STUDY OF FACTORS AFFECTING LABOR PRODUCTIVITY AT A BUILDING CONSTRUCTION PROJECT IN THE USA: WEB SURVEY

A Paper
Submitted to the Graduate Faculty
Of the
North Dakota State University
Of Agriculture and Applied Science

By

Mahesh Madan Gundecha

In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE

Major Department
Construction Management and Engineering

September 2012

Fargo, North Dakota

North Dakota State University
Graduate School

Title

STUDY OF FACTORS AFFECTING LABOR PRODUCTIVITY AT A BUILDING CONSTRUCTION PROJECT IN THE USA: WEB SURVEY

By

Mahesh Gundecha

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Eric Asa
Chair

Charles McIntyre

Selekwa Majura

Abdelrahman Magdy

Approved:

April 03 2013
Date

Yong Bai
Department Chair

ABSTRACT

Construction projects suffer various problems and complex factors such as cost, duration, quality and safety. Construction sector is diverse as it contains, contractors, consultants, designers, owners, and others. The aim of this paper is to identify factors affecting labor productivity at a building construction project.

A literature review and factors recommended by experts were considered to categorize the factors. 40 factors, categorized into 5 groups, were analyzed and ranked considering Relative Importance Index. The questionnaires were distributed to Project Manager, Project Engineer, Architecture, and Others (Scheduler, and Estimator).

It was concluded, final cost of the projects were higher than estimated cost. It's recommended to develop human resources through proper and continuous training programs frame a strong assignment, vision and a planned approach to overcome the disturbances on the performance of the construction projects. The discussed factors are expected to assist in completing construction projects successfully.

ACKNOWLEDGEMENTS

It is my pleasure to thank my adviser, Dr. Eric Asa, who made this research paper possible with his commitment, encouragement, supervision, and support from the commencement of the research to its conclusion. His patience and kindness will never be forgotten. I have enjoyed working with him and appreciate the support and opportunities he provided.

I would like to thank my supervisory committee: Dr. Charles McIntyre, Dr. Magdy Abdelrahman, and Dr. Majura Selekwa. I also extend my sincere gratitude to all the research study's respondents for their valuable input and suggestions. Also, I thank the faculty and staff of the Construction Management and Engineering Department for preparing me to achieve my master's degree and to succeed in future endeavors.

Special thanks to my parents for believing in me even when I doubted myself. Last but not least, heartfelt thanks go to my brother, Mukesh; beautiful wife, Harsha; Cody; in-laws; family; friends; colleagues; and God for their continuous support and love.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

% ..... Percentage

APE .....Assistant Project Engineer

APM .....Assistant Project Manager

CII .....Construction Industry Institute

CO .....Contractor

DE .....Designer

GDC .....Group Discussion Center

IRB .....Institutional Review Board

NDSU.....North Dakota State University

NECA.....National Electrical Contractors Association

OW .....Owner

PM..... Project Manager

PE..... Project Engineer

RII .....Relative Importance Index

USA.....United States of America

CHAPTER 1. INTRODUCTION TO THE STUDY

1.1. Introduction

Several studies related to labor productivity are performed for construction industry in past. Several of them were related to calculating the effect of productivity factors. Measureable calculations about the effects of those factors are required for several purposes, it includes estimation of the construction project, it's planning and scheduling. However, past study shows that it is tough to calculate such an impact, and at present there are no universally accepted standards to measure factors causing labor productivity loss in construction industry. This lack of methods for measuring effects highlights the need to enhance measureable assessments for the factors affecting productivity in building construction, and this is supposed to be the topic of this research.

Achieving better labor productivity requires detailed studies of the actual labor cost. Various labors have different variables affecting their productivity levels. For every project, productivity, cost, quality, and time have been the main concern. Better productivity can be achieved if project management includes the skills of education and training, the work method, personal health, motivational factors, the type of tools, machines, required equipment and materials, personal skills, the workload to be executed, expected work quality, work location, the type of work to be done, and supervisory personnel (Rowlinson and Proctor, 1999).

In today's era, one of the biggest concern for any organization is to improve their productivity, representing the effective and efficient conversion of resources into marketable products and determining business profitability (Wilcox et al., 2000). Consequently, considerable effort has been directed to understand the productivity concept with different approaches taken by researchers, resulting in a wide variety of productivity definitions (Lema and Samson, 1995; Oglesby et al., 2002; Pilcher, 1997).

1.2. Background about Productivity

Productivity is generally defined as the average direct labor hours required to install a unit of material. It is said that perfect productivity (1.0) can be achieved with a 40-hour work week, with people taking all the holidays and vacation days as planned all of the engineering drawings would be 100% complete there would be no delays of any kind during construction; everyone would work safely; everything would fit perfectly the first time; the weather would be 70^{o} F; and there would be no litigation at the end of the project (Rowlinson and Proctor, 1999).

1.3. Definition of Productivity in Construction Industry

The term "productivity" expresses the relationship between outputs and inputs (Borcherding and Liou, 1986). Output and input differ from one industry to another. Also, the productivity definition varies when applied to different areas of the same industry. Labor is one of the basic requirements in the construction industry. Labor productivity usually relates manpower in terms of labor cost to the quantity of outputs produced (Borcherding and Liou, 1986). In other words, the definition of labor productivity is the amount of goods and services produced by a productive factor (manpower) in the unit of time (Drewin, 1982).

In 1883, Littre defined productivity as the "faculty to produce," that is, the desire to produce (Jarkas, 2005). In 1950, the Organization for European Economic Cooperation (OEEC) introduced the definition of productivity as a quotient obtained by dividing the output by one of the production factors (Sumanth, 1984). Depending on measurement objectives and the availability of data, several productivity definitions are encountered. The U.S. Department of Commerce defined productivity as "dollars of output per person-hour of labor input" (Adrian, 1987).

1.4. Significance of Productivity

Productivity has a great significance in construction. Labor productivity constitutes a significant part of production input for construction projects. In the construction industry, many external and internal factors are never constant and are difficult to anticipate. This factor leads to a continuous variation in labor productivity. It is necessary to make sure that a reduction in productivity does not affect the plan and schedule of the work and does not cause delays. The consequences of these delays could result in serious money losses. Further, considerable cost can be saved if productivity is improved because the same work can be done with less manpower, thus reducing overall labor cost (Thomas, 1991).

1.5. Problem Statement

In the construction industry productivity loss is one of the greatest and severe problems. Present construction contracts lack enough to classify recompense for productivity loss due to field factors (Construction Industry Institute [CII], 2000; National Electrical Contractors Association [NECA], 1989). Of various project-costs components such as labors materials and equipment's, labor component is considered the most risk. Whereas others components (equipment and material) are determined by the market price and price and are, consequently, beyond the influence of project management. Labor cost in construction industry is estimated to be about 33%- 50% of the entire project cost (language Hanna et al., 2005). Because labor is more variable and unpredictable than other project-cost components, it becomes necessary to understand the effects of different factors on labor productivity. An increase in productivity can reduce the labor cost in a direct proportion. It can either benefit or reduce a project's profit, making it of vital interest to the construction industry for its success (Hanna et al., 2005).

Previous researches confirm that productivity loss results from various factors, which includes but not limited to various variation in drawings, long hours of extra work, poor field management, and extreme climatic conditions (Alarcon and Borcherding, 1991; Leonard, 1987; Sanders and Thomas, 1991; Thomas and Oloufa, 1995). In fact, these factors typically produce extra disturbances that affect productivity and are beyond the direct control of a contractor, resulting in productivity loss or extra work hours necessary to accomplish the task.

1.6. Misconceptions about Construction Productivity

A study from (Adrian 1990) states the following general misconceptions about labor productivity:

- **i.** Key factor for low productivity in construction industry is labor.
- **ii.** Because the construction industry is controlled by the weather, productivity cannot be improved.
- **iii.** The construction industry always has an unfavorable relationship process.

1.7. Facts about Construction Productivity

Following are a few facts about the construction productivity studied by Adrian (1990):

- **i.** Tuesday is studied as most productive day of the week.
- **ii.** 10 a.m. is studied as most productive time of the day
- **iii.** The least productive time frame for labor is right before the finishing time.
- **iv.** A laborer is capable of lifting approximately 94 pounds on his own.
- **v.** If the laborer is engaged in performing the same task repeatedly, there is a chance of low productivity after 60-70 minutes of performing the same work.
- **vi.** Friday has been proven to be the least productive day of the week.

1.8. Aim and Objective

The objective of this study focuses on views from the construction industry about various factors affecting labor productivity, analyzes factors affecting the labor productivity impact, and suggests appropriate measures that can be taken to improve labor productivity. The aim is supported by the objective stated below.

- **i.** Study and discuss various factors affecting labor productivity in construction industry.
- **ii.** Analyze and calculate the Relative Important Index (RII) of those factors affecting labor productivity.
- **iii.** To statistically analyze the factors affecting labor productivity.
- **iv.** To make recommendations to improve labor productivity in construction.

1.9. Research Contribution

The research study investigates important factors affecting labor productivity in building construction. Understanding these factors is helpful for the construction professionals who work on the initial phases of construction planning in order to efficiently deliver the project plan. The main goal of the research study is to provide essential information about factors affecting labor productivity to the project management teams who enable the project's success. Generally, the factors which affect construction productivity are a lack of required materials, disputes between the major parties, weather, and changes during the construction, accidents, and others. For building construction, extra care must be taken when developing the project time schedule, which is possible only with prior knowledge of factor causes. The research study aims to provide knowledge of building construction-related factors that affect the project's success.

1.10. Research Structure

This research consists of five chapters and appendices (IRB Approval and Web-Survey Questionnaire).

Chapter 1 discusses the background, various definitions, measurement, Problem Statement, misconceptions, and facts related to productivity.

Chapter 2 discusses previous studies for construction labor productivity found in professional journals and texts. It also lists various factors affecting productivity and further identifies the possible factors affecting productivity in the construction industry.

Chapter 3 discusses the research methodology used, including a discussion of the survey approach.

Chapter 4 discusses the analysis method and Statistical Method utilized for the study as well as the results obtained from the web survey.

Chapter 5 discuses conclusions, Recommendations, and suggestions for future research.

Figure 1.1 shows the flow-chart describing various stages in research and its structure.

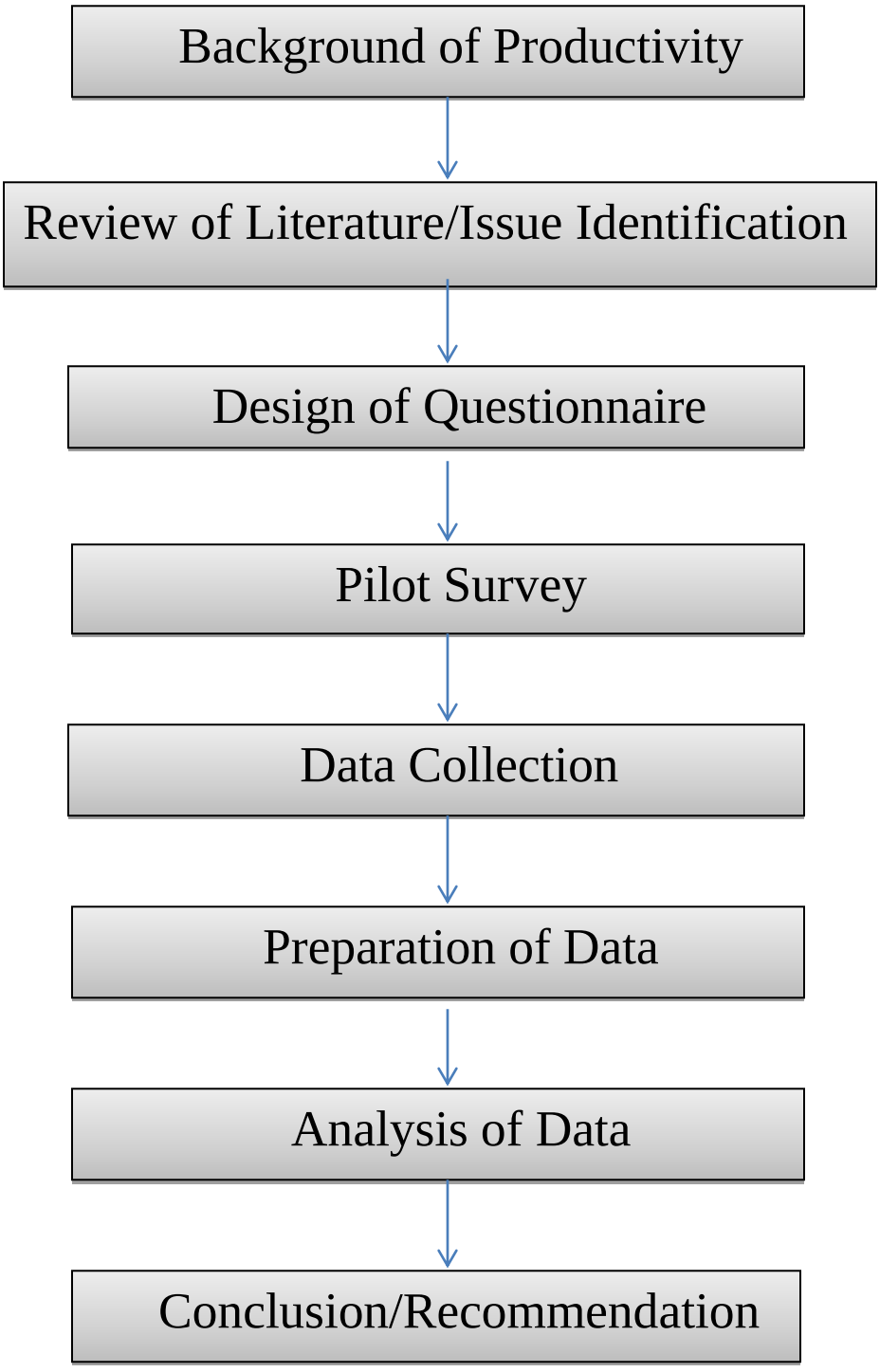


Figure 1.1. Flow Chart Showing Research Structure.

CHAPTER 2. LITERATURE REVIEW

2.1. Review of Labor Productivity from Previous Study

Increase of productivity was calculated prior to mid-1906's, in the construction industry (Stall, 1983). Later, decline in productivity has remained of great concern issue in the construction industry all over the world. In 1968, the Construction Roundtable was established due to concern about the increased cost of construction resulting from an increase in the inflation rate and a significant decline in construction productivity (Thomas and Kramer, 1988). Also in 1965, the United Nations Committee on Housing, Building, and Planning (UNC) published a significant manual concerning the effect of repetition on building operations and processes (UNC, 1965). The research discovered the necessity for a rise in productivity was perhaps more severe in the construction sector compared to any other sector. It was necessary to implement, as far as possible, industry-wide principles of production throughout the construction process. Though, it was known that careful adaptation would be required to implement the knowledge and experience gained in the manufacturing industry to the building construction industry (Alarcon and Borcherding 1991).

Past studies and research show the number of factors affecting productivity, there are still anonymous factors need to be further studied even in developed countries (Makulsawatudom and Emsley 2002). A study by (Polat and Arditi 2005) stated that policies to rise productivity are not always similar in each country. Their study identified different factors affecting labor productivity and grouped them according to their characteristics such as, design, execution plan, material, equipment, labor, health and safety, supervision, working time, project factor, quality, leadership and coordination, organization, owner/consultant, and external factors.

(Adrian, 1987) Classified the productivity factors causing low productivity as industry-related factors, labor-related factors, and management-related factors. Industry-related factors, essentially, are the characteristics of the construction industry, such as the uniqueness of construction projects, varied locations, adverse and unpredictable weather, and seasonality. Labor-related factors include the union's influence, little potential for learning, and lack of motivation. Management-related factors usually refer to a lack of management for tools or techniques.

(Olomolaiye et al. 1998) Classified the productivity factors into two categories: external factors the ones outside the control of the organization management and internal factors related to the productivity factors originating within the organization. From their viewpoint, the nature of the industry, usually the separation of design and construction functions, has affected construction productivity through delay in drawings, design changes, and following rework. Construction clients have sometimes been obstructions to construction productivity because of their lack of suitable knowledge about construction procedures. Moreover, being an outdoor industry, construction performance is extremely affected by weather conditions. In addition to the factors disused, health and safety regulations, and codes of practices are other external factors influencing task operations and productivity. In the internal category, management inadequacies could result in a waste of resources with consequent losses in productivity; adoption of modern technology and training for the laborer would increase productivity.

(Thomas and Sakarcan 1994) Built an ideal to describe the factors affecting labor productivity. In the model, two groups of factors determine the productivity performance, work environment, and task to perform. Work-environment factors refer to how well a job is organized

and accomplished. Work to be done, or work content, relates to work required to perform and includes physical components of work, specification requirements, and design details.

Past study showed that task to be completed could affect the labor resources by as much as 15%, whereas work environment can affect labor requirements by an extra 25%. Based on this factor model, more detailed research was done. One study suggested that scheduled overtime always leads to efficiency losses because of the inability to deliver materials, tools, equipment, and information at an accelerated rate (Ginther, 1993).

Surveys and interviews are standard methods that have already been adopted in many productivity studies. (Lim and Alum 1995) Conducted a survey of top construction contractors to identify the factors affecting productivity in Singapore. The three items of extreme concern were identified as difficulty in the recruitment of supervisors, difficulty in the recruitment of labors, and a high rate of labor turnover. (Portas and AbouRizk 1997) undertook a questionnaire of superintendents and project managers to determine all possible factors affecting productivity. An interview conducted with contractors showed that weather and material delivery were the main adverse factors for site productivity (Hassanein and Melin, 1997). A questionnaire identified rework, material problems, tools, heavy-equipment availability, crew interference, overcrowded work areas, instruction, quality-control inspection, and management interventions as the main factors affecting craftsman productivity and motivation (Chang and Borcherding, 1985).

Another survey with construction personnel (Hanna and Heale, 1994) was conducted to gauge their opinion about the field of construction, specifically their knowledge about the factors that most affect construction productivity. As a result, a set of comprehensive factors was identified and classified into six groups: contract environment, planning, site management, working conditions, working hours, and motivation.

2.2. Different Factors Affecting Labor Productivity from Previous Studies

Productivity is the outcome of several interrelated factors. Discussed below are various factors affecting labor productivity and are reviewed from past studies.

i. **Time:** During construction projects, there are many tasks which causes a loss of productivity. Past study shows productivity decreases with working overtime. The most frequently stated reasons are fatigue; increased absenteeism; decreased morale; reduced supervision effectiveness; poor workmanship, resulting in higher rework; increased accidents (Horner and Talhouni, 1995). Working overtime initially result in increased output, but continuing overtime may lead to increased costs and reduced productivity (Hinze, 1999). Time used by a construction laborer on productive activities averages about 30% of the total time available. An employee in the field only works effectively for 3.5 hours of his 8-hour shift and spends 20% of his time on direct value-adding activities (Alinaitwe et al., 2005).

ii. **Schedule Compression:** When there are early delays in a project, compressions of the overall time frame for a later activity are often the way to compensate interruptions and to complete the assigned task on schedule. From a professional scheduling perspective, schedule compression may be possible without accelerating individual work activities by utilizing float in the project's overall schedule. However, on many projects, schedules are not fully resource loaded. As a consequence, a properly updated schedule reflecting the delays may show the project finishing on time without shortening individual activities. Schedule compression may result to force extra labors for the desired task by the contractor because of shortening the overall duration, allowing the contractor to complete the total remaining work. Schedule compression, when linked with overtime, often results in major productivity losses due to shortages of material tools or equipment to support the extra labor's, resulting in

difficult for planning and coordinating the task, and unavailability of experienced labors (National Electrical Contractors Association, 1983).

iii. **Type of Project:** To accomplish substantial productivity, every member of a crew requires adequate space to perform task without being affected with/by the other crew members. When more labors are allotted to perform particular task, in a fixed amount of space, it is probable that interference may occur, thus decreasing productivity. Additionally, when multiple trades are assigned to work in the same area, the probability of interference rises and productivity may be reduced. Interference among the various crews and laborers is due to mismanagement on construction sites. For example, a steel-fixture crew has to wait before fixing the reinforcement rods if the carpenter's framework is incomplete. The types of activities and construction methods also influence labor productivity (Sanders and Thomas, 1991).

iv. **Safety:** Accidents have high impacts on labor productivity. Various accident types occur at the site, such as an accident causing death and resulting in a total work stoppage for a number of days. An accident that causes an injured person to be hospitalized results in a work decrease of the crew for which the injured employee worked. Small accidents resulting from nails and steel wires can stop work and, thus, decrease productivity (Sanders and Thomas, 1991). Even insufficient lighting shows decreased productivity because sufficient lighting is required to work efficiently and because insufficient lighting has negative effects. Employing a safety officer helps labors to recognize the required safety regulations and to follow them, which can reduce the number of accidents, thus increasing productivity.

v. **Quality:** Inefficiency of equipment and poor quality of the raw material are factors which cause low productivity. The productivity rate of inefficient equipment is low. Old equipment

is subject to a great number of breakdowns, and it takes a long time for the laborers to complete the work, thus reducing productivity. Poor-quality material used for work is the other factor because poor materials generally lead to unsatisfactory work and can be rejected by supervisors, thus reducing the productivity.

vi. **Managerial Factors:** Managers' skill and attitudes have a crucial bearing on productivity. In many organizations, productivity is low even though the latest technology and trained manpower are made available. Low productivity is because of inefficient and indifferent management. Experienced and committed managers can obtain surprising results from average people. Employees' job performance depends on their ability and willingness to work. Management is the catalyst to create both. Advanced technology requires knowledgeable laborers who, in turn, work productively under professionally qualified managers. It is only through sound management that optimum utilization of human and technical resources can be secured.

vii. **Manpower Group:** Literature shows that a lack of labor experience is the factor which negatively affects labor productivity and proves that, to achieve good productivity, labor plays a significant role. Contractors should have sufficiently skilled laborers employed to be productive. If skilled labor is unavailable and a contractor is required to complete specific task with less-skilled labor, it is possible that productivity will be affected. The absence of any crew member may impact the crew's production rate because workers will, typically, be unable to accomplish the same production rate with fewer resources and with a different crew members. Misunderstanding among laborers creates disagreements about responsibilities and the work bounds of each laborer, which leads to a lot of work mistakes and decreases labor productivity. Lack of compensation and increased laborer age negatively affect labor

productivity because labor speed, agility, and strength decline over time and reduce productivity (Heizer and Render, 1990).

viii. **Motivation:** Motivation is one of the important factor affecting construction labor productivity. Motivation can best be accomplished when labors personal ambitions are similar to those of the company. Factors such as payment delays, a lack of a financial motivation system, non-provision of proper transportation, and a lack of training sessions are grouped in this topic (DeCenzo and Holoviak, 1990).

ix. **Supervision:** Generally, projects come across some design, drawings and specification changes during construction. If drawings or specifications are with errors and unclear productivity is expected to decrease since laborers in the field are uncertain about what needs to be done. As a result, task may be delayed, or have to be completely stopped and postpone it until clear instruction. There is a 30% loss of productivity when work changes are being performed (Thomas et al., 1999). Work inspection by the supervisor is an essential process to proceed. For example, the contractor cannot cast concrete before an inspection of the formwork and steel work, thus affecting labor productivity (Zakeri et al., 1996). With non-completion of the required work according to the specifications and drawings, supervisors may ask for the rework of a specific task. Supervisors' absenteeism stops the work totally for activities that require their attendance, such as casting concrete and backfilling, further delaying inspection of the completed work which, in turn, leads to delays in starting new work.

x. **Material/Tools:** Material management is one of the most important factor in construction industry. Productivity can be affected if required materials, tools, or construction equipment for the specific are not available at the correct location and time. Selection of the appropriate

type and size of construction equipment often affects the required amount of time it is, therefore, essential for site managers to be familiar with the characteristics of the major types of equipment most commonly used in construction. In order to increase job-site productivity, it is beneficial to select equipment with the proper characteristics and a size most suitable for the work conditions at a construction site. Laborers require a minimum number of tools and equipment to work effectively to complete the assigned task. If the improper tools or equipment is provided, productivity may be affected (Alum and Lim, 1995; Guhathakurta and Yates, 1993). The size of the construction site and the material storage location has a significant impact on productivity because laborers require extra time to move required materials from inappropriate storage locations, thus resulting in productivity loss (Sanders and Thomas, 1991).

xi. **Project Management Factors:** Improper scheduling of work, shortage of critical construction equipment or labor, may result in loss of productivity. Improper planning of project-initiation procedures generally lead to lost labor productivity. Additionally, poor site layout can contribute to a loss of productivity. Laborers have to walk or drive a long way to lunch rooms, rest areas, washrooms, entrances, and exits, affecting overall productivity (Association for the Advancement of Cost Engineering (AACE) International Recommended Practice No. 25R-03, 2004).

xii. **Natural Factors:** Various natural factors affecting labor productivity collected from previous study are weather conditions of the job-site and geographical conditions. Others factors such as fuel, water, and minerals also affect productivity to certain extent. Productivity is found to be highly affected if weather recorded are too be extreme (too cold, heavy rainfall, too hot.

xiii. **External Factors:** Weather conditions are significant factor to consider for completion of any construction project. Adverse winter weather, such as winds and rains, reduces productivity, particularly for external work such as formwork, T-shape work, concrete casting, external plastering, external painting, and external tiling. Adverse weather sometimes stops the work totally (Sanders and Thomas, 1991).

xiv. **Political Factors:** Law and order, stability of government, etc. are essential for high productivity in the construction industry. The government's taxation policies influence willingness to work and expansion of plants. (A. Kumar, as cited in Desai, 2004).

2.3. Identification of Possible Factors Affecting Productivity in Building Construction

Based upon the Literature Review, this study extracts various factors affecting labor productivity in construction from the previous research studies. Some similar factors were merged together, and some new factors were added. Factors does not take into consideration any values. They are arranged on general criteria. Table 2.1 shows various factors affecting labor productivity in construction extracted from previous studies.

Table 2.1. Factors Affecting Labor Productivity in Construction Industry (Previous Studies)

	Factors Affecting Labor Productivity	A	B	C	D	E	F	G	H	I	J
A	**Management Factors**										
	The level of management control		√	√							
	Professionalism of the design team	√	√	√				√			
	Difficulties in employing site supervisor					√	√		√		
	Work planning and scheduling	√	√	√	√					√	√
	Incompetence of site supervisor		√	√	√	√	√	√		√	√
	Late inspection of completed work							√			
B	**Site and Resource Management Factors**										
	Coordination of subcontractor	√			√						√
	Quality control		√								
	Communication breakdown		√	√	√			√			
	Information		√							√	
	Rework			√	√	√	√	√		√	
	Congestion	√	√	√	√	√	√			√	√
	Sequence of work	√	√	√	√		√			√	√
	Availability of workforce	√	√		√				√		√
	Financial problems	√	√								
	Availability of materials	√	√	√	√	√	√	√		√	√
	Availability of tools and machinery	√	√	√		√	√	√		√	
	Method and machinery	√	√	√		√	√	√			
C	**Project Characteristics Factors**										
	Location										
	Inclement weather		√	√	√			√	√	√	√
	Project characteristics		√				√			√	
	Specification									√	
	Design requirement										
	Project size		√								
	Site access		√								
D	**Workforce Characteristics Factors**										
	Quality Experience and Training		√								√
	Disturbance				√	√	√	√			√
	Morality (e.g., alcohol influence)										√
	Frequent changes in labors							√			
	Communication problems (laborers)					√			√		
	Turnover					√	√	√	√		
	Absenteeism							√	√		
E	**External Characteristic Factors**										
	Overtime (acceleration)			√	√	√					√
	Order Variations		√	√				√			√
	Economic Conditions	√	√								
	Development and research		√								

2.4. Factors Affecting Labor Productivity

Table 2.2. Shows possible factors affecting labor productivity in building construction collected from past study and literature review. It does not take into consideration any significant value, they are arranged in alphabetic order.

Table 2.2. Possible Factors Affecting Labor Productivity (in Alphabetical Order)

Sr.	Factors Affecting Labor Productivity at Building Construction
1	Accidents
2	Construction method
3	Drawings and specifications alternated during execution
4	Government regulation
5	High quality of required work
6	Increasing number of laborers
7	Inefficiency of equipment
8	Inspection delay
9	Insufficient transportation mean
10	Insufficient lighting
11	Labor absenteeism
12	Labor disloyalty
13	Lack of competition
14	Lack of financial motivation system
15	Lack of labor experience
16	Lack of periodic meeting with labor
17	Labor personal problems
18	Lack of place eating and relaxation
19	Lack of training sessions
20	Low quality of raw materials
21	Material shortage
22	Misunderstanding among laborers
23	Misunderstanding between laborers and superintendents
24	Misuse of time schedule
25	Payment delays
26	Rework
27	Supervisors' absenteeism
28	Tool and equipment shortages
29	Type of activities in the project
30	Unsuitability of materials storage location
31	Violation of safety precautions
32	Weather change
33	Working at high places
34	Working overtime

CHAPTER 3. RESEARCH METHODOLOGY

"Survey research is defined as collection of different data by asking people questions" (Fowler, 1993). The data collection process used in this research had the option of two basic methods: questionnaires and personal interviews. A questionnaire was preferred as the best effective and suitable data-collection technique for the study. It was concluded that the questionnaire was described as a self-administered tool with web-design questions, an appropriate response. A questionnaire in a web-survey format comparatively requires less duration and saves cost for the researcher while permits respondents to response the questionnaire at their personal ease. However, for this approach the reply rate is usually lower as compared to face-to-face interviews. Data was collected from literature reviews from books, journals, articles, seminar conferences, and websites which emphasize building construction's labor productivity. A survey was given to employees from different trades involved with the construction project.

3.1. Survey Planning

For the research study, email technology was used to send the survey questionnaire. Collecting general information on various factors affecting labor productivity in building construction all over USA was the basic aim of the survey. The purpose and approach used in the survey was fully explained to the respondents. Guidelines were provided to the respondents to ensure that the procedure was followed properly to reduce errors. During the survey period, some oversights were provided to help ensure the process was going smoothly and consistently. The data were stored in order to maintain confidentiality, and the output was received from the Group Discussion Center (GDC) in the form of electronic mail, which included raw data sheets,

summary sheets, and computer databases. Results included the overall statistics as well as individual statistics.

3.2. Considerations for the Survey

The main consideration for a survey was that it should be easy for respondents. If questions are too complicated, possibility of high drop-out rate was studied. Care was taken so that the initial questions did not negatively influence the results of subsequent questions. Preliminary text was introduced for explaining the survey project to the respondents. Page breaks on the webpages were introduced to improve the text readability. Logic-based questions were avoided because they could cause respondent frustration and increase the drop-out rate. Study was done to find any serious loopholes and if questions were truly answerable.

3.3. Organization of the Questionnaire

One of the biggest concern of the research study was about number of responses with complete information. Recognition of respondents about the benefits and uses of this research study was also of great concern. Following criteria was used to begin the questionnaire design process:

Questionnaire	**Response Rate**
Exactness	Duration
Applicable	Ease of Completion
Completeness	
Understanding	

Carefulness and productivity were achieved by examining the accuracy and completeness of the related questions, taking into consideration the previous studies and Table 2.1. Even tough, great measures were taken to make the questionnaire efficient, it was however not assured that

the response will be of high percentage. Great care was taken to assure respondents get precise duration to respond to the survey questionnaire and turn in to the researcher online. Considering the length, importance, sensitivity, past experience of researcher's advisor and feedback collected from pilot survey it was decided, the average time to complete the whole survey questionnaire would require about 15 minutes. Duration of 6 weeks was assigned to complete and submit the survey questionnaire. Questionnaire were kept effective and simple for the respondents. Various sections were designed for the survey questionnaire and they were assigned distinct colors for appropriate responding.

3.4. Questionnaire

The questionnaire design practice advanced on a communicating basis. It was categorized into profile of the respondent and various factors affecting labor productivity in building construction. Questions in the respondent profile were created to collect information such as job position, experience of the work, locations of the current and/or previous works and contact information. It was studied, these questions in the survey were of great important to the research by analyzing productivity loss concerns from a variety of different profiles from different regions. It was practical to anticipate that a location can have an impact on the loss of productivity due to various field disturbances, especially geographical and climatic conditions.

The next set of questions (Appendix B), was targeting the factors affecting labor productivity in the five different groups. It included factors affecting labor productivity. Respondents simply furnished of factors affecting productivity for given typical condition. Hence, each respondent had a choice to select only one option for each factor. The responses were to be based on the understanding, knowledge and experience of the respondents and not

related to any definite project. This simple and straight method was selected to establish a means of developing a list of factors affecting labor productivity in building construction.

3.5. Pilot Survey and Questionnaire Revision

To improve the questionnaire section, a pilot study was accompanied. This section contained identification of different causes, collection, and conclusions of data. The application of this section benefited in better formation of the web-survey development

Total 155 questionnaires, (shown in Table 2.2) were sent by e-mail to laborers, contractors, architectures, owners, project managers, and project engineers of various building construction organizations. It was expected to complete and submit the response within 2 weeks. By the end of 2nd week, 25 responses collected from the pilot survey, 5 of those were incomplete and were removed from the set, leaving a total of 20 respondents in the database. Information obtained and the recommendations provided in from pilot survey are discussed below.

- **i.** Questionnaire should always start with the general information of the organization
- **ii.** Some factors are not related to construction. They should be removed or modified.
- **iii.** To get more suitable and consistence meaning some factors should be rearranged.
- **iv.** Some factors should be revised with additional information.
- **v.** Factors repeated with similar meaning should be removed.
- **vi.** Some factors should be changed to give clearer importance and understanding.

Better and accurate questionnaire related to the topic was achieved from the pilot study. The perfections related to the organization of the questionnaire and the response time. In terms of organization, the web survey was created using a light appearance and pleasant-looking font colors. It also included a percentage bar for the completed survey and had an option to navigate to any question at any given time. All the information entered via the web had an auto-save

option and the respondents had the luxury to return to the survey within the allotted duration. Respondents were informed about the confidentiality of the responses. The list of questions used for the web survey can be found in Appendix B.

3.6. Questionnaire Distributions

The target groups in this study were professionals from the construction industry. A list of 255 building-construction organizations was obtained from the *Engineering News-Record.* The sample size can be calculated with the following equation for a 94% confidence level (Al-Shahri, M et al., 2001; Israel, 2003; Moore et al., 2003):

$$\mathbf{n= n' / [1+ (n' / N)]}$$

Where, n= Total number of population

N = Sample size from a finite population

n' = Sample size from an infinite population = S^2/V

S^2 = the variance of the population elements and

V = a standard error of the sampling population. (Usually, S= 0.5, and V = 0.06.)

$n'=S^2/V^2= (0.5)^2+(0.06)^2= 69.44$ For N=255

n = 69.44/ [1+ (69.44 / 255)] = 55

To obtain 94% of confidence level, it was calculated to send the questionnaire to 55 organizations to accomplish a 94%.

CHAPTER 4. ANALYSIS AND DISCUSSION OF RESULTS

4.1. Data Collected from the Web Survey

In successfully achieving main objective of the study, one of the most important phase is collection of accurate data. Data collection is a procedure of collecting crucial data records for a certain sample or population of observations (Bohrnstedt and Knoke, 1994). A total of 255 questionnaires were sent to construction professional through e-mail in early October 2009. By the due date, a total of 54 questionnaires were received, resulting in a nearly 21.17% reply rate (Table 3.1). Missing data frequently occur after the respondent chooses not to response a question or when the respondent rejects to answer the question. (Kim, 1993). The most serious concern presented in the responses was some missing data. Some of the unclear response was clarified over the phone. A total of 26 (i.e., 10.19%) invalid data received were deleted from research study. The reason to discard the data was incompleteness and invalid responses.

Table 4.1. Statistical Data of Questionnaires Sent and Received

	No.	Percentage of Total (%)
Total Questionnaires Sent	255.00	
Total Questionnaires Received	54.00	21.17
Invalid Data	26.00	10.19
Used for Study	28.00	11.00

4.2. Measurement of Data Collected from the Web Survey

It is commonly believed, while performing different task on construction projects, disturbances can existent with diverse degrees of danger. In order to overcome with these different degrees, it was decided to consider four condition levels: not applicable, does not affect it, somewhat affects it, and directly affects it. A clear specification of the standard conditions was necessary to enable respondents to clearly distinguish the degree of each adverse condition level. Standard conditions discussing to four different degrees of severity for each field were

recognized by Dr. Eric Asa, Dr. Y. K. Yates, and the researcher. The concept of different degrees of severity for productivity factors was previously used in other studies (Mechanical Contractors of America 1976) and (Neil and Knack 1984). Slight modifications were made to the typical conditions after they were reviewed by the participants. Further, detailed questionnaire was developed to calculate the factors affecting labor productivity in building construction.

In order to select the suitable technique of study, the level of measurement is to be studied. For each measurement type, there is (are) (an) appropriate method(s) that can be applied. In this research, ordinal scales were used. An ordinal scale, as shown in Table 3.2, is a ranking or a rating of data that normally uses integers in ascending or descending order. The numbers assigned (1, 2, 3, 4) neither indicate that the intervals between scales are equal, nor do they indicate absolute quantities. They are merely numerical labels. Based on a Likert scale, we have Table 3.2 (Cheung et al., 2004; Iyer and Jha, 2005; Ugwu and Haupt, 2007).

Table 4.2. Ordinal Scale Used for Data Measurement

Item	Not applicable	Does not affect it	Somewhat affects it	Directly affects it
Scale	1	2	3	4

4.3. Analysis Method Used

In order to facilitate the study, after the Literature Review and the focus interviews, a plan was formulated for collecting field information and creating an evaluation process and numerical values. It was necessary to provide straightforward communication to respondents to ensure a clear understanding of all the applicable definitions, procedures, and guidelines that were used in collecting data. Because the data-collection process included individuals, the study was conducted in accordance with the regulations of the Department of Health and Human Services, the Food and Drug Administration, and North Dakota State University (NDSU) Policy

#345 under the supervision of the NDSU Institutional Review Board (IRB). Two different ways were used to analyze the survey results.

i. Ranking of the various factors according to their significance, and calculating their Relative Importance Index (RII)

ii. Analyze the factors in the questionnaire are significant or non-significant.

The Relative Importance Index (RII) was used to decide various professionals' opinions of the RII in construction projects. RII is calculated as stated below (Cheung et al., 2004; Iyer and Jha, 2005; Ugwu and Haupt, 2007):

$$\boldsymbol{RII} = \frac{\sum \boldsymbol{W}}{\boldsymbol{A}} \times \boldsymbol{N}$$

W is the weight given to each factor by the respondents and ranges from 1 to 4.

W ranges $\begin{pmatrix} \text{1. Not applicable} & \text{3. Somewhat affects it} \\ \text{2. Does not affect it} & \text{4. Directly affects it} \end{pmatrix}$ × Number of respondents for each degree

A is the highest weight = 4.

N is the total number of responses collected for the ordinal scale.

4.4. Size of Organization (Employees)

The average number of employees in an organization was 36. Only building construction projects were considered for the study.

4.5. Number of Projects per Year

The average number of construction projects undertaken per year was 3. Only building construction projects were considered for the study.

4.6. Type of Construction Projects

The type of construction organizations that responded is shown in Table 4.1. Only building construction project were considered.

Table 4.3. Types of Organizations that Responded

Construction Organizations	Respondents
Residential	6
Commercial	6
Industrial	5
Government	1
Engineering	2
Architecture	5
Owner	3

4.7. Job Title

Respondents' job titles are shown in Table 4.2. Various professional in building construction projects were contacted to gather the information from web-survey.

Table 4.4. Job Title of the Respondents

Job Title of the Respondents	Number of Respondents
Project Manager	4
Project Engineer	11
Architecture	3
Others (APM, APE, Scheduler, and Estimator)	10

4.8. Typical Size of Projects

The size of the projects in US$ (Million) undertaken by the respondents' companies is shown in Table 4.3. Only building construction projects were considered for the study.

Table 4.5. Typical Size of Projects

Typical Size of Project	No. of Projects
0-5 Millions	11
5-10 Millions	9
10-100 Millions	7
> 100 Millions	1

Research was performed considering, 40 factors affecting labor productivity for building construction were identified, and their RII was calculated. These factors were classified into five groups: manpower factors, external factors, communication factors, resources factors, and miscellaneous factors. Different groups used in the study are discussed in detail.

4.9. Manpower Factors Affecting Labor Productivity

Table 4.4 and Figure 4.1 shows the ranking of the various factors for the manpower group. A lack of labor experience was ranked first in the manpower group, with an RII value of 488.7, and twelfth among all 40 factors affecting labor productivity (Table 4.11).

Lack of labor experience has a great influence on productivity. This result is supported by Paulson (1975) who found that the craftsmen's experience affects labor productivity. This conclusion is also supported by (Heizer and Render 1990) who established that the knowledge of the craftsman affects job-site productivity. This result is acceptable because experience improves both the intellectual and physical abilities of laborers which, consequently, increases labor productivity.

Labor disloyalty had a great effect on labor productivity and ranked in the 7th position for the manpower group, with an importance index of 373.75, and 39th among all 40 factors in terms of negatively affecting labor productivity (Table 4.11).

Table 4.6. Manpower Factors

Factors	RII	Rank
Lack of experience	488.75	1
Absenteeism	477.25	2
Alcoholism	425.50	3
Misunderstanding among laborers	419.75	4
Age	408.25	5
Lack of competition among the laborers	379.50	6
Disloyalty	373.75	7
Personal problems	368.00	8

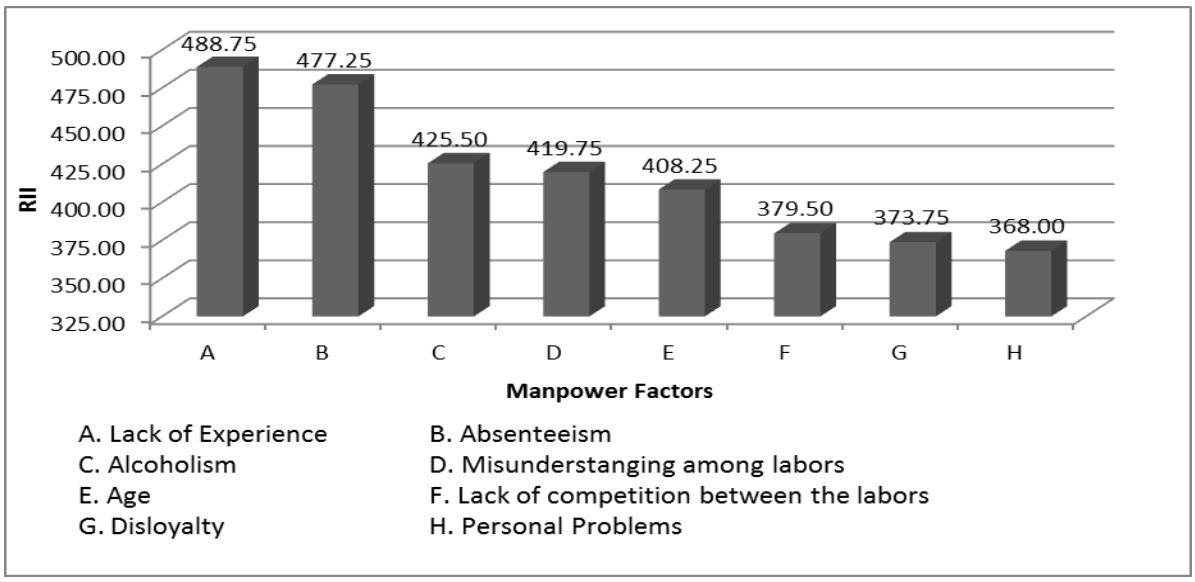


Figure 4.1. Manpower Factors.

Misunderstanding among laborers was ranked 4th in the manpower group, with an RII of 419.75, and 32nd among all 40 factors that affected labor productivity (Table 4.11). This result is acceptable because misunderstanding among laborers can creates disagreement among them and about the responsibilities for each laborer, which leads to a lot of mistakes in work and, consequently, affects labor productivity. A lack of competition among laborers ranked 6th, with an RII of 379.50, and ranked 38th among all 40 factors for negatively affecting labor productivity (Table 4.11.).

Labors' age was ranked 5th in the manpower group, with an RII of 408.25, and 34th among all 40 factors that affected labor productivity (Table 4.11). (Heizer and Render 1990) supported this result, citing that the age factor generally affects job-site productivity. This result is justified because speed required to perform particular task and strength decline over time affecting labor productivity.

Labor absenteeism was ranked 2nd in the manpower group, with an RII of 477.25, and in 18th among all 40 factors that affect labor productivity (Table 4.11). This result is justified given

the transient nature of the local workforce and the ease with which construction contractors could hire additional laborers to cover absenteeism.

Personal problems were ranked 8th in the manpower group, with an RII of 368.00, and 40th among all 40 factors that affect labor productivity (Table 4.11). This result might be justified because personal problems cause mental disturbance for laborers, and thus can affect labor safety more than labor productivity.

Alcoholism ranked 3rd in the manpower group, with an RII of 425.50, and 30th among all 40 factors that affect labor productivity (Table 4.11). Consuming alcohol at the construction site may lead to various negative effects on other laborers who are working. Alcohol consumption may lead to rework, misplacing the job work, and accidents, thus completely or partially stopping the construction work and affecting labor productivity.

4.10. External Factors Affecting Labor Productivity

Table 4.5 and Figure 4.2 illustrate the ranking of factors for the external group. Supervision delays were ranked 1st in the external group, with an RII of 488, and 13th among all 40 factors that negatively affect labor productivity (Table 4.11).

Table 4.7. External Factors

Factors	RII	Rank
Supervision delays	488.75	1
Variations in the drawings	488.75	2
Incomplete drawings	483.00	3
Rework	471.50	4
Design changes	465.75	5
Inspection delays from the authorities	448.50	6
Payment delays	442.75	7
Complex designs in the provided drawings	437.00	8
Implementation of government laws	419.75	9
Training sessions	414.00	10

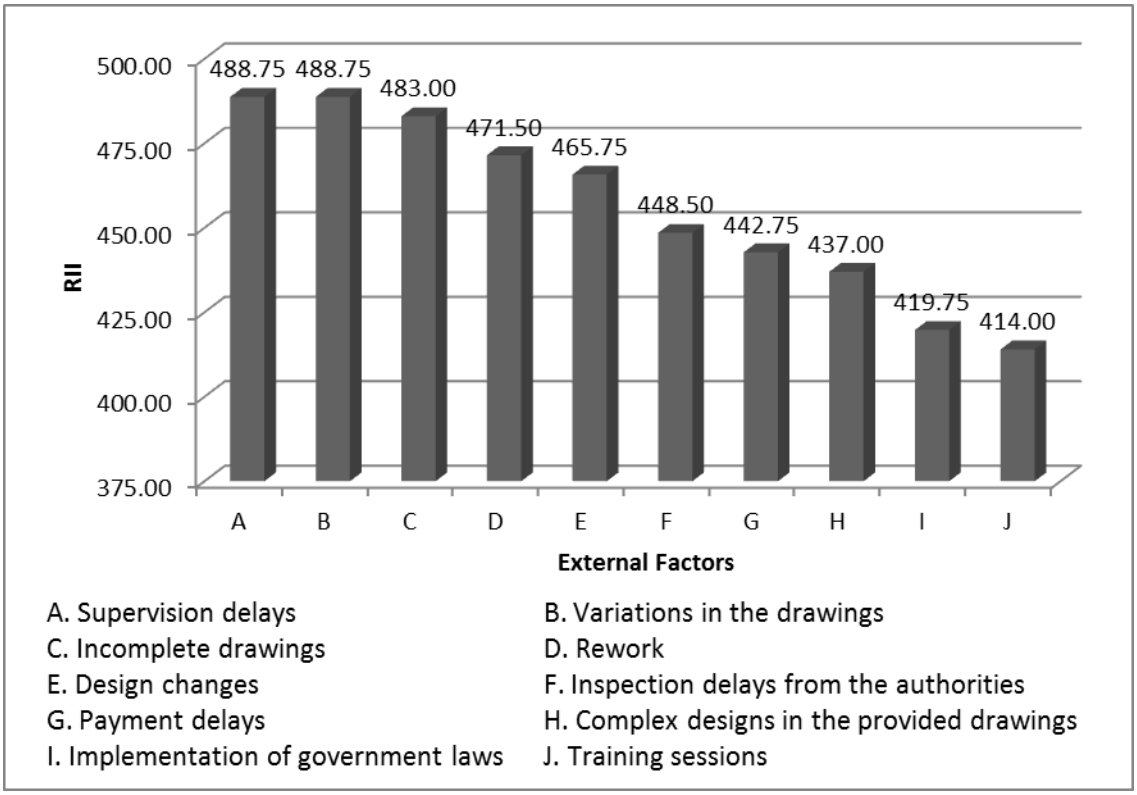


Figure 4.2. External Factors.

Inspection delays from the authorities were ranked 6th in the external group, with an RII of 448.50, and 22nd among all 40 factors that affect labor productivity (Table 4.11). Past study (Guhathakurta and Yates., 1993; Olomolaiye et al., 1996) proves that inspection delays are an important process; for example, because contractors cannot cast concrete before inspection of formwork and steel work, the inspection delay contributes to delays in work activities. It completely stops the task that require the presence of supervisors, such as casting concrete and backfilling. Additionally, it delays the inspection of completed work which, in turn, leads to a delay in the commencement of new work.

Variations in the drawings were ranked 2nd in the external group, with an RII of 488.75, and 14th among all 40 factors that affect labor productivity (Table 4.11). Incomplete drawings were ranked 3rd in the external group, with an RII of 483.00, and 16th among all 40 factors that

affect labor productivity (Table 4.11). Design changes were ranked 5th in the external group, with an RII of 465, and 21st among all 40 factors that affect labor productivity (Table 4.11). A complex design in drawings ranked 8th in the external group, with an RII of 437.00, and 27th among all 40 factors that affect labor productivity (Table 4.11). (Thomas et al. 1999) stated that "there is a 30% loss of efficiency when work changes are being performed. This result can be interpreted as changes to specifications and drawings that require additional time for adjustments of resources and manpower so that the change can be met. Also known as designer errors and omissions, these changes relate to plans that are incomplete or contain errors that are difficult to find until the construction contractor finds them well after the construction phase of the project has started. With most construction contracts, where the contractor bids on designs that are completed prior to contract award, the owner is liable for the designer's errors and omissions".

Payment delays were ranked 7th in the external group, with an RII of 442.75, and 24th among all 40 factors that affect labor productivity (Table 4.11). Payment delays in the construction industry are adversarial and disastrous. Late payment affects a company's cash flow and may ultimately lead to a business's failure. Timeliness of payment is important to avoid the risk of the late-payment problem. A study by Zou et al. 2007 pointed out that project-funding problems have been identified as cost-related risks, time-related risks, and quality-related risks which can significantly influence the delivery of a construction project. The risk of delayed payment from the owner impacts the duration and cost of the project. These risks causes the project's cost to increase abnormally and, subsequently, delay the project's progress.

Rework ranked 4th in the external group, with an RII of 471.50, and 19th among all 40 factors that affect labor productivity (Table 4.11). Past study from (Makulsawatudom and Sinthawanarong 2004) confirmed that rework is one of the major factors in the construction

industry to affect labor productivity in building construction. The study also listed rework as one of the critical factors effecting productivity and stated that rework is due to incompetent craftsmen and supervisors.

Implementing government laws was ranked 9th in the external group, with an RII of 419.79, and 31st among all 40 factors that affect labor productivity (Table 4.11). For most projects, government authorities refer to specific versions and construction standards of their design. Sometimes, government authorities, who have documented standards for design and construction, may decide to revise those standards after the job has been awarded, based on a previous version, thus affecting the overall labor productivity of the building construction.

Training sessions were ranked 10th in the external group, with an RII of 414.00, and 33th among all 40 factors that affect labor productivity (Table 4.11). Past studies from (Lema and Samson 2002), (Cheung et al. 2004), and (Iyer and Jha 2005) stated that persons entering the construction industry directly from high school usually start as inexperienced in construction industry or as laborers. They can learn from their job quickly by working closely with experienced people. Whereas, skilled laborers, such as carpenters, bricklayers, plumbers, and other construction trade specialists, most often get their formal instruction by attending a local technical school or through an employer-provided training program.

4.11. Communication Factors Affecting Labor Productivity

Table 4.6 and Figure 4.3 show the ranking of the factors for the communication group. Change order from the Design Engineer ranked 1st in the communication group with an RII of 465.75, and 20th among all 40 factors affecting labor productivity (Table 4.11).

Table 4.8. Communication Factors

Factors	RII	Rank
Change orders from the designers (DE)	465.75	1
Change orders from the owners (OW)	442.75	2
Misunderstanding among OW, Contractors (CO), and DE	431.25	3
Disputes with the DE	396.75	4
Disputes with the OW	391.00	5

A change order from the OW ranked 2nd in the communication group, with an RII of 442.75, and 23th among all 40 factors affecting labor productivity (Table 4.11). Disputes with the OW were ranked 5th in the communication group, with an RII of 391.00, and 37th among all 40 factors affecting labor productivity (Table 4.11). Misunderstanding among the OW, CO, and DE ranked 3rd in the communication group, with an RII of 431.25, and 29th among 40 factors affecting labor productivity (Table 4.11).

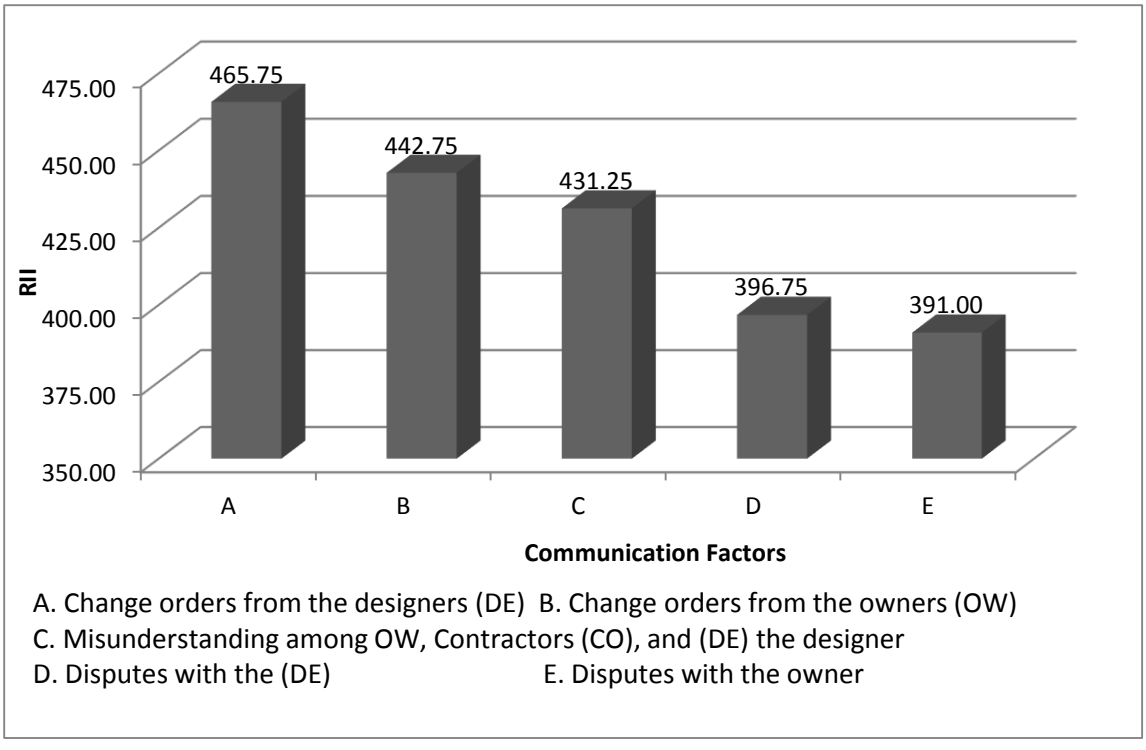


Figure 4.3. Communication Factors.

Disputes with the DE were ranked 4th in communication factors, with an RII of 396.75, and 35th among all 40 factors affect labor productivity (Table 4.11). This result can be justified because DE shortages are changes that result from defective or confusing aspects of construction designs and specifications which cannot be discovered until the contractor begins performing task sketched on drawing sheets. Design deficits are frequently the result of poor quality control in the design process, and they are manageable. The owner is also responsible for the contractor's costs due to designer errors, such as unreasonable delays in reviewing shop drawings, failure to provide drawings or design information in a timely fashion, failure in timely inspections, and other delays due to the designer's contract-administration problems (Bramble and Callahan, 2000).

4.12. Resource Factors Affecting Labor Productivity

Table 4.7 and Figure 4.3 show the ranking for factors of the resource group. A lack of required construction material was ranked first in the resource group, with an RII of 558.00, and was first among all 40 factors affecting labor productivity (Table 4.11)

Table 4.9. Resource Factors

Factors	RII	Rank
Lack of required construction material	558.00	1
Lack of required construction tools/equipment	540.00	2
Insufficient lighting	510.00	3
Poor site condition	510.00	4
Differing site condition from plan	504.00	5
Material storage location	504.00	6
Poor access within construction site	492.00	7
Violation of safety laws	486.00	8
Quality of required work	480.00	9
Inadequate transportation facilities for workers	438.00	10
Inadequate construction material	437.00	11
Increase in the price of material	396.00	12

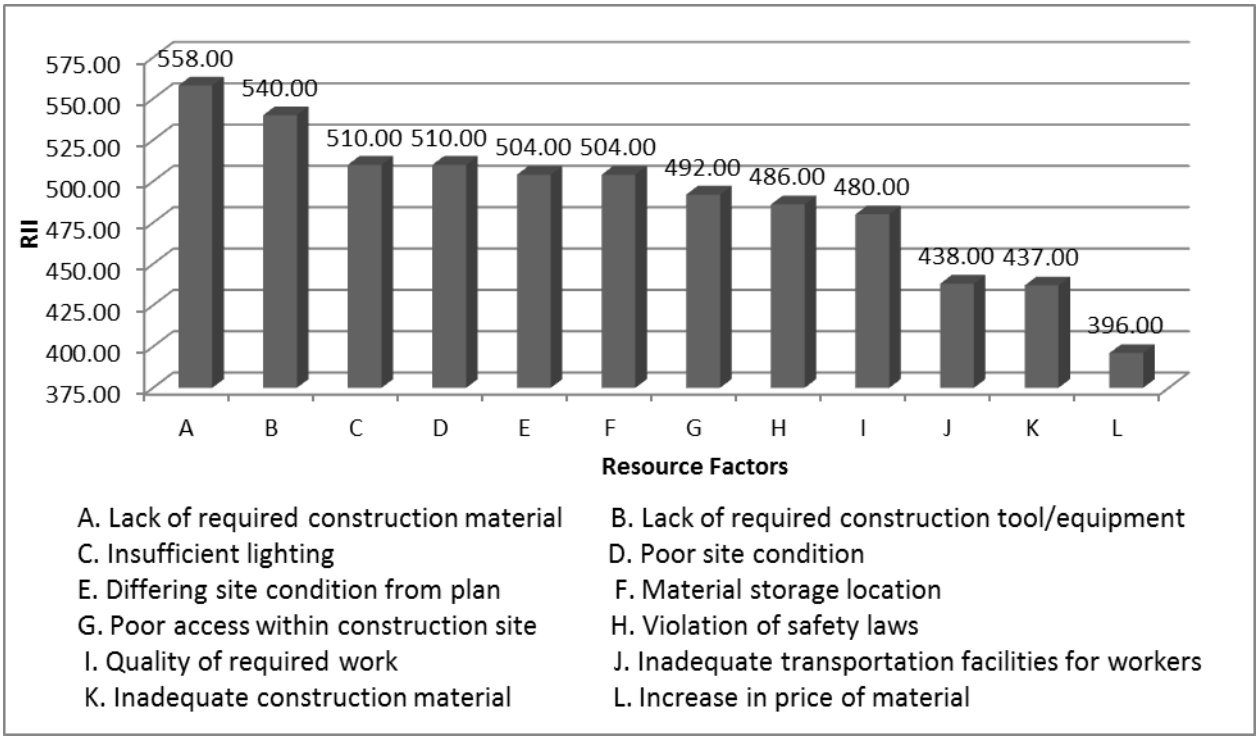


Figure 4.4. Resource Factors.

Inadequate construction material was ranked 11th in the resource group, with an RII of 437.00, and 28th among all 40 factors affecting labor productivity (Table 4.11). An increase in the price of material was ranked 7th in the resource group, with an RII of 396.00, and 36th among all 40 factors affecting labor productivity (Table 4.11).

(Damodara, 1999) Since material resource contribute 40-60% of the total project cost, it is supposed to be one of the most important factors which required good knowledge to improve labor productivity in construction. Past study shows, required consideration is not given to material resource management and its effects on labor productivity. It is impossible to complete any particular task without availability of required materials. A material shortage is ranked first position among factors affecting labor productivity in the United States, United Kingdom, Indonesia, Nigeria, Singapore, and Kenya (Guhathakurta and Yates, 1993; Lim and Alum, 1995; Olomolaiye et al., 1996). A lack of material refers to the inaccessibility of certain materials or

the excessive time expended to obtain them. (Thomas et al. 1999) estimated that poor material management caused an 18% work-hour overrun. This study found a total of 35.6 man hours of unproductive time attributed to material unavailability, which amounts to 9.5% of the total wasted time.

A lack of required construction tools/equipment was ranked second in the resource group, with an RII of 540.00, and fourth among all 40 factors affecting labor productivity (Table 4.11). This result can be justified as major equipment on the site, including cranes, passenger/cargo lift, trailer concrete pump, truck mixer, and safety scaffolding. The entire construction process depends heavily on this equipment. For example, cranes are needed to move and position formwork, and to hoist and place reinforcement; the truck mixer and concrete pump are indispensable to transport and place concrete. Any interruption in the use of the equipment leads to serious material-handling problems as well as a slowdown or a stoppage of operations. Therefore, the availability of equipment is regarded as important for construction progress. Past studies (Guhathakurta and Yates, 1993); (Olomolaiye et al., 1996) prove that a lack of equipment is one of the principal factors that negatively affect labor productivity.

The material storage location was ranked sixth in the resource group, with an RII of 504.00, and ninth among all 40 factors affecting labor productivity (Table 4.11). A past study (Sanders and Thomas, 1991) stated that the size and the organization of the materials' storage location has a significant impact on masonry productivity. This result is justified because laborers need more time to bring required materials from unsuitable storage locations, negatively affecting productivity.

Insufficient lighting was ranked third in the resource group, with an RII of 510.00, and sixth among all 40 factors affecting labor productivity (Table 4.11). Proper lighting is one of the

basic requirements for obtaining fair labor productivity with any construction work. Failure to have adequate lighting may lead to different consequences, such as misplacing a particular job, or even serious accidents and the death of laborers at construction sites, thus negatively affecting labor productivity.

Poor access within a construction site was ranked eighth in the resource group, with an RII of 492.00, and eleventh among all 40 factors affecting labor productivity (Table 4.11). Study from (Sanders and Thomas 1991) proves one of the common reasons for low productivity is poor access within the construction site. Poor access reduces the free movement of labor and, consequently, reduces labor productivity. Interference between crews and laborers is caused by mismanagement on construction sites, with steel fixers suffering more of the mismanagement, possibly because they are more dependent on other trades. For example, if the carpenters have not completed the formwork, steel fixers have to wait before fixing the reinforcement rods.

Differing site conditions from the plan was ranked fifth in the resource group, with an RII of 504.00, and eighth among the 40 factors affecting labor productivity (Table 4.11), Poor site condition ranked was ranked fourth in the resource group, with an RII of 510.00, and sixth among the 40 factors affecting labor productivity (Table 4.11). A differing site or unpredicted condition occurs when underlying site conditions for a construction project are uncovered after the contract between the contractor and the owner has been executed and were not previously expected or included in the design documents. Differing site conditions are worth making note of only if the contractor experiences an increased cost and/or delay. Common examples of differing site conditions occur when a contractor performs earth excavation and uncovers objects or soil types that were previously unforeseen, requiring extraordinary measures to accommodate. These

extraordinary measures can easily cost the contractor extra money and/or time above that for which was originally contracted.

Violation of safety laws was ranked 9th in the resource group, with an RII of 480.00, and 15th among the 40 factors affect labor productivity (Table 4.11). Construction is one of the most unsafe industries (Suazo and Jaselskis, 1993). The major causes of accidents are related to the unique nature of the industry, human behavior, difficult work-site conditions, and poor safety management, which result in hazardous work methods, equipment, and procedures. Preventing occupational injuries and illness should be a primary concern among both employees and employers. In the construction industry, the working environment is constantly changing sites that exist for a relatively short time as well as activities and inherent risks that change daily. Within a short time of a hazard being identified and dealt with, typically, the workplace has changed, bringing new hazards. (Davies and Thomas, 1990).

Quality of the required work was ranked 10th in the resource group, with an RII of 480.00, and 17th among the 40 factors affecting labor productivity (Table 4.11). In many cases, the quality of the product is not present and results in rework. The time required to construct particular task using poor quality material is greater than the time required to build with better quality materials. Additionally, wasting poor-quality materials is high, particularly at the time of handling. In addition, using materials of poor quality generally leads to poor-quality work which can be rejected by the supervisor. Cheung et al. (2004) remarked that the work quality certainly affects the performance of construction projects. Iyer and Jha (2005) observed that performance quality affects the cost performance of construction projects. Quality is also one of the three main constraints, together with cost and time.

An inadequate transportation facility for workers was ranked 12th in the resource group, with an RII of 438.00, and 17th among the 40 factors affecting labor productivity (Table 4.11). Past study from (Lema and Samson 1995) states that a transportation facility also affects labor productivity. If the construction site is located on the outskirts of a city/town with inadequate public transportation facilities, labors find it difficult to reach the construction site.

4.13. Miscellaneous Factors Affecting Labor Productivity

Table 4.8 and Figure 4.5 shows the ranking factors for the miscellaneous group. A shortage of water and/or power supply was ranked 1st in the miscellaneous group, with an RII of 1st 552.00, and 2nd among all 40 factors that affect labor productivity (Table 4.11). Accidents during construction were ranked second in the miscellaneous group, with an RII of 546.00, and third among all 40 factors that affect labor productivity (Table 4.11).

A study from (Sanders and Thomas, 1991) showed that accidents have a significant impact on labor productivity. The authors stated three different types of accidents:

- **i.** Total stoppage of performing task for number of days due to accidents resulting in death of injured labors.
- **ii.** Injured labor or labors hospitalized for at least 24 hrs. It can decrease the productivity at the site or can result in complete stoppage of the work.
- **iii.** Few cases where productivity can be affected marginally is accidents resulting from nail and steel wired at the job task.

Table 4.10. Miscellaneous Factors

Factors	RII	Rank
Shortage of water and/or power supply	552.00	1
Accidents during construction	546.00	2
Weather conditions	510.00	3
Working overtime	504.00	4
Project objective is not well defined	442.75	5

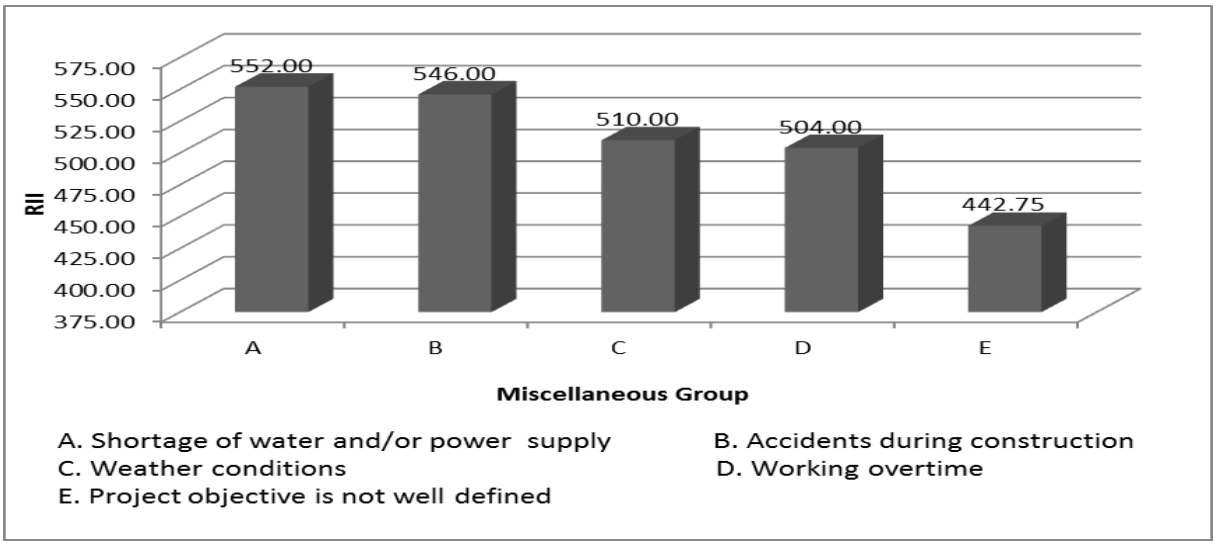


Figure 4.5. Miscellaneous Factors.

Weather conditions were ranked third in the miscellaneous group, with an RII of 510.00, and seventh among the 40 factors that affect labor productivity (Table 4.11). A majority of the construction-related activities are performed in an open atmosphere and can be seriously affected by unexpected, extreme weather. Past studies (Koehn and Brown, 1985; Sanders and Thomas, 1991) prove that temperature and humidity have an adverse effect on productivity. Performing the construction task under extreme weather conditions (below -10^{o} F and above 110^{o} F) is generally difficult. Thomas et al. (1999) show that almost 30% of the productivity loss for steel-erection construction occurred due to a winter climate.

Working overtime was ranked fourth in the miscellaneous group, with an RII of 504.00, and tenth among the 40 factors that affect labor productivity (Table 4.11). Working overtime can be a negative factor causing various problems such as increase in absenteeism and reduced in safety (Horner and Talhouni, 1995). Number of hours worked beyond 40 hours per week is termed as overtime. It is generally introduced to achieve acceleration of the assigned task. It is

generally used to make up for delays in projects. The extra work under overtime is usually paid time and half of the regular wages.

The project objective not being well defined ranked 5th in the miscellaneous group, with an RII of 442.75, and 25th among the 40 factors that affect labor productivity (Table 4.11). Poor planning, inadequate estimates, lack of training, lack of productivity standards, and poor project management are the factors involved with the project objective not being well defined.

4.14. Overall Factors Affecting Labor Productivity According to RII Value

The result in Table 4.11 and Figure 4.6 shows overall ranking of 40 factors that negatively affect labor productivity, identified in this study.

Table 4.11. Overall Ranking of Factors Affecting Labor Productivity

Factors affecting labor productivity in construction	RII	Rank
Lack of required construction material	558.00	1
Shortage of power and/or water supply	552.00	2
Accidents during construction	546.00	3
Lack of required construction tools/equipment	540.00	4
Poor site condition	510.00	5
Insufficient lighting	510.00	6
Weather condition	510.00	7
Differing site conditions from plan	504.00	8
Material storage location	504.00	9
Working overtime	504.00	10
Poor access within construction site	492.00	11
Lack of experience	488.75	12
Supervision delays	488.75	13
Variations in the drawings	488.75	14

(continued)

Table 4.11. Overall Ranking of Factors Affecting Labor Productivity (continued)

Factors affecting labor productivity in construction	RII	Rank
Violation of safety laws	486.00	15
Incomplete drawings	483.00	16
Quality of required work	480.00	17
Absenteeism	477.25	18
Rework	471.50	19
Design changes	465.75	20
Change orders from the designer	465.75	21
Inspection delays from the authorities	448.50	22
Payment delays	442.75	23
Change orders from the owner	442.75	24
Project objective not well defined	442.75	25
Inadequate transportation facilities for workers	438.00	26
Complex design in the provided drawings	437.00	27
Inadequate construction material	437.00	28
Misunderstanding among owner, contractor, and designer	431.25	29
Alcoholism	425.50	30
Misunderstanding among laborers	419.75	31
Implementation of government laws	419.75	32
Training sessions	414.00	33
Age	408.25	34
Disputes with designer	396.75	35
Increase in material price	396.00	36
Disputes with the owner	391.00	37
Lack of competition among laborers	379.50	38
Disloyalty	373.75	39
Personal problems	368.00	40

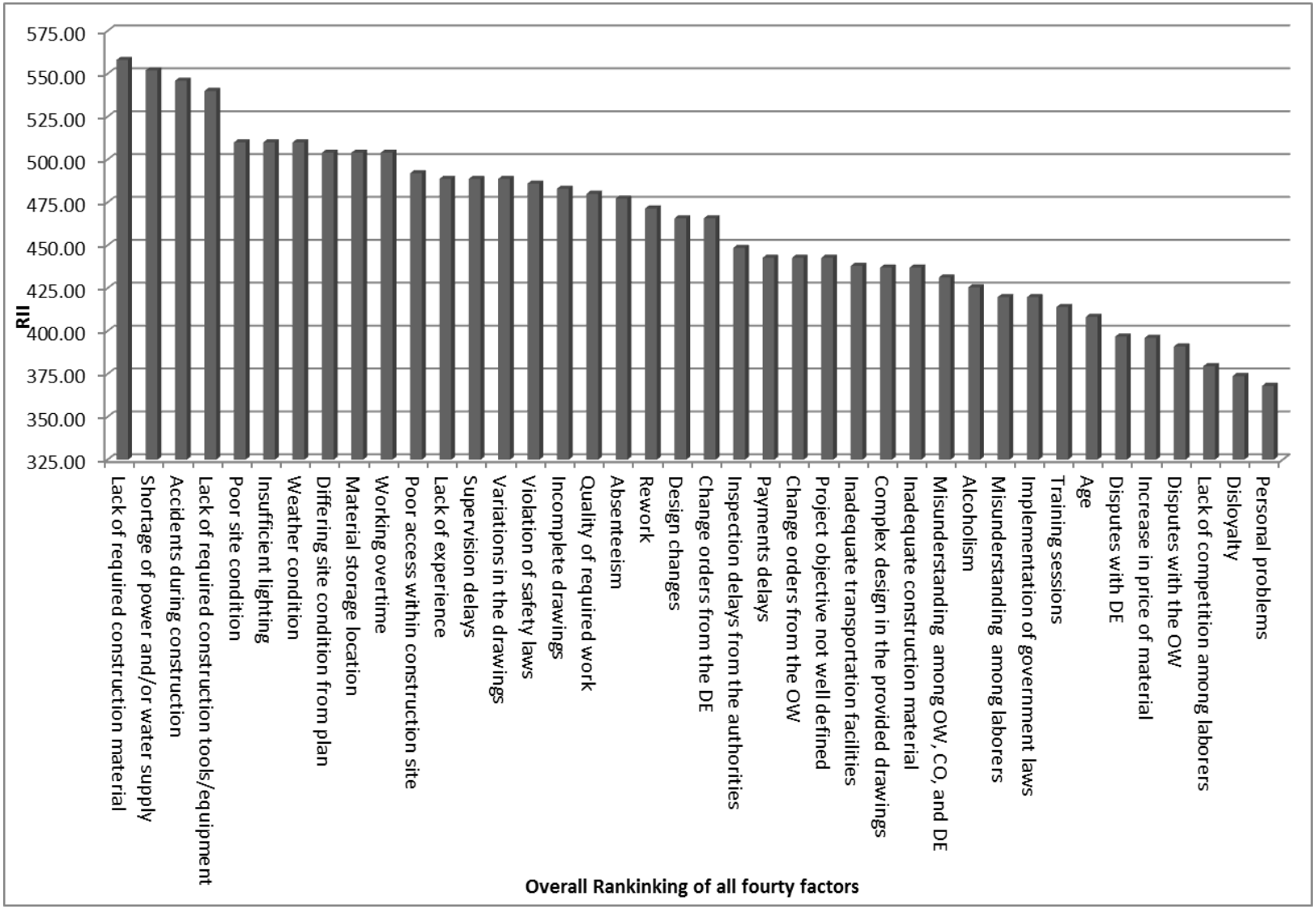


Figure 4.6. Overall Forty Factors.

4.15. Group of Factors Affecting Labor Productivity

Group ranking according to the respective factors affecting labor productivity is shown in Table 4.10 and Figure 4.7. It was calculated by taking into consideration the average RII value for all the factors that affect labor productivity in construction. Miscellaneous factors was the top group, with an average RII of 510.95, and the manpower group was at the bottom, with average RII value of 417.59

Table 4.12. Group Factors

Factors	RII	Rank
Miscellaneous	510.95	1
Resources	487.91	2
External	455.98	3
Communication	425.50	4
Manpower	417.59	5

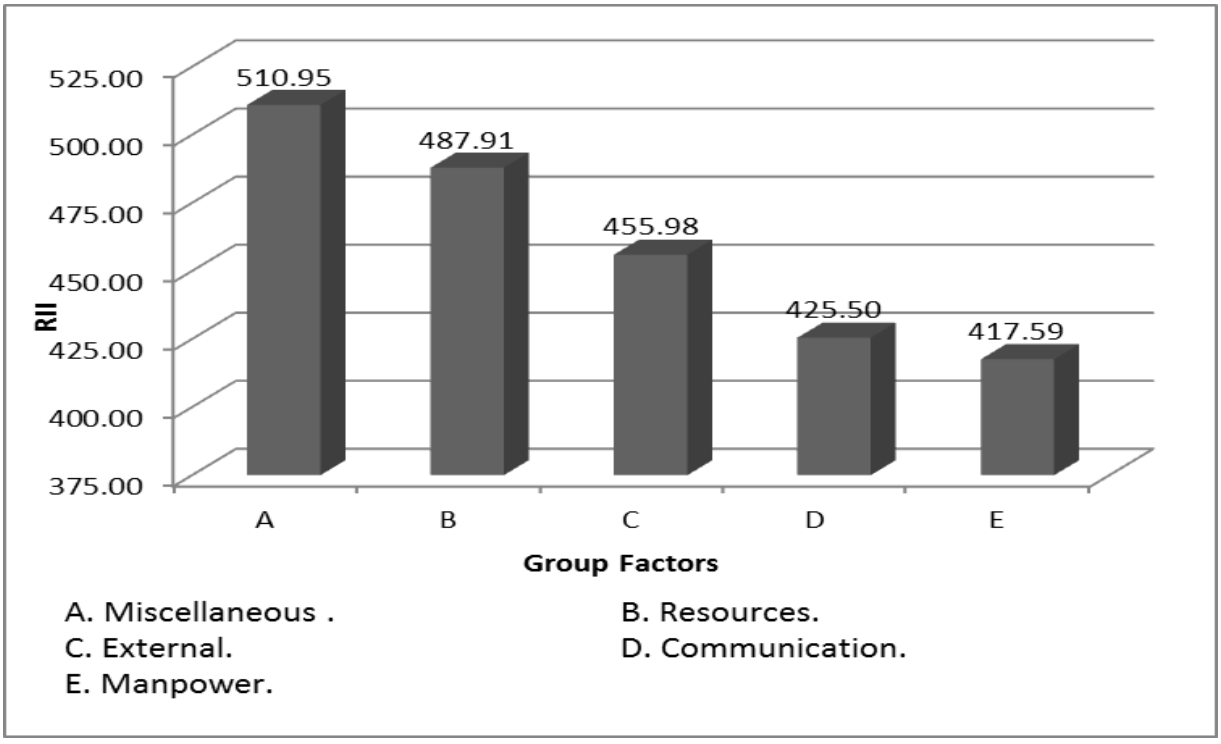


Figure 4.7. Group Factors.

4.16. Statistical Method

A study was used to collect observations about areas of interest, and statistical analysis was performed. Statistics were a supportive tool for this study concerning the analysis and interpretation of the data. The approach used for this study was the Large-Sample Test of Hypothesis used for population proportion, which is a two-tailed test. Population proportions (or percentages) are often made in the context of the probability, *p*, of success for a binomial distribution (Mc Clave, 2006).

4.17. Test Formula

The test is formulated as Ho: $p = po$ Ha: $p \neq po$,

Where, p = population proportion

po = null-hypothesized proportion

Test statistic:

$$z = \frac{\text{Sample proportion - Null hypothesized proportion}}{\text{Standard deviation of sample proportion}}$$

Rejection region when Ha: $p \neq po$. Reject Ho if T is greater than z.05 = 1.96 or less than −1.96.

4.18. Examples of Test

Test was accomplished according to Equation 4.2. Test results are shown in Table 4.11. All the T's that are bigger than 1.96 mean significant factors affecting labor productivity in building construction.

4.19. Identification of Significant and Non-Significant Factors

Identified significant and non-significant are shown in Table 4.13. Testing Ho: $p = 0.50$ vs. Ha: $p \neq 0.50$, where p represents that the proportion of respondents who suggested the factor affects labor productivity is significant or non-significant. (T is the test statistic.)

Table 4.13. Identification of Significant and Non-Significant Factors

Factor	Result	Comment
Lack of required construction material	T = 6.0 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Shortage of power and/or water supply	T = 4.9 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Accidents during construction	T = 5.1 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Lack of required construction tools/equipment	T = 3.1.0 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Poor site condition	T = -1.4 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Insufficient lighting	T = 4.9 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Weather condition	T = 2.8 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Differing site conditions from plan	T = 4.2 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Material storage location	T = 3.8 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Working overtime	T = 3.0 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Poor access within construction site	T = 1.02 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Lack of experience	T = 1.1 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Supervision delays	T = 4.4 Rejection of T	More than 50% suggest significant factor affecting labor productivity

(continued)

Table 4.13. Identification of Significant and Non-Significant Factors (continued)

Factor	Result	Comment
Variations in the drawings	T = 3.3 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Violation of safety laws	T = -1.08 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Incomplete drawings	T = 2.3 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Quality of required work	T = 1.8 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Absenteeism	T = -1.3 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Rework	T = 5.5 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Design changes	T = 3.9 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Change orders from the designer	T = 2.1 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Inspection delays from the authorities	T = 2.9 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Payments delays	T = 4.1 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Change orders from the owner	T = 2.6 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Project objective not well defined	T = 0.2 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Inadequate transportation facilities for workers	T = -1.9 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity

(continued)

Table 4.13. Identification of Significant and Non-Significant Factors (continued)

Factor	Result	Comment
Complex design in the provided drawings	T = 2.8 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Inadequate construction material	T = 2.0 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Misunderstanding among owner, contractor, and designer	T = 1.9 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Alcoholism	T = -1.4 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Misunderstanding among laborers	T = -1.9 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Implementation of government laws	T = -1.1 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Training sessions	T = 5.9 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Age	T = 2.9 Rejection of T	More than 50% suggest significant factor affecting labor productivity
Disputes with designer	T = 0.6 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Increase in material price	T = -1.4 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Disputes with the owner	T = 1.2 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Lack of competition among laborers	T = 1.4 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Disloyalty	T = 1.3 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity
Personal problems	T = 1.1 No Rejection of T	Not enough evidence. Non-significant factor affecting labor productivity

4.20. Comparative Analysis of the Current Study with Other Countries Studied in the Past

Finally, the study also compares the survey results with other countries. Results of the comparative analysis show that the findings of each study are different from the others. These dissimilarities prove that the factors affecting construction productivity change based upon geographical locations and different project types (industrial, commercial, industrial, and highways). The study concludes that these dissimilarities are due to differences in climatic conditions, construction methods, use of materials, availability of innovative technology, and contractual procedures. However, there are some common factors observed among the studies, including a delay in approving the design and drawings, a delay for payments from the owner to contractors, equipment-related delays, improper construction methods, rework due to errors during construction, poor planning and scheduling by the contractor, labor-related delays, a lack of communication and coordination among all parties, material-related delays, extreme weather conditions, and slowness in the owner's decision to approve the design. Table 4.12 lists the top ten factors affecting labor productivity in construction.

Table 4.14. Comparative Analysis of the Current Study with Different Countries Studied in the Past

Rank	USA (Present Study)	Nigeria (Olomolaiye et al., 1987)	Egypt (Enshassi et al., 2006)	Malaysia (Abdul Kadir et al., 2005)	Singapore (Lim and Alum, 1995)
1	Lack of required construction material	Inadequate or poor planning	Material shortage	Material shortage at project site	Difficulties recruiting supervisors
2	Shortage of power and/or water supply	Mismanagement of funds	Lack of labor experience	Stoppage of material delivery due to financial problems.	Difficulties recruiting workers
3	Accidents during construction	Delay making decisions and approvals by the owner	Lack of labor surveillance	Change order by CO causing project delay	High rate of labor turnover
4	Lack of required construction tools/equipment	Affection for the use of low-quality material	Misunderstanding between laborers and superintendents	Non timely issuance of drawings by consultants.	Labor absenteeism at the work site.
5	Insufficient lighting	Poor coordination and communication	Drawings and specifications change during execution	Not able to organize site activities.	Communication problems with foreign workers
6	Poor site condition	Late deliveries	Payment delays	Late issuance of payment by client	Inclement weather
7	Weather condition	Contractor's lack of experience	Labor disloyalty	Late supply of materials.	Health issues
8	Differing site condition from plan	Discrepancies among architectural, structural, mechanical, etc. drawings	Inspection delays	Non-availability of labors for construction tasks.	Material storage
9	Material storage location	Inadequate and unclear drawings	Working seven days a week with no holiday.	Coordination problems with subcontractor	Alcoholism and similar problems among workforce
10	Working overtime	Bad weather conditions	Tool and equipment shortages	Equipment shortage	Disruption of power/water supply

CHAPTER 5. RECOMMENDATIONS AND CONCLUSION

5.1. Recommendations

Construction tasks are expensive and frequently cause in arguments and claims, which generally affects progress of construction projects. The environment of construction organizations should be suitable to implement projects with successful completion. In the construction industry, it is necessary to find the weaknesses of particular task in order to solve and overcome them. Mentioned below are the recommendations which were found to be important factors for improving labor productivity in the construction industry.

i. A detail schedule of material supply schedule for each project should be provided by the contractors. It should contain the time required to supply materials and the availability of the local market to furnish the required materials in time. Extra attention is required on quality of construction materials and tools used in their projects because using suitable materials and tools reduces both the time taken to finish the work and wastage of materials. Using suitable materials and tools also has a positive effect on the task and thus, better labor productivity can be achieved.

ii. Organizations should make sure there is enough lighting present at the construction sites which can indirectly reduce the number of accidents. Continuous safety training and meetings should be arranged to achieve better performance in labor productivity.

iii. Purchased material should be stored at appropriate location and should be easily accessible and close to constructed buildings to avoid wasting labor time for multiple-handling materials.

iv. Recruiting manager and project managers should recruit appropriate candidate to particular task. Friendly relations should be maintained with labors and made aware of their importance to the organization

v. To achieve desired results, time required to implement change orders and to make corrections in drawings and specifications should be estimated and scheduled without affecting the project-time completion. Regular meetings should be arranged with the project authorities.

vi. Various external and natural factor risk should be considered in the budget estimation to minimize delays due to closures and material shortages. There should be suitable emergency budget to cover cost of increased material.

vii. A financial incentive in the form of best employee of the year should be implemented to create competition among the employees, thus achieving better productivity.

viii. Strict drug and alcohol tests should be implemented on a surprise basis and strict action should be taken with the employees who test positive.

ix. Complex design and incomplete drawings should be avoided and care should be taken to avoid confusion among the various construction agencies.

x. If the construction sites are present in remote geographical locations where public or employees' own transportation facilities cannot be made available, appropriate organized transportation should be given to the employees.

xi. Change orders and design error should be avoided as much as possible. These factors can be costly and time consuming if the work has been done. Work sequences can also be affected due to rework.

xii. Absenteeism at work site can be reduced with inclusion of appropriate paid time off and vacations to all employees.

5.2. Conclusion

In today's world, the construction industry is rated as one of the key industry. It helps in developing and achieving the goal of society. Study and knowledge of construction productivity

are very important because they cause losses to the governing agencies and also influence the economics of the construction industry. Prior knowledge of labor productivity during construction can save money and time. Investments for these projects are very high and because of the complexity in construction, various factors can highly affect overall productivity, thus the project can end up adding even more time and money in order to be completed. This research is intended to identify the causes of probable factors affecting labor productivity in building construction. This study investigates all possible factors through a structured questionnaire administered all over the USA. The survey results are subjected to analysis, and the ranking of factors is calculated using the Relative Important Index. The basic ideas of the research is to study various factors affecting labor productivity on construction.

Forty factors considered for the study were categorized in five different groups' manpower, external, communication, resources, and miscellaneous groups. The target groups in this study were construction professionals. Total of 255 questionnaires were distributed, and 28 questionnaires (11.00% response rate) were returned. Because project engineers, project managers have vast experience in construction, their adequate experiences were a proper suggestion to study about the various construction factors affecting labor productivity.

5.3. Future Research

The current research study was limited to the building construction industry in the USA. Future study could be done in other parts of the world and could emphasize specific types of building construction, including commercial, education, government buildings, skyscrapers, etc. A study similar to the present research is needed for transportation projects to find factors that affect the productivity of highway construction, which will help departments of transportation to minimize unnecessary cost escalations and project-schedule delays. Federal and state governments invest significant amounts of capital on road construction.

REFERENCES

Association for the Advancement of Cost Engineering (AACE), International Recommended Practice No. 25R-03 (2004). Estimating Lost Labor Productivity in Construction Claims

Abdul Kadir, M. R., Lee, W. P., Jaafar, M. S., Sapuan, S. M., and Ali, A. A. (2005). "Factors affecting construction labor productivity for Malaysian residential projects." Structure Survey, 23(1), 42-54.

Adrian, J. (1987). Construction Productivity Improvement. Elsevier Science Publishing, Amsterdam, Netherlands.

Adrian, J. (1990). Improving Construction Productivity Seminar, Minneapolis, MN. The Association of General Contractors of America.

Alarcon, L. F Borcherding, J. D., and. (1991). "Quantitative effects on construction productivity." The Construction Lawyer, American Bar Association, 11(1), 35-48.

Alinaitwe, H., Mwakali, J., and Hansson, B. (2005). Labor productivity in the building construction, Proceedings of CIB 2006, W065/W055/W086 – Construction in the XXI century: Local and global challenges, October 2006, Rome, Italy.

Al-Shahri, M., Assaf S., A., Atiyah S., and AbdulAziz.A, (2001). "The management of construction company overhead costs." International Journal of Project Management, 19, 295-303.

Alum, J., and Lim, E. C. (1995). "Construction productivity: Issues encountered by contractors in Singapore." International Journal of Project Management, 13(1), 51-58.

Bernstein, Harvey M., and Lemer, A. C. (1996). Solving the Innovation Puzzle: Challenges Facing the U.S. Design and Construction Industry, New York: 35, 1, 37-50.

Bohrnstedt, G, and Knoke, D (1994). Statistics for Social Data Analysis (3rd Edition). F.E. Peacock Publishers, Inc., Itaska IL.

Borcherding, J. D Chang, L.-M., and. (1985). "Evaluation of craftsman questionnaire." Journal of Construction Engineering and Management, 111(4), 426-439.

Borcherding, J. D, and Liou, F.-S. (1986). "Work sampling can predict unit rate productivity." Journal of Construction Engineering and Management, 112(1), 90-103.

Bramble, B. B., and Callahan, M. T. (2000). Construction Delay Claims. Aspen Publishers

Cheung, S. O., Suen, H. C. H., and Cheung, K. K. W. (2004). "PPMS: A web-based construction project performance monitoring system." Automation in Construction, 13(3), 361-376.

Construction Industry Institute (2000). “Quantifying the cumulative impact of change orders for electrical and mechanical contractors.” Research Summary 158-1, Cumulative Change Order Impact Research Team, Construction Industry Institute (CII), University of Texas at Austin.

Damodara, K. P. E. (1999). “Materials management: The key to successful project management.” Journal of Management in Engineering, American Society of Civil Engineering, 15(1), 30-34.

Davies, V. J., and Thomas. K. (1990). Construction Safety Handbook. Telford, London, England.

DeCenzo, D, and Holoviak, S. (1990). Employee Benefits. Prentice Hall, City, New Jersey, 55-56.

Drewin, F. J. (1982). Construction Productivity: Measurement and Improvementthrough Work Study, Elsevier Science Ltd., NewYork.

Enshassi, A., Al-Hallaq, K. and Mohamed, S. (2006). “Causes of contractor’s business failure in developing countries: The case of Palestine.” Journal of Construction in Developing Countries, 11(2), 1-14.

Fowler, F. J. (1993). Survey Research Methods (2nd Edition). Sage Publications, Inc., Newbury Park, CA.

Ginther, R. S. (1993). “The effect of work environment on labor performance.” ME thesis, Pennsylvania State University, University Park, PA.

Guhathakurta, S. and Yates, J. (1993). “International labor productivity.” Journal of Construction Engineering, 35(1), 15-25.

Halligan, D. W., Demsetz, L. A., Brown, J. D., and Pace, C. B. (1994). “Action-response models and loss of productivity in construction.” Journal of Construction Engineering Management, 120(1), 47-64.

Hanna, A. S., and Heale, D. G. (1994). "Factors affecting construction productivity: Newfoundland versus rest of Canada.” Canadian Journal of Civil Engineering, 21(4), 663-673.

Hanna, A. S., Taylor, C. S., and Sullivan, K. T. (2005). “Impact of extended overtime on construction labor productivity.” ASCE Journal of Construction Engineering Management, 131(6), 734-740.

Harris, F. C., Holt, G. D., Olomolaiye, P. O. and Zakeri, M., (1996). "A survey of constraints on Iranian construction operatives' productivity." Construction Management and Economics, 14(5), 417-426.

Harris, F, Holt, G., Kaming, E., and. Olomolaiye, P. (1998). “Factors influencing craftsmen's productivity in Indonesia.” International Journal of Project Management, 15(1), 21-30.

Harris, F., Jayawardane, A. K. W., and Olomolaiye, P. O., (1998).Construction Productivity Management. Harlow, Addison Wesley Longman, 182-186 pp.

Hassanein, A., and Melin, J. (1997). "Crew design methodology for construction contractors." Journal of Construction Engineering and Management, 123(3), 203-207.

Heizer, J., and Render, B. (1990). Production and Operations Management "Strategic and Tactical Decisions." Prentice Hall, NJ.

Hinze, J. W. (1999). Construction Planning & Scheduling. Prentice Hall, Upper Saddle River, NJ.

Horner, R. M. W., and Talhouni, B. T. (1995). Effects of Accelerated Working, Delays, and Disruptionson Labor Productivity. Chartered Institute of Building, London.

Israel, G. D. (2003). "Sampling the evidence of extension program impact," Agricultural Education and Communication Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Iyer, K. C., and Jha, K. N. (2005). "Factors affecting cost performance: Evidence from Indian construction projects." International Journal of Project Management, 23, 283-295.

Jarkas, A. M. (2005). "An investigation into the influence of build-ability factors on productivity of in situ reinforced concrete construction." Ph.D. thesis, University of Dundee, Dundee, UK.

Kaming, P. F., Olomolaiye, P. O., Holt, G. D., and Harris, F. C. (1997). "Factors influencing craftsmen's productivity in Indonesia." International Journal of Project Management, 15(1), 21-30.

Kim, D. H. (1993), "The individual and organizational learning," Sloan Management Review, 38:49

Koehn, E., and Brown, G. (1985). "Climatic effects on construction." Journal of Construction Engineering and Management, 111(2), 129-137.

Kumar A (2004) Ch. 9 Cited in V.D Desai Small Scale Enterprises, Himalaya Publication, 5th edition New Delhi 233-234

Lema, N. M., and Samson, M. (1995). "Construction of labor productivity modeling." University of Dar Elsalaam, Tanzania

Lema N., and Samson M. (2002), Development of construction contractors performance measurement framework, 1st International Conference of Creating a Sustainable

Leonard, C. A. (1987). "The Effect of Change Orders on Productivity." The Revay Report, On-line. World Wide Web Revay Rep., 6(2), 1-4.

Makulsawatudom, A., and Emsley, M. (2002). Critical factors influencing construction productivity in Thailand. Proceedings of CIB 10th International Symposium on Construction Innovation and Global Competitiveness, Cincinnati, OH.

Makulsawatudom, A. and Sinthawanarong, K. (2004). "Critical factors influencing construction productivity in Thailand." The Journal of King Mongkut's Institute of Technology North Bangkok 14(3), 1-6

Mc Clave, J. T., (2006). Statistics (10th Edition).

Mechanical Contractors of America. (1976). "Factors Affecting Productivity." Mechanical Contractors of America, Bulletin No. 58, January.

Moore, D., McCabe, G., Duckworth, W., and Sclove, S. (2003). The Practice of Business Statistics, Freeman, New York, NY.

National Electrical Contractors Association. (1983). Rate of Manpower consumption in Electrical Construction, Electrical Construction Peak Workforce Report, 2nd edition, page 5

National Electrical Contractors Association. (1989). Overtime and Productivity in Electrical Construction. NECA, 2nd Edition, Washington, DC.

Neil, J. M., and Knack, L. E. (1984). "Predicting productivity." Transactions of American Association of Cost Engineers, H.3.1-H.3.8.

Oglesby, C. H., Parker, H. W., and Howell, G. A. (2002). Productivity Improvement in Construction. McGraw-Hill, New York.

Olomolaiye, P. O., Wahab, K., and Price, A. (1987). "Problems influencing craftsman productivity in Nigeria." Building Environment, 22(4), 317-323.

Ovararin, N., and Popescu, C. M. (2001). "Field factors affecting masonry productivity." The 45th Annual Meeting of AACE International, Association for the Advancement of Cost Engineering, June 17-20, 2001, Miami, FL.

Park, H. (2002). "Development of a construction productivity metrics system PMS." Ph.D. dissertation, The University of Texas at Austin.

Paulson, B. C. (1975). Estimation and control of construction labor costs. Journal of Construction Division, 101(CO3), 623-633.

Pilcher, R. 1992. Principles of Construction Management. 3rd ed. New York: McGraw-Hill.

Poh, P. S. H., and Chen, J. (1998). "The Singapore Buildable Design Appraisal System: A preliminary review of the relationship between buildability, site productivity and cost." Construction Management and Economics, 16(6), 681-692.

Polat, G., and Arditi, P. (2005). “The JIT Management System in developing countries.” Construction Management and Economics, 23(7), 697-712.

Portas, J., and AbouRizk, S. (1997). “Neural network model for estimating construction productivity.” Journal of Construction Engineering and Management, December, 399-410.

Rojas, E. M., and Aramvareekul, P. (2003). "Is construction labor productivity really declining?" Journal of Construction Engineering and Management, 129(1), 41-46.

Rowlinson, M., and Proctor, S. (1999). ‘Organizational Culture and Business History’ Organization Studies 20(3) pp.369-96.

Sanders, S. R. and Thomas, H. R. (1991). “Factors affecting masonry productivity.” Journal of Construction Engineering Management, 117(4), 626-644.

Stall, M. D. (1983). “Analyzing and improving productivity with computerized questionnaires and delay surveys.” Proceedings of the Project Management Institute Annual Seminar

Symposium 1983, Project Management Institution, Drexel Hill, PA, V.M.1-V.M.11.

Suazo, G. A., and Jaselskis, E. J. (1993). "Comparison of construction safety codes in the United States and Honduras." Journal of Construction Engineering and Management, 119(3), 560-572.

Sumanth, D. J. (1984). Productivity Engineering and Management. McGraw-Hill, New York, NY.

Thomas, H. R. (1991). "Labor productivity and work sampling: The bottom line." Journal of Construction Engineering and Management, 117(3), 423-444.

Thomas, H. R., and Kramer, D. F. (1988). “The manual of construction productivity measurement and performance evaluation.” Source Document 35, Construction Industry Institute, The University of Texas at Austin.

Thomas, H. R., and Oloufa A. A. (1995). “Labor productivity, disruptions, and the ripple effect.” Cost Engineering, 37(12), 49-54.

Thomas, H. R., Riley, D. R., and Sanvido, V. E. (1999). "Loss of labor productivity due to delivery methods and weather." Journal of Construction Engineering and Management, 125(1), 39-46.

Thomas, H. R., and Sakarcan, A. S. (1994). "Forecasting labor productivity using the factor model." Journal of Construction Engineering and Management, 120(1), 228-239.

Ugwu, O. O., and Haupt, T. C. (2007). "Key performance indicators and assessment methods for infrastructure sustainability—A South African construction industry perspective." Journal of Engineering Design and Technology. 42(2), 665-680.

United Nations Committee on Housing, Building and Planning. (1965). Effect of Repetition on Building Operations and Processes on Site. United Nations, New York, NY.

Vaggi, G. (1987). The Economics of Francois Quesnay. Duke University Press, Durham, NC.

Wilcox, S., Stringfellow, B., Harris, R., and Martin, B. (2000). Management and Productivity. Transportation Research Board, Committee on Management and Productivity, Washington, DC.

Zou, P. X. W., Zhang, G., and Wang, J. (2007). "Understanding the key risk in construction projects in china," International Journal of Project Management, 25(6): 601-614.

APPENDIX A. IRB APPROVAL

NDSU NORTH DAKOTA STATE UNIVERSITY

701.231.8995
Fax 701.231.8098

Federalwide Assurance #FWA00002439
Expires April 24, 2011

Institutional Review Board
Office of the Vice President for Research, Creative Activities and Technology Transfer
NDSU Dept. 4000
1735 NDSU Research Park Drive
Research 1, P.O. Box 6050
Fargo, ND 58108-6050

August 28, 2009

Dr. Eric Asa
Dept. of Construction Management & Engineering
CME 120C

Re: IRB Certification of Human Research Project:

"Labor Productivity in Building Construction"
Protocol **#EN10049**

Co-investigator(s) and research team: **Mahesh Gundecha**

Study site(s): **US, India** Funding: **n/a**

It has been determined that this human subjects research project qualifies for exempt status (category # 2b) in accordance with federal regulations (Code of Federal Regulations, Title 45, Part 46, *Protection of Human Subjects*). This determination is based on the protocol form received 8/27/09 and consent/information sheet received 8/27/09.

Please also note the following:

- This determination of exemption expires 3 years from this date. If you wish to continue the research after 8/27/2012, submit a new protocol several weeks prior to this date.
- The project must be conducted as described in the approved protocol. If you wish to make changes, pre-approval is to be obtained from the IRB, unless the changes are necessary to eliminate an apparent immediate hazard to subjects. A *Protocol Amendment Request Form* is available on the IRB website.
- Prompt, written notification must be made to the IRB of any adverse events, complaints, or unanticipated problems involving risks to subjects or others related to this project.
- Any significant new findings that may affect the risks and benefits to participation will be reported in writing to the participants and the IRB.
- Research records may be subject to a random or directed audit at any time to verify compliance with IRB policies.

Thank you for complying with NDSU IRB procedures; best wishes for success with your project.

Sincerely,

Kristy Shirley

Kristy Shirley
Research Compliance Administrator

APPENDIX B. WEB-SURVEY QUESTIONNAIRE

Title of Research Study: Labor Productivity in Building Construction.

Mr. Mahesh Gundecha (Graduate Student/Researcher) and Eric Asa (Academic Advisor)

North Dakota State University

Department of Constructin Management and Engineering

Room 106, AR/LA Building, Main Campus Fargo, ND 58102 USA

Ph. 701 231-7246 Fax: 701-2317431.

E-mail: Eric.Asa@ndsu.edu, or Mahesh.Gundecha@ndsu.edu

You are being contacted to request your participation in a research investigation that is being conducted by student working in the Construction Management Department at North Dakota State University, Fargo. North Dakota. New management concepts such as labor productivity improvement provide innovative techniques that could result in more efficient labor and cost performance. Construction labor productivity differs between every project because of different climatic conditions, availability of resources and supervisor personnel for every project. A literature review of articles related to building construction indicated that a lit to support that the lower productivity of craftsmen is one of the causes of cost and delays on building projects. Low productivity of labor is significant particularly in developing countries where majority of construction task is performed manually.

Basic aim of this study project is to collect data on various factors affecting labor productivity in building construction. The reliable data will be collected from contractors, engineers, construction managers, and other professionals in the construction industry. Your valuable participation will allow the research team to document factors affecting labor productivity in building construction, and their effects on project completion. Your contribution

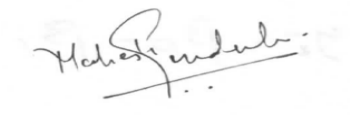
to this study would be appreciated and it would contribute additional knowledge on the subject of productivity improvement. The questions refer to the following scale.

1 Not Applicable 2 Does-not affect it 3 Some-what affect it 4 Directly affect it.

The information you provide will be kept confidential and your name and affiliation will be removed from your survey ant data will be included in the published research.

Please submit your responses by November 07, 2009.Please e-mail, fax, or mail the completed questionnaire to the above listed address. Thank you for your time and input.

If you have any questions about this project, please contact the researchers, or contact North Dakota State University Human Research Protection Program at 701.231.8908, ndsu.irb@ndsu.edu, or by mail at: North Dakota State University HRPP Office, NDSU Dept 4000, and P.O. Box 6050, Fargo, ND 58108-6050.Sincerely,



Mahesh Gundecha.

Labor Productivity in Building Construction Survey Questions

Section 1:- General Information

Name		Title	
Work Phone		Fax	
E-mail Address		Organization	
Mailing Address			
Type of Construction Organization	☐Residential ☐Commercial ☐Industrial ☐Government ☐Engineering ☐Architecture ☐Owner ☐Commercial ☐Others (Please Specify)		
Annual Total Installed Cost (TIC)		Number of Employees working in company	
Number of Projects per year			
Typical Size of Projects($)	☐0-5 million ☐5-10 million ☐10-100 million ☐>100 million		

Section 2:- Specific Questions of Labor Productivity in Building Construction

A) How would you define Labor productivity in the Construction industry?

_____

_____

_____

3) Please indicate to what extent following factors affect labor productivity at construction site
1 – Not applicable; 2 – Does not affect it; 3 – Somewhat affects it; 4 – Directly affects it

No.	***Factors Affecting Labor Productivity in Building Construction***	***Data Measurement***			
1	***Manpower***	**1**	**2**	**3**	**4**
	a) Lack of experience.	☐	☐	☐	☐
	b) Disloyalty.	☐	☐	☐	☐
	c) Misunderstanding among laborers.	☐	☐	☐	☐
	d) Lack of competition between the Laborers.	☐	☐	☐	☐
	e) Age.	☐	☐	☐	☐
	f) Personal problems.	☐	☐	☐	☐
	g) Alcoholism.	☐	☐	☐	☐
	h) Absenteeism.	☐	☐	☐	☐
2	***External***				
	a) Implementation of government laws.	☐	☐	☐	☐
	b) Rework	☐	☐	☐	☐
	c) Supervision delays	☐	☐	☐	☐
	d) Inspection delays from The authorities.	☐	☐	☐	☐
	e) Variations in the drawings.	☐	☐	☐	☐
	f) Complex designs in the provided drawings.	☐	☐	☐	☐
	g) Incomplete drawings	☐	☐	☐	☐
	h) Payment delays.	☐	☐	☐	☐
	i) Training sessions.	☐	☐	☐	☐
	j) Design Changes.	☐	☐	☐	☐
3	***Communication***				
	a) Change orders from the designers.	☐	☐	☐	☐
	b) Change orders from the owners.	☐	☐	☐	☐
	c) Disputes with owner.	☐	☐	☐	☐
	d) Disputes with designer.	☐	☐	☐	☐
	e)Misunderstanding between the owner, the contractor and the	☐	☐	☐	☐
4	***Resources***				
	a) Lack of required construction materials.	☐	☐	☐	☐
	b) Increase in the price of materials.	☐	☐	☐	☐
	c) Lack of required tools and/or equipment’s.	☐	☐	☐	☐
	d) Poor site conditions	☐	☐	☐	☐
	e) Differing site conditions from the plan	☐	☐	☐	☐
	f) Poor access within construction job site	☐	☐	☐	☐
	g) Violations of safety laws.	☐	☐	☐	☐
	h) Insufficient lighting.	☐	☐	☐	☐
	i) Inadequate construction method	☐	☐	☐	☐
	j) Inadequate transportation facilities for workers.	☐	☐	☐	☐
	k) Material storage location	☐	☐	☐	☐

(continued)

Table Factors Affecting Labor Productivity in Building Construction (continued)

No.	*Factors Affecting Labor Productivity in Building Construction*	*Data Measurement*			
	l) Quality of required work.	☐	☐	☐	☐
5	***Miscellaneous***				
	a) Shortage of water and/or power supply.	☐	☐	☐	☐
	b) Working overtime.	☐	☐	☐	☐
	c) Weather conditions	☐	☐	☐	☐
	d) Accidents during construction	☐	☐	☐	☐
	e) Project objective is not well defined	☐	☐	☐	☐

4) Other Comments on Factors affecting Labor Productivity at Construction Job sites

a) _____

b) _____

c) _____

d) _____