Model Labor Productivity of Concrete Pouring in Building Construction Projects Using Multiple Regression Analysis: A Case of Selected Public Construction Projects in Adama.

Desta Nigussu Tessema

A Thesis Report Submitted to the Department of Civil Engineering, School of Civil and Architectural Engineering Presented in Partial Fulfillment of the Requirement for the Degree of Master‘s in Construction Engineering Management

Office of Graduate Studies

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Declaration and Recommendation

I hereby declare that this Master Thesis entitled "Model Labor Productivity of Concrete Pouring in Building Construction Projects Using Multiple Regression Analysis: A Case of Selected Public Construction Projects in Adama" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation. It is being submitted for the partial fulfillment for the award of the degree of Master of Science in Construction Engineering Management at Adama Science and Technology University School of Civil and Architectural Engineering.

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I/we hereby certify that I/we have read and evaluated this thesis entitled "Model Labor Productivity of Concrete Pouring in Building Construction Projects Using Multiple Regression Analysis: A Case of Selected Public Construction Projects in Adama" prepared under my guidance by **Desta Nigussu** submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Construction Engineering Management. Therefore, I/we recommend that the candidate has fulfilled the requirements and hence he/she can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the thesis open defense by Desta Nigussu have read and evaluated his thesis entitled “Model Labor Productivity of Concrete Pouring in Building Construction Projects Using Multiple Regression Analysis: A Case of Selected Public Construction Projects in Adama” andexamined the candidate. This is, therefore, to certify that the thesis has been accepted inpartial fulfillment of the requirement of the degree of Master of Science in Construction Engineering Management.

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Table of Contents

List of Tables

Lists of Figure

Acronyms

CLP	Construction Labor Productivity
PFP	Single/Partial Factor Productivity Measures
TFP	Total /Multi Factor Productivity Measures
GDP	Gross Domestic Product

Abstract

Construction industry is considered to be one of the important contributor key factors in the economy of any country, especially the developing countries. The main objective of this thesis is to develop labor productivity model for the building construction industry regarding concrete pouring. Increasing the construction work productivity benefits a contractor/client in several ways. Therefore measuring productivity, identifying factors affecting productivity and use productivity modeling approaches methods should be a major and continual concern for construction sector to increase the probability of projects to be completed as per the budgeted cost and specified time. Data collection method that were employed under this study were primary data from a construction worker(s) at cites.The data were collected by trained data collectors fromMarch 4, 2004 to April 19, 2004 using a standard, structured and pre-tested questionnaire which design to have both qualitative and quantitative data relevant to the study problem. Construction labor productivity is influenced by a multitude of factors. Pearson chi-square test is asymptotically equivalent to the likelihood ratio; hence, it was used in the analysis. The preliminary analysis has been done to know which of the variables appears to have a strong association with labor productivity and the results were described under univariate analysis section. Productivity models analyze and estimate the impact of these various factors on labor productivity. In the research, multiple regression analysis was used to develop a model to quantify the impact of the influential factors on labor productivity. The multiple linear regression analysis showed that ; Rainfall, Labor Physical fatigue, Materials Delay, Lack of required construction materials, Crew size, Poor working condition, Inadequate formwork and/or temporal transport structure during execution, Time lost – rework, and Lack of labor supervision, were major factors that had a significant contribution with labor productivity. Based on results obtained from the model, we observed that some of the assumed factors (nine (9)) factors were found to be influential factors that are assumed to maximizing labor productivity rate of concrete pouring. From the fitted regression model, it has been indicated that the rate of labor productivity varies by the condition of laborer as they becomes tired or not (Fatigue). The odds of being not productive having tired were 3.381 times more likely than those laborers which not/less tired.The other significant variables were also be interpreted based on the odds multiplier or odds ratio with an odds ratio of one for the reference category, and all other groups are compared on the basis of the reference group. Hence, awareness creations have to be made toward these significant predictors' variables. It is recommended that further studies, involving data collection from more number of construction sites, are carried out to study the impact of labor related and various other factors on productivity of concrete pouring.

Key Words: *Labor Productivity, Building Construction, Multiple Regression, Public Constructions.*

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Construction industry is the main indicator of the economic growth of the country throughout the world.The industry is considered to be one of the important contributor key factors in the economy of any country, especially the developing countries, in comparison to developed countries (Gerges, 2015). The value of any industry can be assessed through the contribution of this sector to the Gross Domestic Product (GDP) and the employment status for economy of the country (Sweis et al, 2009, cited in, Gerges, 2015). Many construction projects in a lot of developing countries constitute around 10% of the GDP and roughly 50% of the wealth as fixed assets (Gerges, 2015).

Construction industry relies mainly on labor productivity, as it is well known as labor oriented industry. Hanna & Sullivan (2004) referred that 33-50% of the total project costs accounted to labor costs. Moreover, non-value adding activities form around 50-70% of the total work time in a traditional construction site (Kazaz, A., Ulubeyli, S., Acikara, T., & Er, B. (2016). Therefore, it is very essential to investigate and to detect the adverse factors that affect the productivity and performance of labor. In order to improve the productivity of a construction labor, it is required to measure and evaluate it first. Chan and Kaka (2004) explained that less than 50% of the construction industry measure and monitor the productivity in reality, most of the companies which measure the productivity depends on intuition. They added that existing measurement techniques are seen as a theoretical approach more than empirical approach, in addition to it is high cost to be implemented by construction companies. Lorys (2018) explained that there is a confusion and in consistency in measuring productivity, due to the shortage of consensus in defining and measuring productivity.

Construction projects are delivered in a multidisciplinary environment which need continues coordination. Good project management in construction must strongly measure and monitor productivity on construction site Chris Hendrickson (2000). Construction productivity has got increased attention from different construction researchers. Researchers and practitioners around the world have provided several contributions on areas related to construction work productivity. In addition, the result of different researches indicated that productivity is a complex issue as many factors influence productivity such as labor, capital, material, tools and equipment's, poor communication or relationship between workers and management, disorganized projects, poor supervision, lack of cooperation and communication between different workers, and unfair workloads are some of the factors that affect productivity. Technical problems like inadequate designs or incomplete engineering work can also lead to a decrease in construction productivity Dozzi, S.P. and AbouRizk, S.M.(1993). The main findings of previous studies indicate that the critical areas affecting construction productivity were related to materials, tools, equipment availability, and the workers' performance.

Increasing the construction work productivity benefits a contractor in several ways: projects can be completed more quickly, project cost will be lowered, the contractor can submit more competitive bids, the project becomes more profitable and in addition it makes the firm to be capable and also helps to have good will among different stakeholders. Therefore measuring productivity, identifying factors affecting productivity and use productivity improving approaches should be a major and continual concern for construction contractors to increase the probability of projects to be completed as per the budgeted cost and specified time.

In light of making the industry profitable , many researchers have been working tirelessly to improve the efficiency of the Construction labor productivity which is the key indicator of both the performance of construction industry and the success of a construction project; a labor is the most crucial resource used to measure construction productivity and it also constitutes large portion of the project cost and requires to be fully utilized ,it constitutes 20-50% of the total cost of the project. Construction labor productivity (CLP) affects the profitability of construction companies; however, CLP are highly variable influenced and are the main project resources which makes it a major source of project risk Fayek, A.R., & Oduba,. (2005).

Its common attitudes in Ethiopia for the contractors to use previous projects rates to predict production rates of future projects and do not account different factors and parameters that affect project from place to place. M.uqueem and Khamidi (2012) found that the use of previous projects production rates for estimation of future projects requires a readjustment for each project and takes into account the various site factors and conditions that influenced the CLP for construction operations.

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 Song L, AbouRizk S. (2008). In today’s era, one of the biggest concerns 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 Durdyeu , Serdar and Mbachu (2011).

1.2 Statement of the Problem

Productivity rates of construction sector are the basis for accurately estimating time and costs required to complete a project. Improved productivity helps contractors not only to be more efficient and profitable; knowing actual productivity levels also helps them to estimate accurately and be more competitive during bidding for projects. Construction labor productivity is the key indicator of the performance of construction industry as labor is the most crucial resource used to measure construction productivity and it also constitutes large portion of the project cost and requires to be fully utilized.

In Ethiopian construction industry, there is a lack of standards for contractors as reference of production rates for purposes of construction cost estimation and a lack of an accurate model for CLP prediction. The CLP has a significant impact on project costs, as on-site labor costs contribute between one third and one half of overall project costs (Heravi G, Eslamdoost E. 2015).

The identification of the CLP parameters is a priority in order to accurately model the CLP, as they are made of various objective and subjective factors and practices (e.g., crew size, complexity of task, quality of drawings, weather condition etc.), define the internal and external environments that in turn, whether directly or indirectly, influence the efficiency of the conversion process (Naoum, S. G. 2015). In a way of making the construction projects more profitable, construction managers need to implement new strategies to improve the labor productivity and this can be done if they have a clear understanding on the factor affecting the CLP and a model which helps them to know by how much they contribute the CLP. Resolving this issue can help to improve the overall performance of construction projects through the implementation of a model. Also, it gives an up-to-date concept of loss of productivity measurement for construction productivity. (M.uqueem and Khamidi 2012). 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 concern of this study.

1.3 Objectives of the Study

1.3.1 General objective

- The main objective of this thesis is to develop labor productivity model for concrete pouring in public building construction using multiple regression model.

1.3.2 Specific objectives

Particular goals for the research included:

- To identify influencing factor(s) that affect labor productivity on concrete pouring in public building construction project.
- To test whether there is an association between the assumed covariate variables with the response variable; productivity of concrete pouring.
- To analyze and estimate the impact of significant factors on productivity of concrete pouring.

1.4 Research Questions and Hypothesis

The following queries emerged in light of the study's issue and its analytical techniques.

i. What are the factors affecting labor productivity in public building construction specifically in concrete pouring work?

ii. Can we develop a prediction model for those factors?

iii. Does the construction industry uses regression analysis to forecast labor productivity rates for pouring concrete during building construction?

Hypothesis:

The research hypothesis is formulated as "Multiple Linear Regression (MLR) has strong modeling technique with optimization mechanism and effective recognition capabilities to predict the production rates of a labor under concrete pouring in building construction".

1.5 Significance of the Study

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 bear in mind that a reduction in productivity affects the schedule of the work and causes 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, 1999).

Increased labor productivity in the construction industry benefits the two contracting agents; the Client and the Contractor of the project. From the Clients' perspective, increased labor productivity lowers costs, shortens construction schedules and achieves better returns on investments. From the contractor's perspective, increased labor productivity leads to a more satisfied customer, and leads to faster turnover and increased profits. The conclusions that will be drawn from the study were used by the construction practitioners to take account of these factors at an early stage in order to minimize the time and cost overrun. Besides, the investigate factors can serve as a checklist for construction practitioners to give attention to enhance the productivity of labors so as to make the project to be completed as per the plan.

Therefore, by utilizing a multiple linear regression model to predict the most important factors impacting construction labor productivity (CLP), the study will make a substantial contribution to estimate and improve labor productivity for concrete work.

1.6 Scope of the study

The scope of the study is limited to the study of labor productivity of concrete work in building construction projects. Low labor productivity affects all contractors of different class and category. However, the study focus is only on public building construction projects due to thefact that construction of buildings uses many labors with various positions.As it is studied by different researchers most of construction projects fails to be completed withinthe contract time and budgeted cost. Low labor productivity is one of the reasons for such impact for the construction projects. Thus, the study mainly studies the critical factorswhich affect labor productivity of concrete work in public building projects and model it.

1.7 Expected Outcomes and Beneficiaries

Expected Outcomes:

- Factors that can positively or negatively affect labor productivity rate of concrete pouring in building construction projects will be identify.
- After the labor productivity model is generated, calculating labor productivity becomes easy, and simple.

Beneficiaries:

- The results of this study were also expected to provide input for contractors, especially on building construction projects that are the object of the study to increase labor productivity and are expected to be useful as a reference for construction service entrepreneurs, that professional workers have high productivity. A further benefit to science is that it is easy to calculate labor productivity using mathematical model.

CHAPTER TWO

2. REVIEW OF RELATED LITERATURE

2.1 Introduction

This chapter will review the literature on the definition and measurement of labor productivity, previous research relating to the factors affecting labor productivity rate, and different modeling approaches for related data.

Construction industry is fragmented and complicated industry. A Substantial amount of craft workers, machines, materials, equipment's and tools, in addition to different construction methods are used in one construction project only, all of these reasons lead to a complexity of construction activities and inefficiency in cost controlling. Construction industry encompasses high percentage of temporary specialists, providers and workers entwined with different contractual and procurement agreements. Also, the concluding outcome of every single project is exceptional and distinctive in terms of design; however, there are many analogous features that are common during the design stage (Palop, 2016). All of the above mentioned issues affect directly the productivity of construction industry, in particular the productivity of labor. In construction, the terms productivity is usually concerned and referred to labor productivity, as the construction industry is relies mainly on the physical input of workers.

Productivity rates are essential data for estimating, scheduling, resource management, and cost control for building the quantitative relationship between the influence factors and productivity rates Zohar H, Raplh E (1990).

2.2 Definitions of Labor Productivity in Construction Industry

2.2.1 Different Labor Productivity Definitions and Concepts

The term "productivity" can be defined and measured in many different ways; there is no standard definition and measurement for productivity (Gerges, 2015). The productivity can be defined generally as the ratio of output to input, the ratio of the quantity produced (output) to the quantity of resources used in the production phase (input). The resources can be materials, manpower, land and machines, the productivity increases if the output increases for constant amount or reduced amount of input and if the input increases indirectly proportional to the output, the productivity will remain constant (Palop, 2016). The word "productivity" was historically mentioned for the first time in an article by Quesnay in 1776, after around one century in 1883, it was described as faculty to produce (Soham & Rajiv, 2013).

AbouRizk and Song (2008) have defined the productivity as the ratio of the quantity of input to the quantity of output. Another definition of productivity is the working hours in a particular time frame divided by the quantities achieved during the same time frame, this time frame is daily or weekly or throughout the whole project, it is called unit rate. Other definition for productivity is relationship of an output created by an organization and amount of input elements used by the organization to create that output (Herrala et al., 2011). Nicolaou (1987) suggested a good interpretation for productivity as; the quantity of products and services created by a unit of a productive factor in a specific time and also assumed that the productive factors are land, machines, capital and labors, these factors do not depend on each other's but interdependent. Another definition was a measurement for productivity in terms of efficiency, in which it is the same ratio between outputs to input.

Productivity can be defined also as the amount of work accomplished per hour, such as; how many meter squared of tiles fixed per hour or how many block units installed per hour (Nicolaou, 1987). Ghobadian and Husband, 1990, cited in Amanuel (2016) explained that most of the productivity definitions can be located in one of three broad classifications. First classification is related to engineers and economists perspective, which is the traditional ratio between outputs to inputs, it can be the number of units produced per unit time. The second classification is the mixture efficiency (outputs/inputs) and effectiveness (outputs/goals). In this category the organization can measure the productivity efficiency and effectiveness; it can be the number of produced units divided by the number of expected units that should be produced per unit time that represents the target and the goal of the organization. The third classification is too wide and relevant to the organization level, the definition falls into anything that can make the function of organization better.

2.2.2 Productivity and Profitability

Many companies deny the significance of productivity, as they always link both productivity and profitability as one issue. Profitability is the main goal for the success and growth of any company and it is defined as ratio between revenue and cost (i.e. profit/assets). Profitability as a performance measure is mainly used by shareholders, however many researches do not suggest using profitability (money ratio), as it results in many disadvantages (Tangen, 2002). There is a usual confusion between productivity and profitability. Profitability considers the monetary aspects, while productivity refers to a real process that is produced by physical aspects and it is ratio is also outputs to inputs (Herrala et al., 2011).

The term profitability comprises productivity constituent, however it is highly affected by the prices which the company pays for the input and the money which earns for its produced outputs, if the company earns from the outputs more than the cost of the input, the profitability will increase even if the productivity minimizes (Tangen, 2002). Since profitability is an outcome or a result, and not as a participant to the processes like productivity, as a result it does not affect the processes strongly, it can improve the whole process and provides a true performance. However, profitability aspect can be integrated with productivity and performance in order to determine and detect the effects of monetary aspects like inflation, currency change and price changes, so it can provide a clear and true performance to the process (Grunberg, 2004).

2.2.3 Productivity and Performance

Performance can be considered as the broadest terms among productivity and profitability, as it can almost cover all the economical (profitability) and operational (productivity) features (Grunberg, 2004). Tangen (2004) described the performance as: "Performance can be described as an umbrella term for all concepts that considers the success of a company and its activities ". Measuring and investigating performance includes two targets, first to link the goals and objectives of the organization to improvement and the second one is to establish a goal for improvement activity. Both can help to maximize the effect of any improvement initiative (Grunberg, 2004).

2.3 Construction Productivity Measurement

2.3.1 Task, Project, and Industry Levels

As a result of the complexity of construction nature, construction productivity is needed to be measured at three levels: (1) task level; (2) project level; and (3) industry level. Task level is concerned with the construction activities (e.g., steel reinforcement bars fixation or concrete pouring). Project level refers to the collection of all tasks needed for constructing a new building (e.g., the construction of new residential or office building) or the renovation of an old or current building. Industry level represents the whole construction industry and the entire portfolio of projects (Huang et al., 2009). The measurement of the productivity for each level requires the improvement of both metrics (i.e., the most proper parameter that forms the foundation of calculation) and tools (i.e., identifies which construction discipline can achieve these metrics calculation). Metrics and tools will support the improvement of effective cost investment in productivity and also the life cycle construction processes, moreover, both tools will offer construction stakeholders with new measurements and evaluation abilities (Huang et al., 2009).

Stephen F. Weber and Barbara C. Lippiatt, 1983, cited in Huang et al. (2009) explained that the generic concept of construction productivity measures depends on the comparison of output of a task or project or industry with the production elements (input) needed to produce that output. Traditionally, productivity is usually generated from the ratio of output to one or more inputs, if one only input is used then it is single factor productivity measure as the output per labor hour, if all the inputs are used then it is multi factor productivity measure (Huang et al., 2009).

2.3.1.1 Task Level Productivity Measures

The usage of Task level metrics, are very common in construction industry, Most of task level metrics measurement concentrate on labor productivity and are often considered as single factor productivity measure (Huang et al., 2009). (R.S. Means, 2008, cited in Huang et al., 2009) explained task level metric measurements for task labor productivity in two ways: the first one is how much output will be produced by a crew of labors in an 8 hours normal day. In the first way, the denominator is the number of hours of the crew in a day and the numerator is amount of output, the higher output means higher task labor productivity with single factor productivity. In the second way, the output produced by a crew in an 8 hours normal day in addition to equipment, which the labors use, in this case it is multi factor productivity. The CII Benchmarking and Metrics Program show another metric measure for task labor productivity; it makes the output constant (e.g., cubic meters of cast in place concrete) and it tries to measure the amount of labor hours needed to produce the output. In this case, the denominator is constant output and the numerator is the amount of labor hours. The lower the labor hours means higher task labor productivity (Huang et al., 2009).

2.3.1.2 Project Level Productivity Measures

Project level metrics measurement is much more complicated because it deals with a mix of tasks that constitutes a single project. It is very hard to unify the inputs and outputs for all the construction activities, (e.g., the input and output of a task of pouring concrete is totally different than a task of steel reinforcement erection). Therefore, it is impossible to cumulate the individual raw task productivity metrics in project productivity metrics except in some modifications (Huang et al., 2009). The modifications which are required to use the project level productivity metrics, one of them is to use a reference data in order to determine the baseline value for each task. Moreover, information needed to know the task weight and how it is signifies to the overall project, information required to detect the task flows as some tasks are finished in parallel and the others are in sequence.

2.3.1.3 Industry Level Productivity Measures

In the industry level, the amount of output created by a unit of input can give an efficiency indicator for the industrial level measurement. The construction industry creates various types of products such as different types of buildings and infrastructures, for each product has a productivity measures, and it should be accumulated. The Bureau of Labor Statistics (BLS) conducted two common productivity measures, one of them is single factor labor productivity and the other is multi factor productivity. There are many reasons for increasing in labor productivity such as quality and the efforts of the labors, technology and increased capital utilization, however, the quality or the effort of the labor can remain the same (Huang et al., 2009). Huang et al. (2009) explained also that the increase in labor productivity leads to an increase in capital-labor ratio, which does not necessarily results in improving the quality of labors and their efforts. Therefore, they suggested that Multifactor productivity is more effective to use in measuring than labor productivity.

2.4 Approaches for Measuring Construction Labor Productivity

There are several ways to measure productivity; the selection between them depends mainly on the purpose of the productivity measurement and the availability of data. Generally, the traditional concept for measuring productivity is the ratio of output to input. However, measuring productivity can be classified into two main broad approaches. The first one, single/partial factor productivity measures (PFP) and the second one is total/multi factor productivity measures (TFP) or (MFP) (OECD, 2001; Ying, 2004; Amanuel, 2016).

Total factor productivity (TFP) represents the measurement of output to a combination of input factors such as; labors, management, material, capital, technology and equipment's. The average weight of each input in the denominator reflects its share in the total expenditures. Shehata and El-Gohary (2012) presented the total factor productivity approach in an economical monetary aspect, as well as the department of Commerce, Congress, and other governmental agencies expressed TFP in equation 1.

$$Total\ Factor\ Productivity\ (TFP) = \frac{Total\ Output}{Labor + Material + Equipment + Energy + Capital}$$

$$= \frac{Construction\ Output}{Resource\ Used} ------------------------------ (\boldsymbol{Eqn.1a})$$

$$TFP = \frac{Dollars\ of\ Output}{Dollars\ of\ Input} ------------------------------ (\boldsymbol{Eqn.1b})$$

It is suggested that TFP is commonly used in economic studies more than in construction industry (Palop, 2016; Shehata & El-Gohary, 2012). Moreover, equation 1 can be presented in another inverse form which can be used for estimating as equation 2; however, the first form (equation 1) is widely used in construction (Palop, 2016)

$$TFP = \frac{Labor + Material + Equipment + Energy + Capital}{Total\ Output} = \frac{Dollars\ of\ Output}{Dollars\ of\ Input} -- (\boldsymbol{Eqn.2})$$

Ying (2004) explained Partial factor productivity as the relationship between output and a specific input or an incomplete partial combination shown in equation 3.

$$Partial\ Factore\ Productivity\ (PFP) = \frac{Total\ Output}{Partial\ Input} = \frac{Output}{Labor\ Input} -------- (\boldsymbol{Eqn.3})$$

Moreover, the concept of the incomplete combination of inputs agrees with the following equations conducted by Shehata and El-Gohary (2012). Shehata and ElGohary (2012) provided a precise measurement for productivity that is used by governmental agencies for specific program planning and by the private sector for conceptual estimates on individual projects. Example for that is the design specialists use productivity measurement in the following form.

$$Productivity = \frac{Output}{Labor + Equipment + Material} = \frac{Square\ feet}{Dollars} ---------- (\boldsymbol{Eqn.4})$$

Single factor productivity measures are mostly used in two approaches, the most famous is to measure construction labor productivity (CLP) and capital productivity. Amanuel (2016) defined capital productivity as the relation between outputs to a capital input. The term "capital" means a physical capital not as an economical aspect, it is the machines and equipment's, it is measured as a depreciated value, the capital input is the how much the equipment is consumed during the production of output related to wear and tear. The relation is illustrated in equation 5.

$$Capital\ Productivity = \frac{Output}{Capital\ Input} ----------------------(\boldsymbol{Eqn.5})$$

For Construction labor productivity (CLP) (Thomas et al., 1990, cited in Shehata & El-Gohary, 2012) suggested that at the construction sites, contractors are focusing on measuring labor productivity in several ways presented in the following equations.

$$CLP = \frac{Output}{Labor\ Cost} ------------------------------(\boldsymbol{Eqn.6})$$

2.5 Methods for Measuring Labor Productivity

Lema (1995) explained that Labor productivity standards can be produced throughout two techniques which are; accountancy based and engineering-based techniques. The accountancy based depends on the studying and breaking down the historical accounting data, in order to create the work hours required for a particular task, on the other hand, the engineering based depends on fragmenting the work processes into small sections to facilitate the analysis process for the time required to achieve these processes. On construction sites, there are four measurement methods for measuring labor which are; time study, activity sampling, craftsman questionnaire and foreman delay survey (Abo Mostafa , 2003).

2.5.1 Time Study

The time study was initially presented to improve productivity, and it was applied in the late of 19th and 20th centuries by Taylor and Gilbreth, it is considered to be one of the fundamental commonly used methods currently. Barnes (1980) discussed that It is an important method to detect the time needed for a qualified and trained person to perform a task at a normal speed, furthermore, Armstrong (1990) added that it can be the foundation for controlling and monitoring the human resources costs efficiently, and it helps in supplying standards and increasing productivity (Abo Mostafa , 2003).

2.5.2 Activity Sampling

It is a technique, which is applied by undertaking a huge amount of instantaneous observations that are concerned to labors, equipment and activities in a particular time, each observation records the events that occur during that moment, hence, the percentage of observations carried out for a specific activity or a delay is considered to be the measurement of the percentage of the time for the activity or the delay. Activity sampling is a great method in order to detect the time consumed by labors and it helps to determine the causes of the delay, and it can help in improving productivity (Thomas et al, 1986, cited in, Abo Mostafa , 2003). Furthermore, one of the main benefits of activity sampling that it allows the integration of many elements during observations as large number of workers and machines to be observed and studied at one time, which is better than other methods which focus only on a particular group or element to be studied (Pilcher, 1997, cited in, Abo Mostafa , 2003).

Activity sampling method consists of two main facts; the first fact is that the working day comprises 3 main time elements, which are; productive, contributory and unproductive time. Productive time is the actual time consumed directly to install or add or to put a particular element in a process to generate the final output.

2.5.3 Craftsman Questionnaire

It is a method to explore and determine the challenges that affect the productivity and motivation of labors negatively. Craftsmen are responsible for providing information about the area of losses, the importance of the problems that adverse productivity and trying to rank it, and also to provide solutions for these problems (Olomolaiye et al, 1998, cited in, Abo Mostafa , 2003). Oglesby et al. (2002) discussed the areas in which the questionnaire will be applied for each specific craft and activity such as; Materials management and availability, lack and availability of required tools, equipment availability and its break down, occurrence of rework and it is causes, interference of crews and if they are from the same craft or not, overcrowding in each crew, shortage in instructions and other necessary data, and finally inspections and if it is done at the right time or suffer from delays (Abo Mostafa , 2003).

2.5.4 Foreman Delay Surveys

It is a method in which the foremen present the productivity problems which occurs daily among the crew, it helps to determine the reasons of delay. The main objective of this method is to identify the issues of productivity and delays that are not in the scope of the foremen responsibilities (Olomolaiye et al, 1998; Oglesby et al, 2002, cited in, Abo Mostafa , 2003). It is commonly used method and simple, the foremen can finish it in short time, it helps to establish a relationship between causes of delay and the lost hours, so that it could provide a better knowledge for project managers to eradicate delay and find solutions for productivity problems (Alfeld, 1988, cited in, Abo Mostafa , 2003).

2.6 Overview of Factors Affecting Construction Labor Productivity in Existing Literatures

Introduction

There are a wide range of factors that affect construction labor productivity. Different researchers from all over the world have investigated and discussed these factors, several researches suggested and concluded the most critical factors and ranked these factors according to their relative important index. Survey and interviews were the most typical methods for conducting these researches, these extensive studies were a helpful tool in order to attain the knowledge for detecting labor productivity factors and improving it, thus, it reflects better results on cost and time as an indicator of better project performance. The classification of these factors and categorizing it in groups was an essential duty to attain better understanding and managing those factors.

2.6.1 Material Management

Hasan et al. (2018) did a comprehensive systematic review on the most common studies, which discuss the construction productivity factors published from 1986 to 2016, throughout 46 published works. They concluded that non-availability of materials have been cited the most among the 46 articles. Naoum (2015) and Hasan et al. (2018) considered the management of materials is as the one of the major universal concern that has been cited and affect labor productivity. Naoum (2015) in addition to Easeph and Maarof (2017) classified material management on site as a factor affecting labor productivity in a group of factors related to activities during construction stage.

Several researchers stated that the lack or non-availability of material on site is the most crucial influential factor among all the other factors; it was concluded after different surveys with different practitioners of construction industry (Zakeri et al., 1996; Makulsawatudom et al., 2004).

2.6.2 Equipment and Tools Management

Productivity increases with the efficient and effective usage of tools and equipment, however, a crucial effect can happen, it was estimated that 4.6 hour lost per operative per week due to the shortage of proper tools and equipment, thus resulting in productivity loss (Zakeri et al., 1996). This agrees with Klanac and Nelson (2004), they explained that if the proper tools and equipment are not available on site, contractor will struggle from productivity loss due to his responsibility for tools and equipment management. Similarly, Lorys (2018) categorized the lack of tools and equipment under the group of labor related factors. Naoum (2015) classified equipment and tools management on site as a factor affecting labor productivity in a group of factors related to activities during construction stage.

(Goodrum and Haas, 2004 cited in, Naoum, 2015) discovered that construction activities associated with technology of equipment had a remarkable labor productivity improvement more than activities which did not implement technology of equipment, however, there is a cost accompanied with adopting technology.

2.6.3 Lack of Proper Supervision

According to Hasan (2018), lack of proper supervision is considered to be the second most influential factor after Lack of material affecting construction labor productivity. Enshassi et al. (2007) suggested that delay of inspection and Supervisors' absenteeism are among the factors under supervision group. For inspection delay, it leads to disruption of the sequence activities and contributes in the overall schedule delay; it is well known that the contractor cannot pour concrete unless the formwork and steel work are inspected. And for Supervisors' absenteeism, it results in delay or postponing the inspection of the work that has already done on site and ready to be inspected, thus it delays the start of the new successor activity. Moreover, the activities which require the attendance of supervisors will be stopped, as pouring concrete and backfilling (Enshassi et al., 2007).

The size and the area of the site has a relation to the number of site engineers and supervisors, they also proposed that the long existence of many supervisors on site close to labors may adverse the overall efficiency because labors feel stressed and embarrassed and they cannot work freely (Kazaz et al., 2008).

2.6.4 Labor Related Factors

It is well known that the construction industry is a labor oriented industry; it highly depends on the skills and experiences of both labors and supervisors on construction sites. As a result, recruitment of skilled experienced labors and supervisors encounter big challenges in some countries. Alinaitwe et al. (2007) concluded that lack of labor skills to be the second ranked factor affecting labor productivity in their study. They explained that lack of labor skills has a great impact on construction productivity; it affects the cost, time and the quality of the work. In addition to, in New Zealand, the level of skills and experiences for labors have been ranked the most effective sub-factors under the workforce broad category of on-site labor productivity constraints (Durdyev & Mbachu, 2011).

Labor markets conditions are always have been considered the responsibility of the contractor. If a great change arises in the local labor market, the contractor is required to employ not qualified labor, which leads to productivity loss. If the wage for labors is high, the contractor is free to hire skilled labor that can meet his required expectations (Klanac & Nelson, 2004). The following labor market conditions are; "(1) size and the skills of local labor pool. (2) Union versus nonunion labor rules. (3) Rewards and wages. (4) Craft turnover and absenteeism. (5) Cultural aspects such as; holidays and religious events. (6) Abuse of drugs and alcohol"(Klanac & Nelson, 2004).

2.6.5 Design, Procurement and Build-ability Related Factors

The issue of incomplete design and drawings has been addressed in several researches. It is well recognized that design errors, problems associated with design processes are one of the major roles for productivity loss, delay and rework in construction sites. Naoum (2015) put design and procurement methods as a factor under the group Factors related to pre-construction activities, similarly, Easeph and Maarof (2017) put design management factor under the group Impacting Factors in preconstruction Stage. Moreover, Naoum (2015) concluded that delay caused by design error and variation orders factor is the second most influential factor in his study, as well as, Dai et al. (2007) in which they ranked engineering drawing management as the second most significant factor in their work study.

2.6.6 Project Management Related Factors

Project planners, project managers and construction managers create several expectations and prediction regarding the planning of construction activities, allocation of resources, compatibility of methods of constructions and the condition of the completed activities during the execution phase, they do not consider the preconstruction planning before the commencement of the activities on site, as a result, it can affect the productivity of labor during the execution phase such as; delay, rework and increases the cost (Naoum, 2015). This agrees with study conducted by Doloi (2008). He concluded that pre-planning and programming before the construction starts as the most crucial factor affecting labor productivity. He indicated that pre-planning includes scheduling for manpower and physical resources that will occur during execution phase, scheduling the activities, site planning and expected cash flow.

2.6.7 Construction Site Management and Layout

Site congestion and overcrowding issues are almost generated as a result of improper site management and poor layout. Overcrowding creates a disruption and obstacles to achieve the required productivity on construction sites due to, the poor planning for site activities leads to overcrowding of workers, hence affecting productivity rate of labors (Naoum, 2015). Interference between labors can be produced if several labors work on a specific task in a confined space area or when various construction trades are performing their tasks in the same work area. Thus, site congestion and overcrowded issues occurs, due to the improper planning and management on site. More adequate space for each worker is needed to perform his task without interruption with other worker or another trade crew (Gundecha, 2012). Smith 1987 proposed that the density should not exceed one labor per 30 meters squared; moreover, 40 percent productivity loss will be achieved if the working space area declines from 30 meters squared to 10 meters squared (Naoum, 2015).

2.6.8 Management and Leadership Skills

Naoum (2015) pointed that the factor of success and failure in any construction project dramatically depends on the efficient and effective management of construction resources and leadership style. He also indicated that, there are two aspects that significantly affect the productivity, which are; management skills and proper management and allocation of manpower, he believed that managerial and leadership styles are considered to be the most influential outlines that cover most of the factor argued in his study. Moreover, contractual schemes of the project and leader of the staff can highly affect the productivity and performance of all disciplines of the project (Naoum, 2015).

2.6.9 Change Orders and Changes of Project Scope

Changes of the project scope have a strong correlation with the decline of project performance and labor productivity. Variation in work flow can be a result from changing of project scope. Liu et al. (2011) discussed the relationship between workflow variation and labor productivity. They investigated in the relationship between percent plan complete (PPC), which is the ratio of total task completion to planned tasks and labor productivity. Hence, direct labor cost and overhead will increase and decline in labor productivity, consequently, decreasing the profitability of the contractor. He added also, that changes in contract will be reflected on the price or the time of contract. Moreover, any change performed by the owner, the consequences cost and schedule effects are merged in the original contract under change orders (CO). As a result, adjustment can be performed according to the contract; however, owners and contractors have always disputes regarding CO processes.

2.6.10 Rework

Rework was extensively investigated in several existing literature, as one of the critical factors that adverse the construction labor productivity. Mahamid (2013) ranked rework, as the most critical factor among overall factors which affecting labor productivity in his study. He defined rework, as the needless work of second performing and repeating an activity or a task that has been wrongly executed, so that it could meet the original required specification (Mahamid, 2013). There are several causes for rework mentioned in various studies such as; lack of labor skills, incompetent supervisors and craftsmen; in which lack of knowledge for drawings regarding craftsmen and inefficient supervision skills related to supervisors causes rework.

2.6.11 Poor Communication

In order to improve productivity on site, it is believed that proper communications between construction parties is inevitable. Labors feel comfortable if there is a non-variable and clear flow of information from middle and top management. Proper flow of information between labors, proper knowledge for site changes, appropriate employing of qualified employees with respect to the required assigned tasks, lead to productivity improvement (Choudry, 2017). Lack of communication and cooperation between construction members such as; client, contractor, sub-contractor, consultant and suppliers lead to several challenges and difficulties.

2.6.12 Weather Conditions

Weather conditions have been addressed to be a considerable important contributor in productivity loss in several previous studies. Construction activities exist in an open outdoor environment, as a result, heat, cold, high wind, high humidity and rain are external factors have an impact on site condition and productivity of labors explained that extreme rainfall and bad weather conditions lead to a huge amount cost to many construction projects in Iran every year. In Gulf countries, Gulf Cooperation Council (GCC) enacts a break in the middle of a working day on construction sites, in case if the temperature exceeds 50°C and if the humidity exceeds 90 percent, in which it is usually associated with heavy wind and sandstorms (Jarkas et al., 2012, 2015, cited in Hasan et al., 2018).

2.7 Various Prediction Models for Labor Productivity

In addition, various techniques and models have been developed for predicting labor productivity that considered specific construction operation by identifying the factors influencing that construction activity through work sampling. Productivity Models that have been developed includes Factor Model for predicting productivity using factors (Arun Emsely et al., 2004), Expectancy model for predicting performance of workers to estimate productivity , Action Response model to evaluate losses in construction productivity , Statistical model developed to identify the effects of factors on productivity (Ayodele.Olu,2002), An expert simulation model developed to identify the combined effects of all the factors on productivity , Feed forward back propagation neural network model developed to estimate the production rates of formwork and Fuzzy expert system to predict the production rates of labor. Various shortfalls of all the models mentioned above have been found by researchers. Among those models neural network is more effectively and commonly used by the estimators (Ayodele.Olu, 2002).

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 Description of the Study Area and Population

The study was conducted in Adama city. Adama (Oromo: *Adaamaa* or *Hadaamaa*, Amharic: አዳማ), is a city in the central Oromia Region of Ethiopia.Adama city is one of the fast-growing cities in Ethiopia. It stretches between 8°26′15″N to 8°37′00″N latitude and 39°12′15″E to 39°19′45″E longitude. The computed population growth rate of the City from 2004 to 2016 was nearly 9%. Adama is located in the East Shewa Zone around 80 km (50.1 mi) southeast of the capital, Addis Ababa, the city sits between the base of an escarpment to the west, and the Great Rift Valley to the east.

Adama has an estimated population density of 15,300 km^2 (2022). The city had a population of 220,212 in 2007 census and the population projection of 456,868 for 2022. The city is considered the most populous woreda in the Misraq Shewa Zone With an estimated area of 29.856 km^2. *(Source: Ethiopian statistics Service (web)).*

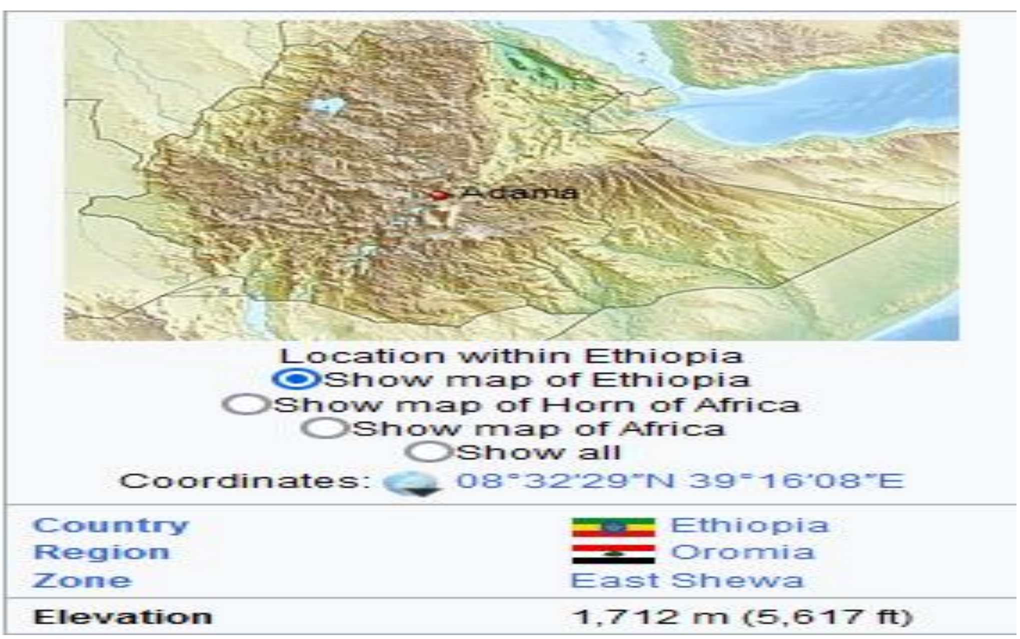

Fig 3.1: Map of Ethiopia

The City has various advantages that make it an appropriate selection for the study area. Among these, the study can provide important information for the on-going construction project (Building construction) and for future also. In addition, it is located at easy to find data and verify and interpret the findings. The population for the study were public on-going building construction projects in the city.

3.2 Research Processes Layout

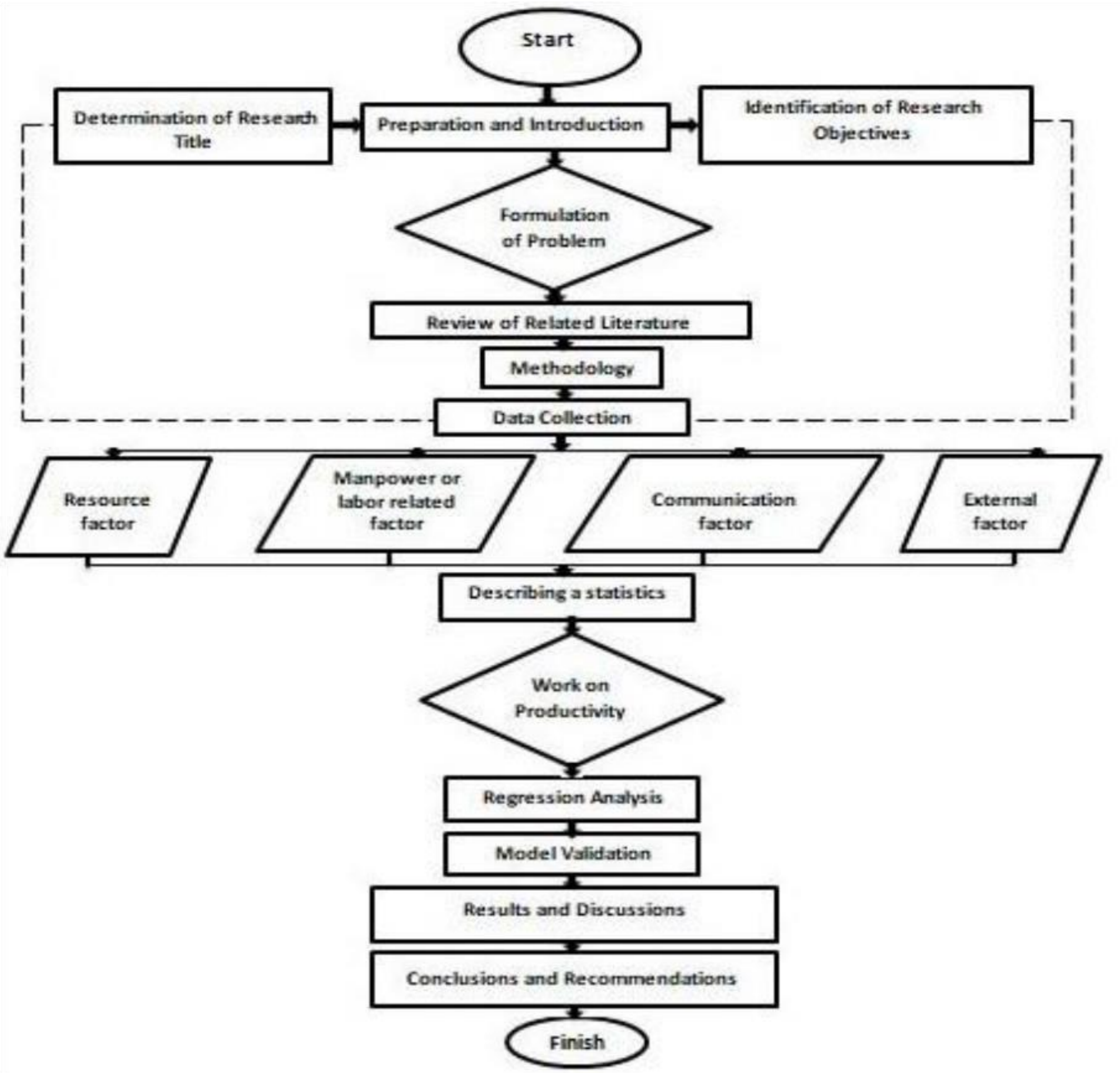

Fig 3.2: Research Processes Layout

3.3 Population of the Study

Direct population data were collected for the study, but at the proposal stage, it was suggested to sample a few public projects using a probabilistic sampling design because, at that point, I was unsure of the precise number of building construction projects that had begun in the city. That was the rationale behind the sample technique suggestion at the proposal stage. I want to make it clear now that population data is required. The table below (Table 3.1) contained a list of the actively ongoing building construction projects in a city.

Table 3.1: List of Target Populations

S/N	Project Name	Project Type	Location	
			Sub-city	Woreda
1	Dairy and Fattening Project	G+0	Bole	Goro
2	Pig and Poultry Project	G+0	Dembella	Malka-Adama
3	City Complex Project	G+8	Logo	Berecha
4	Obo Park Expansion Phase Lot-1 (Main get and fence)	Fence	Bole	Goro
5	Whole and Office Project	G+0	Dembela	Malka-Adama
6	Attorney Office Project	G+2	Aba Geda	Buta
7	Construction of Public Space Around Stadium and Derartu Round Project	G+0	Lugo	Berechaa
8	Construction of Nursery Plant Site Project	G+0	Lugo	Garaa-Lugo
9	Expansion Of City Youth Center Project	G+1	Dabe	Hangatu
10	Condominium Construction project	G+8	Dembella	Degaga
11	Construction of Bu'ura Boru School lot-1(Aroreti) Project	G+0	Boku	Aroreeti
12	Construction of Bu'ura Boru School lot-2(Wonji) Project	G+0	Dembela	Wonji
13	Aba-Geda Park Expansion	G+0	Dhadacha	Melka-Adama
14	Dibibissa Park Expansion	Fence and Guard House	Dabe	Hangatu
15	Bole Sub-city Office Expansion Project	G+1	Bole	Dhadacha Arara

Source: *Adama Municipality – Infrastructure and Construction Office*

3.4 Data Source and Collection Method

The data collection method that were employed under this study were primary data from a construction worker(s) at cites. It was identified that suitable method of data collection influenced the accuracy of the data values. However, questionnaire survey is the most commonly data collection method adopted by the study to collect information on factors and production Therefore, structured questionnaire were used as a method of data collection. Pilot surveys were employed by selecting few public construction projects in different parts of the city for the period covering February 15, 2024 to February 20, 2024 in order to strengthen our assumption about factors strongly affect labor productivity in building construction regarding concrete pouring.

The data were collected by trained data collectors using a standard, structured and pre-tested questionnaire which originally prepared in English and then translated in to Amharic as well as Afan Oromo language. In order to minimize the errors in data collection that may be introduced by the enumerators, training was provided for data collectors to ensure that they understood the questionnaire. The questionnaire was designed to have both qualitative and quantitative data relevant to the study problem.

A primary data were collected in a period of seven weeks from March 4, 2004 to April 19, 2004. A total of five (5) activities were considered during data collection stage. The activities studied, description of the activities, and the number of total data instances used for the multiple regression model analysis is presented in Table 3.2 bellow.

Table 3.2: Activities and number of data collected on each activity

Activity	**Activity**	**Activity Description**	**Total Data Collected**
Concreting (concrete pouring)	Slab	concrete placement for slab	2
	Column	concrete placement for column	49
	Beam	concrete placement for beam	32
	Stair	concrete placement for stair	5
	Footing Pad	concrete placement for footing pad	4

3.5 Inclusion and Exclusion Criteria

With certain limitations, the study covers all building construction sites that were actively under construction in the city. Projects larger than G+2 are known to not be regarded as extremely labor-intensive construction activities since the contractors were required to use technology for the mixing, transporting, and pouring of the concrete product. Therefore, throughout the data collection phase of this study, construction projects larger than G+2 (high raised buildings) were excluded.

3.6 Variables Considered in the Study

In the study, a list of multi-level factors and practices will be identified through the literatures, ranked and then a factor model to predict a CLP will be developed by taking the influencing factors and parameters as the independent variables and the CLP as the dependent variables.

3.6.1 Dependent Variables

The dependent variable assuming to be influenced by independent variables is labor productivity rate ($product\ /labour\ cost$) rate of concrete pouring work in building construction projects in the City.

3.6.2 Independent Variables

The independent variables that are assumed to impact the productivity rate of labor in concrete pouring in building construction are those that have been identified from prior research and those that have been recommended by various stakeholders and construction industry professionals during the pilot survey stage. Lastly, (Table 3.3) displayed the independent variables that were supposed to significantly affect the labor productivity rate in concrete pouring in building construction. These variables were categorized as resource related, labor-related, communication related, and external factors.

Table3.3:Independent Variables Included in the Analyses with their Designation,Description and Types.

Variable Designation	Description	Type of Data	Unit
	a) Labor Related Factors		
RAT_STT	- Ratio of skilled to total labor	Continuous	Number
RA_F	- Rainfall	Continuous	mm.
SAL_PDE	- Salary payment delay	Continuous	Hours
PHY_FA	- Physical fatigue	Categorical	Coded
ALC_OM	- Alcoholism	Categorical	Coded
MISU_AL	- Understanding among laborers	Categorical	Coded
	b) Resource Factors		
DEL_MAT	- Delay materials	Continuous	Hours
LAK-RCM	- Lack of required construction materials	Categorical	Coded
CR_SI	- Crew size	Continuous	Number
PSI_CO	- Site condition	Categorical	Coded
MS_LOC	- Material storage location (proximity)	Categorical	Coded
UT_OTA	- Unavailability of tools/equipment on time at the work site	Categorical	Coded
IF_TTSDCA	- Inadequate formwork and/or temporal transport structure during execution	Categorical	Coded
SHO_OEPL	- Shortage of experienced labors	Categorical	Coded
MO_PAP	- Mode of preparing a product		
	c) Communication Factors		
CHO_FDDE	- Change order from the designer during execution	Categorical	Coded
DW_DS	- Dispute with the designers	Categorical	Coded
TL_RE	- Time lost – rework	Continuous	Hours
	d) External Factors		
TL_WNR	- Time lost – work not ready	Continuous	Hours
LL_SUB	- Labor supervision	Categorical	Coded
PR_DEL	- Procurement delay	Categorical	Coded
LOM_INC	- Lack of monetary incentives*	Categorical	Coded

3.7 Method of Analysis

Based on the data collection nature, it was provided that Multiple Linear Regression Model as a best method to analyze the data as to predict and estimate productivity of labor workers on concrete pouring and discusses the results.

3.7.1 Multiples Regression Model Analysis

Multiples regression is a form of regression, which is used when the dependent variable is dichotomous, such as presence/absence, success/failure, productive/not productive etc. and the independent variables are of any type. Multiple regressions can be used to predict dependent variable on the basis of continuous and/or categorical independent variables and to determine the percent of variance in the dependent variable explained by the independent variables; to rank the relative importance of the independent variables; to assess interaction effects; and to understand the impact of the covariate control variables.

It is a statistical test used to predict a single binary variable using one or more other variables. It also is used to determine the numerical relationship between such a set of variables. The variable you want to predict should be binary and your data should meet the other assumptions multiple regression analysis.

3.7.1.1 The Multiple Regression Model Description

The basic aim of modeling is to derive a mathematical representation of the relationship between an observed response variable and a number of explanatory variables, together with a measure of the inherent uncertainty of any such relationship. Statistical models constructed for response variables are the best an approximation to the manner in which an observable variable depends on other variables. No statistical model can be claimed to represent truth and, by the same token, no one model can be termed the correct model. Some models will be more appropriate than others, but typically, for any set of data, there will be a number of models, which are equally well suited to the purpose in hand, and the basis for choosing a single model from amongst them will not rest on statistical grounds alone (Collett 2000).

Regression analysis is an extremely powerful tool that enables the researcher to learn more about the relationships within the data being studied. There are many texts that describe this technique, and the theory behind its use will not be discussed in detail here. In this instance multiple linear regressions will be used to determine the statistical relationship between a response (e.g., actual productivity) and the explanatory variables (e.g., labor experience, design quality, rework, etc.).

The regression model requires a few assumptions. It is of the form:

$$\boldsymbol{Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + --- + \beta_p X_{ip} + \varepsilon_i} ----------(\boldsymbol{Eqn. 3.1})$$

Where,

- $i = 1,2,3,\dots,n$
- Y_i *is the response that corresponds to the levels of the explanatory variables* $X_1, X_2, X_3 \dots X_p$ *at the* i^{th} *observations.*
- $\beta_0, \beta_1, \beta_2, \beta_3, ---, \beta_p$ *are the coefficients in the linear relationship. For a single factor (p = 1),* β_0 *is the intercept, and* β_1 *is the slope of the straight line defined.*
- $\varepsilon_1, \varepsilon_2, \varepsilon_{3,\dots,}\varepsilon_n$ *are errors that create scatter around the linear relationship at each of the* $i = 1,2,3,\dots n$ *observations.*

The regression model assumes that these errors are mutually independent, normally distributed, and with a zero mean ($\mu = 0$) and variance $\sigma^2 = 1$. It is important to rate that this sometimes difficult to achieve. To make estimates of the coefficients in the regression model, the method of least squares is used for both its mathematical convenience and its ability to provide explicit expressions for these estimates.

3.7.2 The Multiple Linear Regression Analysis

Construction labor productivity in concrete pouring process is influenced by a multitude of factors. Productivity models analyze and estimate the impact of these various factors on labor productivity. In the research, multiple linear regression analysis was employed to develop a model to quantify the impact of the influential factors on labor productivity of concrete pouring.

The multiple linear regression models is used to predict the CLP in the study, it was consist of the identification of factors affecting the CLP and their quantification, descriptive analysis, inferential analysis, regression model analysis, and model validation of the data were assessed. In the identification of factors, an initial wide review papers from developing countries were performed and the considered factors those repeatedly observed in different journals and articles with some factors estimated by different scholars in the area during pilot survey were taken as significant factors might have an effect on the output variable (Labor Productivity).

After the identification of the factors analysis were done by calculating a number of statistics including means standard deviations, and making several analysis. The purpose of this stage was to identify the factors that might have an effect on production rate of concrete pouring. Results of previous construction labor productivity studies will also use in combination with the data identification stage to define the initial regression model that has all the factors that might have a significant effect on the production rate for a building construction. The initial regression model for each task will be a pure linear regression model without any interaction and nonlinear terms. In the study parsimonious models was considered for modeling. A parsimonious model can be defined as a model that fits the data adequately without using any unnecessary parameters. The principle of parsimony is important because in practice parsimonious models generally produce better forecasts. In the regression analysis stage the factors that did not improve the model significantly were dropped. This was done by dropping one factor at a time. T-statistic of the factor in the model, comparisons of closeness of fit, and prediction performance of the models with and without the factor, were the criteria to be used to determine the significance of the factor in the model.

3.7.3 Fitting the Multiple Regression Model

The general method of estimation that leads to the least squares function under the linear regression model (when the error terms are normally distributed) is called maximum likelihood. It is this method that provides the foundation for our approach to estimation with the multiple regression models. In a very general sense the method of maximum likelihood yields values for the unknown parameters which maximize the probability of obtaining the observed set of data. In order to apply this must first construct a function called likelihood function. The maximum likelihood estimators of these parameters are chosen to be those values which maximize this function. Thus, the resulting estimators are those which agree most closely with the observed data.

The maximum likelihood and non-iterative weighted least squares are the two most computing estimation methods used in fitting multiple regressions model (Hosmer –Lemeshow, 2009; Greene, 2001; collet, 2001). When the assumption of normality of the predictors does not hold, the non- iterative weighted least squares method is less efficient (Maddala, 2004). In contrast, the maximum likelihood estimation method is appropriate for estimating the regression model parameters due to this less restrictive nature of the underlying assumptions (Hosmer – Lemeshow, 2009). Hence, in this study the maximum likelihood estimation technique was employed to estimate parameters of the model. Consider the Multiple Linear Regression models$P_i = \frac{e^{x'\beta}}{1+e^{x'\beta}}$ since observed values of Y say, $y_i's$ (i=1, 2, 3…., n) are independentlydistributed as binomial with parameter P_i, the maximum likelihood function of Y is given by:

$$L(\beta/Y) = \prod_{i=1}^{n} P(y_i / X_{i1}, X_{i2}, X_{i2}, \dots, X_{im}) = \prod_{i=1}^{n} \left[\frac{e^{x'\beta}}{1+e^{x'\beta}}\right]^{y_i} \left[\frac{1}{1+e^{x'\beta}}\right]^{1-y_i} --- (Eqn. 3.2)$$

where, $\beta' = (\beta_1, \beta_2, \beta_3, , , \beta_r)$

The objective of stating likelihood function is to get an estimator $\hat{\beta} = (\hat{\beta}_0, \hat{\beta}_1, \dots, \hat{\beta}_r)\ of\ \beta$which maximizes the likelihood function expressed in equation (3.2). Since the likelihood equations are non- linear in the parameters, the Newton Raphson iterative maximum likelihood estimation method that expresses $\hat{\beta}$ at the $(u+1)^{th}$ cycle of the iteration is expressed as $\hat{\beta}_{u+1} = (X'\hat{V}_u X)^{-1} X R_u$ Where u=0,1,2,3, …and is a diagonal matrix with its diagonal elements $X_i = 1$,$\hat{V} = diag[P_i(1-\hat{P}_i)] = cov(y)$.Finally $\hat{\beta}$is the resultant maximum likelihood estimator of $\beta$with residual $R = y - \hat{p}$ (collet, 2001: Greene, 2001). Newton's method usually converges to the maximum of the log – likelihood in just a few iteration unless the data are especially badly conditioned (Greene, 2001). All the parameters $\hat{\beta}_0, \hat{\beta}_1, \dots, \hat{\beta}_r$ and estimates of Prob ($y_i = 1/X$) for each subject were computed using the IBM SPSS version 24 package.

3.7.4 Assessments of the Fit of the Model

Here it is required to know how effective the model that is developed in the above steps is in describing the outcome of the variable. Several steps are needed in assessing the suitability, adequacy and usefulness of the model. Measures of goodness of fit are statistical tools used to explore the extent to which the fitted response obtained from the postulated model compares with the observed data. Clearly, the fit is good if there is a good agreement between the fitted and the observed data. In practice, any model may not exactly represent the true relationship between θ(x) and x. Thus, as the sample size increases, the model-based estimator may not converge exactly to the true value of the probability. As explained above multiple regression models was used to describe and make inferences about the effects of predictors on the response. There is no guarantee, however, that a particular model of this form is appropriate or that it provides a good fit to the data. Hence, we need to assess the goodness of fit of the model (Agresti, 2006). The Pearson's Chi-square, the likelihood ratio test (LRT), Deviance, (Hosmer and Lemeshow, 2000) test, and the Wald test are the most commonly used measures of goodness of fit for categorical data. The following section will give a brief discussion on how each of these criterions can be used as a measure of goodness of fit of a multiple regression model.

3.7.4.1 The Likelihood Ratio Test

The likelihood ratio is a function of log likelihood and is used in significance testing. A“likelihood" is a probability, specifically the probability that the observed values of the dependent may be predicted from the observed values of the independents. Like any probability, the likelihood varies from 0 to 1. The log likelihood (LL) is its log and varies from 0 to minus infinity (it is negative because the log of any number less than 1 is negative). LL is calculated through iteration, using maximum likelihood estimation (MLE).

Likelihood ratio test is a statistical test that is used to compare the fit of two models - one ofwhich is a model which contains only an intercept term with all coefficients corresponding to the explanatory variables are set to zero (null model) and the other model containing all the parameters under consideration (full model). The test is based on the likelihood ratio, that is, the ratio of the maximum likelihood (ML) function under the null model (restricted ML) to the ML under the full model (unrestricted ML). The test statistic for testing the goodness of fit of a model is twice the difference in these log – likelihoods (-2LL).

3.7.4.2 Hosmer and Lemshow (H-L) Test

The H-L statistic is another measure of lack of fit. Hosmer and Lomeshow recommendpartitioning the observation in to 10 equal sized groups according to their predictedProbabilities. Then,

$$G^2{}_{HL} = \sum_{j=1}^{10}\left[\frac{\left(O_j - E_j\right)^2}{E_j\left(1 - \frac{E_j}{n_j}\right)}\right] \sim \chi^2{}_{\alpha} \;\; where, n_j = number\ of\ observations\ in\ the\ j^{th}\ group,$$

- $O_j = observed\ number\ of\ cases\ in\ the\ j^{th}\ group,$

- $E_j = Expected\ number\ of\ cases\ in\ the\ j^{th} group,$

If H- L goodness of fit test is greater than 0.05, we can’t reject the null hypothesis that there is no difference between observed and model predicted values, implying that the model estimates fit the data and acceptable level. That is well fitting the models shown non significance of on H-L goodness of fit test.

3.7.4.3 R^2–Statistic

A number of measures have been proposed in multiple regressions as an analog to R^2 inmultiple linear regression analysis. The Cox and Snell measure is based log-likelihoods andconsiders population size. The maximum value that the Cox & Snell R^2 attains is less than 1.The Nagelkerke R^2 is an adjusted version of the Cox & Snell $R^2$and covers the full rangefrom 0 to 1, and therefore it is often preferred. Therefore, in this study R^2statistics toindicate how useful the explanatory variables in predicting the response variable were used (Bewick et al., 2005).

$$R^2{}_{CS} = exp[-\frac{2}{n}[D(model\ without\ variable)] - D(model\ with\ the\ variable)]$$

The Nagelkerke measure is as follows:

$$R^2{}_N = \frac{R^2{}_{CS}}{R^2{}_{MAx}}, where\ R^2{}_{MAx} = 1 - \exp[2^{n-1}D(model\ with\ the\ variable)]$$

The multiple regressions in SPSS uses R^2like measures as Nagelkerke and Cox and Snell was implemented.

3.7.4.4 The Wald Test Statistic

The Wald test is a way of testing the significance of particular explanatory variables in a statistical model. In multiple regressions we have a binary outcome variable and one or more explanatory variables. For each explanatory variable in the model there will be an associated parameter. The Wald test, described by Polit (2006) and Agresti (2006), is one of a number of ways of testing whether the parameters associated with a group of explanatory variables are zero. If for a particular explanatory variable, or group of explanatory variables, the Wald test is significant, then we would conclude that the parameters associated with these variables are not zero, so that the variables should be included in the model. If the Wald test is not significant then these explanatory variables can be omitted from the model. Wald χ^2 statistics was used to test the significance of individual coefficients in the model and are calculated as follows:

$$Z = \frac{\hat{\beta}_j}{SE(\hat{\beta})} ------------------------------------ 3.4$$

Each Wald statistic was compared with a χ^2distribution with 1 degree of freedom. Wald statistics are easy to calculate but their reliability is questionable, particularly for small samples. For data that produce large estimates of the coefficient, the standard error is often inflated, resulting in a lower Wald statistic, and therefore the explanatory variable may be incorrectly assumed to be unimportant in the model (Bewick et al., 2005).

3.7.4.5 Model Adequacy

Once a model is fitted to the observed values of a binary response variable, a thorough examination of the extent to which the fitted model provides an appropriate description of the observed data is a vital aspect of modelling process. The fitted multiple linear regression model may be inadequate due to a particular observation, termed outliers, or observations, termed influential values that have an undue impact on the conclusions to be drawn from the analysis and presence of complete or near complete linear dependencies among the predictor variables. Some of the statistical techniques which reemployed to examine the adequacy of a fitted model include: detection and treatment of outliers, and influence diagnostics.

3.7.4.6 Influence Diagnostics

An observation is said to be influential if its omission from the data set results in substantial changes to certain aspects of the fit of the multiple regression model. In most cases, it is more important to pay attention on outliers that are influential than those that are not. Although outliers may also be influential observations, an influential observation need not necessarily be an outlier. In particular, an influential observation that is not an outlier will occur when the observation distorts the form of the fitted model to such an extent that the observation itself has a small residual.

Some of the statistical methods used in influence diagnostics are: Leverage statistic; $\hat{h}_{ii}$, which is called the diagonal elements of the matrix $H = X\,(X\,'X\,)^{-1}X\,'$with diagonal elements of $\hat{P}_i\big(1-\hat{P}_i\big)$called the "hat" matrix); DFBETA (the change in the Multiple regression parameter estimates when the observation is deleted); Cook's distance $C_i = \frac{r_i h_{ii}}{p(1-h_{ii})}$, where r_i is the Pearson residual h_{ii} the leverage of case i and p the number of parameters in the model); and the change in the Pearson statistic or goodness-of-fit statistics (-2log-likelihood). The study used Cook's distance to assess the overall impact of an observation on the estimated parameter vector β. Hence, points for which Cook's distance greater than one was considered as influential.

3.7.4.7 Assumptions of the Multiple Linear Regression Model

- There are assumptions one should consider for the efficient use of multiple regression. These are:

i. The multiple linear regression coefficients must be coded meaningfully by giving the codes 0 for the dependent class of lower interest and 1 for the dependent class of greatest interest.

ii. The dependent variable must be categorical.

iii. The independent variables need not be interval, nor normally distributed, nor linearly related, nor of equal variance within each group.

iv. Linearity in the legit regression equation should have a linear relationship with the logit form of the dependent variable.

v. All relevant variables must be included and all irrelevant variables must be excluded.

vi. Absence of multi-collinearity. As with multiple regressions, multi co linearity is a potential source of confusing or misleading results and needs to be assessed. Multi-collinearity occurs when there are high inter correlations among some set of predictor variables.

vii. The sample size must be large in order to make the Multiple regression accurate.

viii. Error terms are assumed to be independent.

ix. No outliers.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

The main aim of this study was to identify factors that have an association with labor productivity and statistically model labor productivity of concrete pouring in building construction based on the data obtained from construction workers especially Forman, in the city from the period March 4, 2004 to April 19, 2004. The number of cases on each activities for the study area were 125 but 20 of them could not respond to the questionnaire and 13 of them did not correctly respond. Hence, the analysis was based the data obtained from 92 correctly responded questionnaires which is collected from eight (8) ongoing projects (City Complex Project, Whole and Office Project, Attorney Office Project, Construction of Nursery Plant Site Project, Expansion Of City Youth Center Project, Construction of Bu'ura Boru School lot-1(Aroreti) Project, Dibibissa Park Expansion Project, and Bole Sub-city Office Expansion Project) through data collection period.

The data were analyzed using IBM SPSS version 22.Summary statistics were used to describe a set of observations; the Pearson Chi-square test was conducted to assess the association between variables. Finally, multiple linear regression analysis was run to assess the relationship between each predictor variable with the dependent variable while controlling the other predictor variables.

4.1 Univariate Analysis

Model-building strategies begin with a careful univariate analysis of each variable. The chi square test with k-1 degrees of freedom, where k is the levels of the independent variable is exactly equal to the value of likelihood ratio test for the significance of the coefficients forthe k-1 design variables in a univariate multiple regression model that contains the single explanatory variable. Since the Pearson chi-square test is asymptotically equivalent to the likelihood ratio, it was used in the analysis. The preliminary analysis has been done to know which of the variables appears to have a strong association with labor productivity. For each one of the independent variables, a test of association was carried out using the Pearson Chi-Square at 5% level of significance. High values of Pearson chi-square for a given independent variable indicate that there is a strong association between each of the given independent variables and labor productivity keeping the effect of the other factors constant.

Table 4.1, shows the bivariate association between labor productivity of concrete pouring and independent variables. The predictor variables like; Rainfall, Labor Physical fatigue, Delay materials, Lack of required construction materials, Crew size, Poor working condition, Inadequate form work and/or temporal transport structure during execution, Time lost – rework, and Lack of labor supervision, were statistically significant variables using chi-square test. Whereas, the predictor variables like; Ratio of skilled to total labor,Misunderstanding among labourers, Salary payment delay, Alcoholism, Unavailability of tools/equipment on time at the work site, Material storage location (proximity), Shortage of experienced labors, Lack of monetary incentives, Change order from the designer during execution, Dispute with the designers, Time lost – work not ready and Procurement delay were insignificant predictor variables using Pearson chi-square test because the asymptotically significance value of both tests result exceeds 5% level of significance ($\alpha = 0.05$).

From Table 4.1, we observe that the highest percentage: 38.1% of the variable ratios of skilled to total labor and out of these, 32.1% of crew composition of 1 – 4 were not being productive.

The lowest percentage for such a variable was 5.4% of which 81.5% were not productive whereas 18.5% were productive. About 60.8% of a crew composition 1 – more than 5 compositions were not being productive.

From the association table, we can observe that rainfall during work time was one of the significant variables. During high rain when work times, out of 17(18.5%), 93.6% of laborers were being not productive this case takes the highest percentage from the rest conditions. Among 92 cases 39(42.4) of them encountered physical fatigue. From such a case 73.6% were being not productive and the rest 26.4% were productive.

When we concern to other significant variable material delay, 78.3% of the cases were not productive due to delay or interruption. This figure reduced to 35.8% if the construction materials were not delay on work time. Lack of required construction materials can be considered as one of significant variable as we discussed above and this problem was highly occurred on 19.6% of the data. From such a situation, 89.9% of the worker were not being productive as well as 10.1% were being productive. The proportions indicate that the opportunity of labor productivity is high for that case shaving no lack of required construction material during execution. Out of 25(27.2%) having no lack of the materials, 73.7% of the mwere being productive.

As to the mode of supervisions, 5(5.4%) of the laborers having no proper supervision as scheduled out of those, 85.1% did not productive and the rest 14.9% were being productive. About 40.2% of the cases were rarely supervised of which 73.3% did not productive. As a good opportunity, 26.7% of them were being productive.

Table 4.1: Chi-square test of an association between Labor productivity and Explanatory Variables (Adama City, April. 2024)

Variables	Category	N	Total %	Not Productive %	Productive %	Pearson Chi-square	d.f
Ratio of skilled to total labor	1 to more than 5	26	28.3	60.8	39.2	69.499 (0.502)	4
	1 to 5	11	11.9	56.7	43.3		
	1 to 4	35	38.1	32.1	67.9		
	1 to 3	15	16.3	23.4	76.6		
	1 to less than 3	5	5.4	81.5	18.5		
Rainfall	High	17	18.5	93.6	6.4	51.878 (0.029)	3
	Medium	7	7.6	78.9	21.1		
	Low	41	44.6	22.4	77.6		
	No rain at all	27	29.3	16.7	83.3		
Salary payment delay	Delay mostly	24	26.1	63.9	36.1	1.078 (.299)	2
	Delay for some cases	48	52.2	62.9	37.1		
	Not delay	20	21.7	48.3	51.7		
Labor physical fatigue	Happens	39	42.4	73.6	26.4	5.555 (.018)	1
	Not happen	61	66.3	33.4	66.6		
Alcoholism	It happen mostly	12	13.0	86.6	13.4	1.078 (.245)	2
	It happen rarely	31	33.7	45.5	54.5		
	There is no such a problem	49	53.3	47.2	52.8		
Understanding among laborers	Not understand to each other in most cases	9	9.8	90.3	9.7	37.639 (.099)	2
	Some what they understand each other	33	35.9	68.5	31.5		
	Well understand to each other	50	54.3	21.7	78.3		
Delay materials	Delay	17	18.5	78.3	21.7	5.555 (.018)	1
	Not delay	75	81.5	35.8	64.2		
Lack of required construction materials	Highly occurs	18	19.6	89.9	10.1	62.715 (.010)	2
	It occurs rarely	49	53.3	41.6	58.4		
	Not occurs at all	25	27.2	18.3	73.7		
Crew size	Large size	36	39.1	52.9	47.1	4.494 (.037)	2
	Medium size	46	50.0	49.1	50.9		
	Small size	10	10.9	17.8	82.2		
Working condition	Poor working condition	29	31.5	71.3	28.7	49.832 (.000)	2
	It happens rarely	12	13.1	34.8	65.2		
	Not happens	51	55.4	22.2	77.8		

Material storage location (proximity)	Far from working place	16	17.4	43.6	56.4	13.649 (.093)	2
	A little bit far	33	35.9	32.5	67.5		
	Near to the work location	43	46.7	40.1	59.9		
Unavailability of tools/equipment on time at site	It happens for most cases	19	20.6	63.9	36.1	2.001 (.979)	2
	Rarely happens	45	49.0	23.6	76.4		
	Not happen almost in all cases	28	30.4	70.2	29.8		
Inadequate formwork for temporal transport and concrete casting	Inadequate	37	40.2	76.3	23.7	15.023 (.006)	1
	Adequate	55	59.8	38.6	61.4		
Shortage of experienced labors	There is such a shortage	15	16.3	47.6	52.4	3.568 (.743)	1
	There is no shortage	77	83.7	59.1	40.9		
Method of preparing a product	Manually (by labor hand)	14	15.2	54.9	45.1	1.856 (.081)	1
	Using mixer (machine based)	78	84.58	43.4	56.6		
Change order from the designer during execution	Happen	51	55.4	28.4	71.6	62.715 (.416)	1
	Not happen	41	44.6	32.5	67.5		
Dispute with the designers	Occurs	18	19.6	53.6	46.4	7.210 (.061)	1
	Not occurs	74	80.4	48.3	51.7		
Time lost – rework	>1hr	12	13.0	81.6	18.4	11.427 (.001)	3
	30 – 60min	21	22.8	60.3	39.7		
	15 – 30min	49	53.3	38.9	61.1		
	No lost	10	10.9	4.9	95.1		
Time lost – work not ready	>1hr	17	18.5	41.6	58.4	50.169 (.111)	3
	30 – 60min	13	14.1	63.0	37		
	15 – 30min	51	55.4	52.8	47.2		
	No lost	11	12.0	26.3	73.7		
Labor supervision	No proper supervision as scheduled	5	5.4	14.9	85.1	26.327 (.025)	3
	They supervise rarely	37	40.2	26.7	73.3		
	They supervise in most cases	41	44.6	68.1	31.9		
	There is a strict supervision	9	9.8	86.3	13.7		
Procurement delay	There is a delay Procurement	33	35.9	66.3	33.7	6.398 (.082)	2
	There is some delay	53	57.6	46.2	53.8		
	No delay of procurement	6	6.5	57.2	42.8		
Monetary incentives	Lack of monetary incentives	62	67.4	48.2	51.8	10.539 (.071)	1
	No it has not happens	30	32.6	50.9	49.1		

4.2 Results for Multiple Linear Regression Analysis

The primary issue with any univariate approach is that it fails to consider the possibility that a group of variables, each of which has a weak correlation with the outcome, may combine together to form a significant predictor of the outcome. (Hosmer and Lemeshow, 2000). Hence, multivariate regression approach that takes into account the drawback mentioned by the univariate technique is considered in this analysis.

4.2.1 Estimates for Multiple Linear Model

Fitting a model to a set of data first entails estimating the unknown parameters in the model. In order to fit a multiple linear model to a given set of data, the k + 1unknown parameters β_0, $\beta_{1\ldots}$ β_k have to be estimated. These parameters are readily estimated using the method of maximum likelihood. The multiple linear regressions using the "forward stepwise (likelihood)" were run. This procedure revealed that out of twenty three (23) statistically associated variables in the bivariate analysis at 5% level of significance, only nine (9) variables became significant predictors of labor productivity in multiple linear regression analysis. These are rainfall , Labor physical fatigue, delay of constructions material, Lack of required construction materials, Crew size, poor working condition, Inadequate form work for temporal transport and concrete casting, Time lost – rework and Lack of supervision. Results obtained by the procedures are shown in Table 4.2. The final regression model included only the significant variables.

Table 4.2:Parameter Estimates, Standard Errors, and Odds Ratios for the Final Multiple Linear Regression Model.

Covariates	Sub - group	$\hat{\beta}$	S. E ($\hat{\beta}$)	Wald	d. f	P – value (Sig.)	Exp ($\hat{\beta}$)
Labor physical fatigue	Happens	1.218	.298	16.706	1	.000	3.381
	Not happen (Ref.)	-	-	-	-	-	-
Rainfall				23.106	3	.000	7.665
	High	2.037	.425	22.972	1	.002	4.553
	Medium	1.516	.365	17.251	1	.000	2.687
	Low	2.561	.714	11.977	1	.030	.523
	No rain at all (Ref.)	-	-	-	-	-	-
Delay materials	Delay	1.256	.179	49.235	1	.020	5.258
	Not delay (Ref.)	-	-	-	-	-	-
Lack of required construction materials				27.469	2	.000	7.223
	Highly occurs	2.518	.335	22.437	1	.005	12.409
	It occurs rarely	1.367	.257	20.697	1	.000	8.236
	Not occurs at all (Ref.)	-	-	-	-	-	-
Crew size				12.564	2	.000	3.358
	Large size	3.691	.298	41.563	1	.010	.221
	Medium size	0.273	.095	3.258	1	.003	1.865
	Small size (Ref.)	-	-	-	-	-	-
Poor working condition				25.368	2	.000	4.387
	Yes it happens	2.365	.184	19.350	1	.020	3.213
	It happens rarely	1.314	.288	20.816	1	.005	2.458
	Not happens (Ref.)	-	-	-	-	-	-
Inadequate formwork for temporal transport and concrete casting	Inadequate	3.213	.858	14.069	1	.000	10.064
	Adequate (Ref.)	-	-	-	-	-	-
Time lost – rework				22.514	3	.000	2.358
	>1hr	2.356	.541	18.965	1	.002	4.589
	30 – 60min	3.284	.867	14.347	1	.005	1.321
	15 – 30min	4.210	.886	22.579	1	.004	.963
	No lost (Ref.)	-	-	-	-	-	-
Lack of supervision				18.154	3	.000	17.201
	No proper supervision as scheduled	2.584	.752	31.831	1	.000	5.895
	They supervise rarely	3.654	.854	11.807	1	.006	2.248
	They supervise in most cases	4.156	.152	18.307	1	.010	.285
	There is a strict supervision (Ref.)	-	-	-	-	-	-

4.2.2 Variables in the Equation

Labor physical fatigue, Rainfall, Materials Delay, , Crew size, poor working condition, Lack of required construction materials, Inadequate formwork for temporal transport and concrete casting, Time lost – rework, Lack of supervision were the variables which constructs the regression model from step 1, step 2, …, step 10 respectively. The likelihood ratio test criterion is used to select and remove variables at each step of the procedures. $\alpha = 0.05$ Level of significance was used for entry of variables.

The reference category is the last category of all independent variables. Table 4.2 above contains the estimated coefficients $(\hat{\beta})$ .The standard errors of the estimates $S.E(\hat{\beta})$ which help in computing the values of Wald statistics W,

$$W = \left(\frac{\hat{\beta}}{S.E(\hat{\beta})}\right)^2$$

Which is given in the column " Wald" and it has a chi-square distribution with one degree of freedom. The significance of the Wald statistic in the column with heading Sig. indicates the importance of the predictor variables in the model and high values of the Wald statistic shows that the corresponding predictor variable is significant.

$Exp(\hat{\beta}) = e^{\hat{\beta}}$ Which is given in the last column of Table 4.2 is called the odds multiplier or odds ratio with an odds ratio of one for the reference category, and all other groups are compared on the basis of the reference group. Values greater than one indicate that the variable in question increases the odds of labor productivity of worker's and values between 0 and 1 indicate a decrease in the odds of labor productivity of concrete pouring.

$Exp(\hat{\beta})$, is a factor by which the odds of labor productivity of a laborer change when i^{th} independent variable increases by a unit. Prior to using the fitted model for theintended purpose, it is necessary to assess and diagnose the goodness of fit of the model.

4.2.3 Assessing the Goodness of Fitted Model

After fitting a model to a set of data, it is natural to enquire about the extent to which the fitted values of the response variable under the model compare with the observed values. If the agreement between the observations and the corresponding fitted values is good, the model may be acceptable. If not, the current form of model will certainly not be acceptable and the model will need to be revised. This aspect of the adequacy of a model is widely referred to as goodness of fit.

4.2.3.1 The Likelihood Ratio Test

The LR test statistic is asymptotically chi-square statistic which is the difference in the -2log likelihoods between the Null and Final models distributed with degrees of freedom equals to the difference between the numbers of parameters estimated in the two Models. Here, the degrees of freedom equals to 8 ($df = 9 - 1 = 8$). If the difference of Deviance ofthe Null model and Deviance of Full model, i.e. Chi – square, is greater than$\chi^2(\alpha, df)$ $where\ \alpha = 0.05\ and\ df = 8$, then the model is good fit model for the data (see Table 1). From the table, the deviance (224.55) is greater than $\chi^2(\alpha, df) = 15.507$.Therefore; we can accept the null hypothesis stating that the model is a good fitting modeland reject the alternative hypothesis stating that the model is not a good fit model.

Table 1: The Deviance

-2log likelihood		Deviance	df	$\chi^2(\alpha, df)$
Null Model	Full Model			
547.23	322.68	224.55	8	15.507

4.2.3.2 Omnibus Tests of Model Coefficients

From the results in Table 4.3 below, the omnibus tests of model coefficients have a chi-square value of 224.55 with 21 degrees of freedom and p-value of 0.000, which is highly significant at level of significance α = 0.05 indicating that the predictor variables presented in Table 2 have a joint significant importance in predicting the phenomenon labor productivity, the inclusion of the explanatory variables contribute to the improvement in fit of the full model as compared to the null model and the model is a good fit model.

Table 2: Omnibus Test of Model Coefficients

		Chi-square	df	$Sig.$
	Step	21.412	2	0.001
	Block	224.55	21	0.000
	Model	224.55	21	0.000

4.2.3.3 Model Summary

The Model Summary provides some approximations of R^2 statistic in multiple regressions (Results are displayed on Table 3). Cox and Snell's R-Square attempts to imitate multiple R Square based on 'likelihood'. In this study Cox and Snell R- square indicate that 62.7% of the variation in the dependent variable, labor productivity, is explained by its explanatory variables. Nagelkerke's R^2 in Model Summary Table is 0.717, indicating a moderately strong relationship of 71.7% between the predictors and the prediction. Meaning, 71.7% of labor productivity of concrete pouring in building construction was explained by the explanatory variables.

Table 3: Model Summary

Model Summary		
-2Log likelihood	Cox & Snell R-square	Nagelkerke's R –Square
158.68	0.627	0.717

4.2.3.4 The Hosmer and Lemeshow Test

The hypothesis to be tested is:

H_0: Model fits the data

H_a: Model does not fit the data

If the Hosmer and Lemeshow goodness-of-fit test statistic is greater than 0 .05, as we want for well-fitting models, we fail to reject the null hypothesis that there is no difference between observed and model-predicted values, implying that the model's estimates fit the data at an acceptable level. That is, well-fitting models show non-significance on the Hosmer and Lemeshow goodness-of-fit test.

The desirable outcome of non-significance (Table 4) indicates that the model prediction does not significantly differ from the observed. Hosmer and Lemeshow statistic has chi-square value of 9.813 and a significance of 0.278, which means that Hosmer and Lemeshow Test is not statistically significant and therefore our model is quite a good fit. Because p-value exceeds 0.05 level of significance, that shows there is no difference between the observed and predicted model value and hence estimates of the model fit the data at level of an acceptance.

Table 4: Hosmer - Lemeshow Test

Chi-square	df	$Sig.$
9.813	8	0.278

4.2.3.5 Classification Table

An intuitively appealing way to summarize the results of a fitted Multiple model is displayed by classification table (Table 5). This table is the result of cross - classifying the outcome variable labor productivity whose values are derived from the estimated multiple probabilities (Hosmer and Lemeshow, 2000). The classification table helps us to assess the performance of our model by cross tabulating the observed response categories with the predicted response categories. Our model showed, out of the 92 questionnaires, 80(86.9. %) were correctly classified in their status. Specifically 94.1% Productive and 70.8% not productive were correctly predicted in their respective status.

The number of errors where the dependent variable is predicted to be not productive but is in fact productive is 7.4% and the number of errors where the dependent variable is predicted to be productive but is in fact not productive is 29.2%.

Table 5: Classification Table for Labor productivity

Classification table				
Observed Values		Predicted Values		
		Productivity level		Percentage Correct
		Productive	Not Productive	
Productivity level	Productive	63	5	94.1.8
	Not productive	7	17	70.8
Overall percentage				86.9

4.3 Outliers and Influential Diagnostics

In addition to global examination of a model, it is also useful to examine the characteristics of individual cases in our data set. We are concerned with cases that might improperly influence our parameter estimates. Cook's distance is one way of analyzing influence statistic in multiple linear regressions. This is the same statistic that is used as a measure of influence in multiple regressions. However, the criteria for determining that a case is influential in multiple linear regressions differ from the criteria in multiple regressions. In multiple linear regressions, a case is identified as influential if its Cook's distance is greater than one. This is according to Hosmer and Lemeshow (2000). The influence diagnostic must be larger than 1.0 for an individual covariate pattern to have an effect on the estimated coefficients. Accordingly, since the minimum and maximum value of Cook's influence statistics are less than one (Table 6) bellow indicating that the Cook's distance for each one of the observations in our data is less than one, so we conclude that there were no influential observations.

Table 6: Cook's Influencial Statistics

	N	Minimum	Maximum	Mean
Analog of Cook's influence statistics	92	0.00000	0.45805	0.0272077

- **Model formation**

Since these different statistical tests implemented above fulfilled the criterion under each test, the model appears to be useful for predicting labor productivity of concrete pouring. The values in the second column ($S.E(\hat{\beta})$) above Table 4.2, indicate that none of the model coefficients is nonzero. This model included all the potential independent variables that have been identified. The model obtained is:

$$Y_i = 42.192 + 3.381X_1 + 4.553X_2 + 5.258X_3 + 12.409X_4 + 0.221X_5 + 3.213X_6 + 10.064X_7 + 4.589X_8 + 5.895X_9$$

Where,

Y_i = The dependent variable (Labor productivity)

X_1 = Labor physical fatigue

X_2 = Rainfall

X_3 = Material delay

X_4 = Luck of required construction material

X_5 = Crew size

X_6 = Working condition

X_7 = Inadequate formwork

X_8 = Time lost – rework

X_9 = Supervision of labor

4.4 Interpretation and Discussion of the Multiple Linear Regression Model Results

The multiple linear regression model analysis indicated that labor productivity rate of concrete pouring (productive, not productive) is affected by many factors considered in the study. Based onthe results on Table 4.2, out of the twenty three (23) variables included in the model, only nine (9) ofthem were found to have significant effect on labor productivity at $p < 0.05$.

From the fitted regression model, it has been indicated that the rate oflabor productivity varies by the condition of laborer as they becomes tired or not (Fatigue). The odds of being not productive having tired were 3.381 times more likely than those laborers which not/less tired than others not fatigue (ref.) and its effect was statistically significant. This indicated that the problem was severe for laborers facing fatigue than not fatigue. The result is in harmony with the results of some researchers. Heavy rain falling while workers are at work is another major indicator that they won't be productive. Heavy rain falling while workers are at work found to be 4.553 times more likely to minimize labor productivity than no rain fall at work place during execution of concrete pouring.

The odds ofbeing not productive with the consequence of delay of materials wasfound to be 5.258 times more likely for being not productive than the situation in which there is no delay of material on working hour (Ref.). This implied that a work condition with a minimum possible occurrences of delay of construction material at cite exhibited a lower chance to not to be productive (for the worker). The result for the variable lack of construction materials if it highly occurs, the odds ofbeing not productive with the consequence of shortage of material was found to be 12.409 times more likely for being not productive than the situation in which there is no shortage of material (Ref.). When we come to see the odds ofcrew size, in the case of having medium crew size, it has a chance of 1.865 times more likely to be not productive.

The odds of being not productive with the consequence of poor working condition was found to be 3.213 times more likely for being not productive than the situation in which there is no such a problem (if it no happens) (Ref.). The odds of being not productive with the consequence of inadequate formwork for temporal transport and concrete casting was found to be 10.064 times more likely for being not productive than the situation in which if such a facility was satisfied (Ref.). The odds of being not productive with the consequence of Time lost – rework (for the interval more than an hour) was found to be 4.589 times more likely for being not productive than the 0 (zero) time lost for rework (Ref.) with $\alpha = 0.002$ level of significance. The chance of being not productive with the consequence of lack of supervision was found to be 5.895 times more likely for being not productive than the supervisor strictly supervise the work (Ref.) with $\alpha = 0.000$ level of significance.

5. Conclusions and Recommendations

5.1 Conclusions

The objective of this study was to identify main factors having correlation with labor productivity of concrete pouring for public building construction in the city by using multiple linear regression analysis. The multiple linear regression result showed that ; Rainfall, Labor Physical fatigue, Materials Delay, Lack of required construction materials, Crew size, Poor working condition, Inadequate formwork and/or temporal transport structure during execution, Time lost – rework, and Lack of labor supervision, were major factors that had a correlation with labor productivity of concrete pouring .

The odds of being not productive having tired were 3.381 times more likely than those laborers which not/less tired than others not fatigue (ref.) and its effect was statistically significant. This indicated that the problem was severe for laborers facing fatigue than not fatigue. The result is in harmony with the results of some researchers. Happening a high rainfall during work time also be one of the most important predictor for the labors to be not productive.

Heavy rain falling while workers are at work is another major indicator that they won't be productive. Heavy rain falling while workers are at work found to be 4.553 times more likely to minimize labor productivity than no rain fall at work place during execution of concrete pouring.

Lack of required construction material also another significant variable having an impact on labor productivity of concrete pouring. It is 12.409 times more likely a laborer to be not productive as comparing with situation no scarcity materials occurred.

The odds of being not productive as a results of poor working condition was found to be 3.213 times more likely for being not productive than the situation in which there is no such a problem happened at the work place.

The current study suggest that, holding other factors constant ; increasing the scheduled supervision of labor and making the construction material available at work time are associated with a great increase in the concrete pouring productivity rate of labors. It is also justifiable based on the result of this study.

5.2 Recommendation

Based on results obtained from the study, we observed that some of the assumed factors (nine (9)) factors listed above in conclusion part were found to be influential factors that are assumed to maximizing labor productivity rate of concrete pouring. Hence, awareness creations have to be made toward these predictors' variables. Construction firms are potential institutions for a society as well as for a country; hence further studies might be necessary on different parts of the country so that the factors that affect specifically labor productivity of concrete pouring be well identified.

Since the construction firms have no proper program to train their workers, we find that most the labor has little skills to perform their work. Construction industry especially the ministry of construction should start encouraging the construction companies to have a program to train their skilled labors. Training programs should include on the job initiatives targeting those already working and help them with what they really need.

It is recommended that further studies, involving datacollection from more number of construction sites, are carried out to study the impactof labor related and various other factors on productivity of concrete pouring.

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