achieve project costs savings from relatively small investments early on in the project.

Figure B-1 The questionnaire.
APPENDIX C
EXAMPLE WORKSHEET APPLICATION OF WEIGHTS

**Worksheet #1 – SCHEDULE MANAGEMENT**  
(Weight Value 13.22%)

<table>
<thead>
<tr>
<th>Activities Weight Grade (1 – 10)</th>
<th>Value (Grade x Weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Construction milestone schedule</td>
<td>40%</td>
</tr>
<tr>
<td>2. Continuous Monitoring of Project</td>
<td>20%</td>
</tr>
<tr>
<td>3. Activities and milestones in proper sequence</td>
<td>5%</td>
</tr>
<tr>
<td>4. Critical path is determined.</td>
<td>10%</td>
</tr>
<tr>
<td>5. Trend and Change Order Procedure.</td>
<td>10%</td>
</tr>
<tr>
<td>6. Accurate activity duration estimates</td>
<td>20%</td>
</tr>
</tbody>
</table>

**TOTAL VALUE FOR COST**  
100%

Figure C-1 Example worksheet for the application of weights.
## APPENDIX D

### EXAMPLE EVALUATION SHEET

<table>
<thead>
<tr>
<th>Factor</th>
<th>Weight</th>
<th>Value</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Worksheet 1-12)</td>
<td>(Weight * Value)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) Tool Management</td>
<td>4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Equipment Management</td>
<td>8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3) Access Planning</td>
<td>6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4) Management Skills</td>
<td>17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5) Safety</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6) Quality Control</td>
<td>8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7) Scheduling</td>
<td>13%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8) Employee Training/ Skills</td>
<td>9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9) Employee Age</td>
<td>4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10) Temperature/ Humidity</td>
<td>5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11) Employee Motivation</td>
<td>9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12) Degree of Bilateral Communication</td>
<td>6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL PROJECT</strong></td>
<td><strong>100%</strong></td>
<td><strong>600</strong></td>
<td><strong>600</strong></td>
</tr>
</tbody>
</table>

Figure D-1 Final Evaluation Sheet
APPENDIX E

IRB APPROVAL

Figure E-1 IRB approval form.
LIST OF REFERENCES


BIOGRAPHICAL SKETCH

Casey Kuykendall was born and raised in Punta Gorda, Florida. Her parents are William and Selina Kuykendall. She was the third of three children. She has two brothers: Jeremy and Travis Kuykendall. In 2001, she moved to Gainesville to attend the University of Florida’s Warrington College of Business. Upon graduating with a Bachelor of Science degree, she continued her education in the master’s program at the Rinker School of Building Construction also at the University of Florida. In December 2007 she will graduate with a Master of Science in Building Construction. Upon graduation, Casey, newly married, plans to start a new career and a family with her husband, Ryan Kennedy.