THE EFFECTS OFPRODUCTIVITYAND WORK FLOW VARIABILITY ON CONSTRUCTION JOBSITE LABOUR PERFORMANCE IN NIGERIA

By

IDIAKE, JOHN EBHOHIMEN.

DEPARTMENT OF BUILDING
FACULTY OF ENVIRONMENTAL DESIGN
AHMADU BELLO UNIVERSITY
ZARIA. NIGERIA.

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By

IDIAKE, JOHN EBHOHIMEN
HND (1983), B.Tech (RSUST, 1988), M.Tech (FUTM, 1999)
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DEPARTMENT OF BUILDING
FACULTY OF ENVIRONMENTAL DESIGN
AHMADU BELLO UNIVERSITY
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DECLARATION

I declare that the work in this dissertation entitled '**The Effects of Productivity and Work FlowVariability on Construction Jobsite Labour Performance in Nigeria'** has been performed by me in the Department of Building under the supervision of ProfessorKabir Bala, Dr. Shehu Ahmed Bustani and Professor Ikemefuna Mbamali.

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at any university.

Idiake, John Ebhohimen

Name of student	Signature	Date

CERTIFICATION

This dissertation entitled '**THE EFFECTS OF PRODUCTIVITY AND WORK FLOW VARIABILITY ON CONSTRUCTION JOBSITE LABOUR PERFORMANCE IN NIGERIA'** by John Ebhohimen,IDIAKEmeets the regulations governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

_____ Date_____
ProfessorKabir Bala
Chairman, Supervisory Committee

_____ Date_____
Dr. Shehu AhmedBustani
Member, Supervisory Committee

_____ Date_____
Professor Ikemefuna Mbamali
Member, Supervisory Committee

_____ Date_____
Professor Kabir Bala
Head of Department

_____ Date_____
Professor Adebayo A. Joshua
Dean, Postgraduate School

DEDICATION

This dissertation is dedicated to my **LORD AND SAVIOUR JESUS CHRIST** who loved and saved me from eternal damnation.

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ABSTRACT

The management of daily labour productivity variability on site is an important aspect of lean thinking. The lean construction technique suggests that reducing variability gives better labour performance. Therefore, this work examines the analysis of labour productivity data of four cement-based activities which are; block laying, concreting, wall plastering and tiling from two hundred and forty-four construction sites of single storey buildings in Abuja metropolis. The objective was to determine the relationship between labour productivity variability and crew jobsite performance andalso to identify the level of gap between the present performance of all the builders handling the sampled projects and expected benchmark performance. The daily method of productivity data collection was adopted in this research. The data used were subjected to test for normality and found to be slightly normal with skewness values of 0.425, -0.247, 0.645 and 0.336 forblock laying, concrete activity, wall plastering and tiling work respectively. It was observed that the skewness value for concrete work was found to benegative which means that the distribution was negatively skewed while other results were positively skewed.The research variable, performance index that is the Project Waste index (PWI) wascomputed usingconceptual (site-based) model of labour productivity measurement and the resultsrevealed that many of the projects studied had low performance rating while few performed well. The values for coefficient of variation of labour productivity were also computed. A simple regression and correlation analyses were used to determine relationships of the research variables. Correlation results showed that there are strong associations between dependent variableprojectwaste index (performance) andindependent variablewhich is the coefficient of variability for labour productivity. The analysis yielded ***R*** *values as follows;blockwork = 0.630; concrete work = 0.601; plastering work = 0.764 and tiling work = 0.588 at 0.001 significant level. This showed that, the independent variables are thus found to be significant predictors of performance of site labour crew for all activities investigated. Also the results showed that the variability in daily labour productivity is more highly correlated to project performance than workflow output which means that reducing variability in labour productivity appears to have a significant effect on performance. The performance gap values for block laying, concrete activity, wall plastering and tiling work were found to be 0.374man hrs/m^2, 3.62 man hrs/m^3, 0.362man hrs/m^2 and 0.324man hrs/m^2 respectively. A conceptual model was developed for the study.It was recommended that the site managers should be determined to get more output with a reduction in input. Alsoit was proposed that site managers should close up performance gaps in single storeyproject execution by reducing the disparity in values between baseline productivity and the mean labour productivity for the project.*

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The building construction industry in Nigeria is an important sector for employment and economic growth (Ogunsemi and Jagboro, 2006). The development of infrastructure in any nation contributes significantly to the gross capital formation, therefore the performance of the building construction firms (contractors) in this regards would be of utmost importance. Recent analysis of the Federal Government budget shows that construction expenditure accounts for about 50% of government spending(Eze, 2011). As a consequence, any effort geared towards improvement in construction efficiency by means of increasing productivity would be a worthwhile venture (Kazie, 1987 cited in Ogunsemi and Jagboro, 2006). The foregoing assertion is corroborated by Hormer and Zakiel(1996) in their analysis that 10% increase in construction labour productivity will represent an enormous annual savings.

According tothe Centre for the Study of Living Standard report (2008), the rate of labour productivity growth is thus the driving force behind improvement in per capital real incomes and seemingly small declines in productivity growth can accumulate into large differences in the pace of living standards improvement. Labour productivity has been identified as an index for measuring productivity because labour is acknowledged as the most important factor of production since it is the only factor that creates value and sets the general level of productivity (Ameh and Odusamu, 2002). Enshassi*et al*(2007) identified labour productivity as the key factor contributing to the inability of many construction contractorsto achieve their project goals, which include most importantly, the profit margin. Enshassi*et al*(2007) suggested the need to investigate and understand the key variables of labour productivity and to keep as well as compare accurate records of productivity levels across projects.

In Nigeria, building construction contractors are usually categorized by several criteria. The classifications are mostly based on the scope of operation, ownership and management control. Idoro (2007) cited in Idoro(2010) defines indigenous contractors as "those contractors that are fully owned and managed by Nigerians, while the expatriate contractors in other words referred to as foreign contractors, are mainly private firms that are jointly owned by Nigerians and foreigners but solely managed by expatriates". Theindigenous ones need careful attention and development because of the contribution of this sector to social and economic development in the nation especially in the areas of jobcreation, 'entrepreneurship', wealthdistribution, financial effectiveness in deployment of resources, elasticity to market demand, distribution of development, "economic and political independence, and innovation"(Olugboyega, 1998).

Olugboyega (1995), Enshassi *et al.* (2007) and Idoro (2010) identified the preference of foreign contractors to their indigenous counterparts in the awards and execution of contracts. This is borne out of the fact that the latter lack managerial exposure, have inadequacies in planning and management skills and low productivity. Other reasons for preference include problems of poor financial management, storage and retrieval of empirical data for the purposes of planning capital, labour and material resources.

Kerzner (1998), Bolles (2002),Dai and Wells (2004) observed that inconsistent modern project management practices can influence a company's competitive position in the market place. They added that organsations failing to adopt consistent production management methods such as lean (benchmarking) principles regularly lose market share to peer companies that have institutionised modern management techniques. They further pointed out

that firms or organisations that delay in adopting formalised practices suffer specific consequences, including failure to learn from shared experiences, late and over budget projects, and low labour productivity.

Andersen and Petterson (1995) had earlier suggested the application of benchmarking technique to accelerate change in attitude and behaviour in an organisation.In view of the fact that it is a mechanism for "improvement and change",it will further help an organisation to search for industry best practices that will bring about superior performance by examining the performance and practices of other firms. Therefore to complement previous government efforts to promote and develop indigenous contractors (Olugboyega, 1995; 1998) there is the need to investigate labour productivity variability in terms of output and input resources for indigenous firms with a view to increasing performance.Construction works experience variability or changeability at varying degrees.Variability in the management of construction work can be caused due to ineffective site supervision and other factors affecting site productivity (Abdel Razek *et al.,* 2007). It is also believed that the nature of a project, shortcoming of management to predict and establish effective defensive actions could induce various degrees of variability on a construction project.

In Nigeria, researchers(Olomolaiye*et al.,* 1989,Ayandele, 1999, Ameh and Odusami, 2002) have attempted to study methods of improving labour productivity in the construction industry. Ayandele (1999) investigated management impact on productivity of construction workers and concluded that good management manifested in the provision of enabling environment will improve labour productivity. Iyagba and Ayandele(1999) studied factors affecting labour productivity in the Nigerian construction industry and suggested that the interplay of forces on all influenced factors would eventually lead to improvement.The

application of modern production concept, for instance reduces variability to increase labour performance in the local industry in Nigeria is very sparse.In this research, with the application of the lean technique, labour productivity data will be obtained from block, concrete, plastering and tiling activities on a number of projects to test relationships between output variability and performance.

1.2 STATEMENT OF THE PROBLEM

The low level of productivity in the building construction industry compared to the manufacturing industry world-wide has resulted in calls for improvement in performance in the construction industry(Lema, 1996).Drops in construction productivity have been tracked down to lack of upgrading in the construction process as a whole. The main performance lies in theknowledge of construction processes, process variables and process performance indicators. Process accomplishment improvement can be effected by changing the variable or set of variables that most influence the performanceindicator. The primary step in searching for performance improvement includes the analysis of the scope of the process performance variability. This would uncover the extent of performance variance. One of the major performance indicators in the construction industrythat can be examined to bring to light the extent of performance disparity is labour productivity(Lema and Price, 1996).Variability affects project performance and extends project cycle time thereby causing continuing widespread under-achievement of project objectives in many construction firms.

In Nigeria, there has beenno attempt to measure the effects of variability on performance from labour productivity studies. A critical examination of previous studies(Olomolaiye*et al.*, 1989;Ayandele 1999; Ameh and Odusami, 2002)showed that the analyses were based on mere ranking of factors affecting labour productivity. Other studies showed that data sets

used were inadequate and out of the range of normal distribution which may have rendered the results of these studies unreliable. Therefore there is need to adopt a method of using large productivity data sets from building trades to investigate the effects of variability on performance of local contractors within the study area.

1.3 RESEARCH QUESTIONS

(i) Which of the critical factors affecting labour productivity ranked most in the order of relative importance?

(ii) What kind of relationship exists between variability in labour productivity and performance?

(iii) Are there any relationships existing between construction output and performanceof each of thecement based trades being investigated?

(iv) What percentage level is variation in job-site performance accounted for by variability in labour productivityof each of the building activities investigated?

(v) Can a conceptual model be developed for purpose of evaluating variability of labour productivity on construction sites?

1.4 AIM

The aim of this research is to determine the effects of labour productivity and work flowvariability on performance for the purpose of improving job-site labour performance of building construction contractors in Abuja, Nigeria.

1.4.1 Objectives

The objectives of this study are:

(a) To identify the critical factors affecting variability in daily productivities on building construction sites.

(b) To determine the relationship between variability in job-site labour crew productivity and performance in the following activities; (i)Block laying (ii) Concreting (iii) Wall Plastering (iv) Floor Tiling.

(c) To determine the relationship between variability injob-sitework flow and performance in the following activities; (i) Blocklaying (ii) Concreting (iii) Wall Plastering (iv) Floor Tiling.

(d) To determine the effectslabour productivity variabilityhas on the job-site performance of all the cement based buildingactivities investigated.

(e) To develop a conceptual model for evaluating variability of labour productivity on construction sites.

1.5 SCOPE OF THE STUDY

The research is specific to the indigenous building construction firms and covers the following areas;

(i) Cement based building elements which are labour intensive activities such as block laying, concreting, wall plastering, and floor tiling elements were investigated from life construction projects sampled within Abuja. Cement based building elements were considered becausea combination of these elements is said to be appropriate based on the aggregate cost contribution to the cost of the building. Also the cement based materials absorb a large percentage of labour force on site. Ndubisi (1998) observed that a combined cost of cement based elements in a residential storey building such as concrete and masonry trades, exhibits a strong significant relationship. The result

showed a coefficient of determination of 62.1% at 5% significance level, which means that 62.1% variations in the total cost of the building is accounted for by the change in cement based items of the building. This percentage level of investigation is considered to be significant.

(ii) Abuja was chosen to be the study area because it is presently the focus of the nation in terms of development. The development of mass housing and other infrastructures are at their zenith in the area. These huge construction activities have attracted large numbers of building contractors and labour force to the territory with the intention of getting involved in the development process of the area.

(iii) Single storey buildings were investigated for the purpose of homogeneity in the study area. This is to ascertain whether there exists any significant difference in labour productivity variability in non homogeneous and homogeneous projects.

(iv) The concept of this research was based on the theory of regulating variability to improve labour performance and establishing benchmarks.

1.6 LIMITATIONS

The research design of this dissertation was to collect large samples from the population of indigenous contractors in the study area but the non existence of records of construction firms restricted the sampling to real estate developers currently constructing in Abuja.Also, in the course of collecting data for the research, the research assistants were restricted or debarred from entering many of the sites to collect data because of the insecurity situation in the country.

1.7 ASSUMPTIONS

(a) Environmental conditions in all sites were the same. Here the weather condition is held constant to eliminate the influence of weather on crew members working on site which may affect labour productivity.

(b) All the firms studied were taken to be of the same structure, capacity and experience. This is considered in order to remove the element of excessive performance from highly structured firms over less structured ones.

(c) All tradesmen and labourers were assumed to have the same common capability and experience.Variations in human ability will influence labour productivity therefore itwas assumed here that the workforce are men of common natural abilities, this assumption was made to mitigate theundue influence men of natural ability could have on the data collected.

(d) Variations in weight and thickness of 225mm blocks were taken to be constant. The blocks used in all the sites investigated were from differentsources. Also the moulds used in the production of the 225mm blocks may have been of different thicknesses and sizes. The result of these variations could likely lead to block production of different weights hence the assumption to keep the weight and thickness of the blocks constant.

(e) Mechanical plant input on concrete is held constant for all sites in respective of size,manufacturer and speed. These three elements have the capability of influencing output.

1.8 HYPOTHESES

Based on the above assumptions the following hypotheses are formulated;

$H_0$1 = There is nostatistically significant relationship between variability inlabour productivity and performance in block work.

$H_0$2 = There is nostatistically significant relationship between variability inlabour productivity and performance in concrete work.

$H_0$3 = There is nostatistically significant relationship between variability inlabour productivity and performance in wall plastering work.

$H_0$4 = There is nostatistically significant relationship between variability inlabour productivity and performance in tiling work.

$H_0$5 = There is nostatistically significant effects oflabour productivity variability on the job-site performance of all the cement based buildingactivities investigated.

1.9 JUSTIFICATION OF THE STUDY

The importance of improving labour productivity in any organisation needs to be stressed for the establishment to record meaningful growth (Enshassi *et al,* 2007). Any serious organisation wishing to influence its competitive position in the open market needs to put in place a structure of productivity improvement within the establishment (Bolles, 2002). Some of the labour productivity improvement studies conducted in Nigeria centre on analysis of factors affecting productivity (Olomolaiye,Wahab, and Price, 1989; Ayandele, 1999; Iyagba and Ayandele, 1999; Ameh and Odusami, 2002) with no continuous improvement strategies. One of the major benefits of lean construction technique found in literature is the in-built continuous improvement structure it has. Review of literature revealed that the application of some of the lean principle tools such as percentage planned completed, labour variability reduction and benchmarking have yielded tremendous results in labour productivity

improvement (Thomas and Zavrski, 1999; Abdel-Razek *et al.*, 2007; Enshassi *et al.*, 2007). In literature the application of modern production concepts, for instance lean benchmarking and variability reduction technique to improve performance of building contractors in Nigeria is very sparse. This research therefore attempts to explore thisprinciple to develop site labour productivitymodelsto guide in labour resources planning of local construction firms in Nigeria especially those working within the Federal Capital Territory which is presently the political and economic focus of the nation and construction work is at its zenith in this area.This investigation is necessary to fill the gap in the existing body ofknowledge.

1.10 SIGNIFICANCE OF THE STUDY

The local content policy of the nation encourages efficiency and competition among indigenous contractors and the development of local companies' capacity to compete on the global platform. Therefore, this declaration for total transformation of all critical segments of the economy is a signal to all the sectors to brace up.The indigenous building construction firm is not an exception to this transformation or revolution bearing in mind that the sector in Nigeria is an essential segment for employment and economic growth.The development of this sector will certainly contribute to the social and economic development of the nation especially in the areas of employmentgeneration, 'entrepreneurship', wealthdistribution, financial efficiency in deployment of resources, elasticity to market demand, distribution of development, "economic and political independence, and innovation"(Olugboyega 1998).

According to Mersi (2005), the major contributors to economic growth and change are increase in labour utilisation and productivity. Therefore improving labour productivity leads to growth of gross domestic product (GDP) (Bergen and Langenberg, 2009). The productivity of the construction industry makes up a significant proportion of the gross capital and is 3

to8% of the GDP (Arditi and Mochtar, 2000). Kazie (1987) cited in Ogunsemi and Jagboro (2006) stated that construction expenditure accounts for about 50% of the Nigerian government's expenditure. Therefore efforts geared towards improving construction efficiency by means of increase in productivity by regulating variability in productivity would be ameaningful venture and certainly contribute to cost savings for the contractors.The study will help the contractor to identify its position with respect to the global market,increase productivity and reliability of its operations and provide quality goods and services to customers more quickly. Knowledge of productivity variability would provide the prospect for managers to achieve a leading advantage in a competitive environment.

The result of this study is important because it could provide an empirical basis for regular assessment and measurement of variability effect on jobsite labour performance in a building construction firm. The findings from the study might provide a basis to improve labour performance, help management with invaluable information to guide in decision making and also make management to fulfill its potentials and transform average site managers to performers.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW OF PRODUCTIVITY CONCEPTS

Productivity is the relationship between output of goods and services and the inputs of resources, human and non-human used in the production process, with the relationship usually expressed in ratio form(Centre for the study of living standard, 1998). Both output and inputs are measured in physical volumes and thus are unaffected by price changes. Dileep (2006) defined productivity to mean the amount of product created by one unit of a given factor of production over a stated period of time. Productivity expresses the marginal relationship of inputs to outputs and measures the economic efficiency of production.

Furthermore productivity is an index that measures output (goods and services) relative to the input (capital, labour material, energy, and resources) used to produce them.TheOrganization for Economic cooperation and Development (OECD) productivity Manual (2001) cited in Building Futures Council (2004) stated five most widely used productivity concepts which are labour productivity based on gross output; labour productivity based on value-added; capital–labour Multifactor productivity based on value–added; capital productivity based on value-added; and KLEMS Multifactor productivity (KLEMS – MFP).Robert and David (2009) suggested three levels on which productivity can be examined. These are the task level, project level and industry level. Task level refers to specific construction activities such as Block laying, casting of concrete or plastering. Projects are the collection of tasks required for the construction of new facility, for example construction of an office block or residential block building: while industry refers to the total portfolio of projects.

2.1.1 Task or Activity Productivity Measurement

According to Kingston and Means (2005) task level metrics are widely used within the construction industry. Most task level metrics are single factor measures and the focal point is on labour productivity. Typical task level metrics estimate how much of a given output is produced by a designated crew in a normal 8 – hoursa day. Equation 2.1 shows that the denominator is the number of hours associated with Selected "crew day". This means that for a chosen crew day, higher output gives a better result of labour productivity. This could also mean higher task labour productivity. This is expressed as:

$$\textit{Labour Productivity} = \frac{\textit{Quantity output}}{\textit{Crew day hours}} \quad (2.1)$$

For instance in the U.S, the Construction Industry Institute (CII) (2003) uses a different method to measure task labour productivity. The institute fixes the output (e.g. cubic yards of concrete put in place) and measures the labour hours required to produce that output. In this case the denominator is the fixed outputand the numerator is the number of labour hoursas shown in equation 2.2. Thus, for a given amount of output, a lower labour hour is better. In this situation lower labour hours equate to higher task labour productivity. This is expressed as,

$$\textit{Labour Productivity} = \frac{\textit{labour hours}}{\textit{gross output}} \quad (2.2)$$

CII regards the computation of labour productivity using unadjusted values in the above equations as "raw metrics". In order to mitigate the effects of such values the CII suggested the use of task productivity index. It is a dimensionless number, pegged to a reference data set where the reference data set establishes the baseline value for one or more component of the index.

2.1.2 Project Level Productivity Measurement

Project level metrics are more complicated because a project is a collection of tasks(Roberts and David, 2009). The inputs and outputs for a given task for instance, say concrete placement, differ from those of another task like structural steel roof work. Theyopined that it is not possible to aggregate the individual raw task productivity metrics into project productivity metric unless adjustments are made. This can be achieved by using a reference data set to compute baseline values for each task in similar manner explained above. The project level productivity index calculated is useful in measuring how an individual project compares to the overall average in the reference data set.

2.1.3 Industry Level Productivity Measurement

At the industry level, Bureau of Labour Statistics (1997) reported that the amount of output produced per unit of input provides a measure of industrial efficiency. The agency published two common measures or productivity. Single factor labour productivity and multi factor productivity. Because of varying factors or forces exogenous to labour, the multifactor productivity measure is preferred as single factor option, though it is more costly in terms of the data required. Where multiple outputs are being produced, the BLS recommended the use of "Tornqvist" index to convert the input into a single measure of production.

At this level, productivity measures can be prepared from availabledata. Published statistics from the Central Statistics Office can be used to obtain productivity indices for different sectors of the economy. At the construction industry level, information are accessible which supply approximate estimates of the wherewithal required to construct a structure of a certain magnitude anddesign.

Noor (1992) for example, in his study of the variability of labour productivity in building trades, referred to the industrial level as the level which gives a universal calculation of productivity of the construction industry. A relative study(Noor, 1992) of the productivity accomplished by "different industries, is useful in policy planning and in highlighting areas of investment and training among the different sectors of an economy".

Project level and industry level productivity measurements are complex in computation because of the collection of tasks involved. The inputs and outputs for various tasks in a given project vary significantly. This makes it difficult to aggregate the individual raw task productivity measurement into single project productivity metric except adjustments are made. The task level productivity measure is widely used and it is simple in its computation. Both task and project level productivity measurements are assessed using single factor labour productivity measure, while industry level metric is best assessed using multifactor or total factor productivity measure. Multifactor productivity measures supply a useful indicator of industrial productivity because the value of output is affected by other forces external to labour such as technology. In terms of data gathering, task productivity measure is the cheapest compared to the other two measures. This study is carried out from the perspective of productivity at task level.

2.2 GENERAL MEASURES OF PRODUCTIVITY

Building Futures Council (2004) states that productivity measures can broadly be placed into two categories. Single factor or partial productivity measures, this relates a particular measure of output to a single measure of input such as labour or capital. Multifactor or total productivity measures (MFP), which relates a particular measure of output to a group of inputs or total inputs used. There are several different measures of productivity. The

preference in usage depends on the intention of productivity measurement and in many instances, on the existence of data(Diewert 2001).

Labour productivity can be expressed or stated in different ways depending on the purpose of measurement. This was corroborated by Schreyer (2001) by asserting that the use of the productivity measurement determines choice of assessment and in many cases on the accessibility of data.The cumulative labour productivity is a measure of the general labour contribution needed to establish the work (Abdel-Razek *et al.,* 2007). As can be seen from equation 2.7, it is a reciprocal of the labour productivity given in equation 2.4. Equation 2.7 has also been discussed by other researchers(Thomas, 199, Thomas and Raynar, 1997) as labour productivity measured as the work hours per unit of output which amounts to unit rate productivity measurement. This type of productivity is easier to measure on a construction site than the capital productivity measure. It is easier to manage because of its simplicity in computation. Also the level of data collection exercise is less cumbersome than that of Multi-factor productivity measure.

However, Schreyer (2001) points out that, single factor productivity measurement only partially reveals the output of labour in terms of the individual capabilities of employees or the strength of their endeavour and that this is affected by the extent of incentives and the workings of "other technological and organisational factors". Furthermore he observed that labour input reveals the time, effort and skills of the workers. While time component is captured by data on hours worked, it does not show the skill aspect. When total hours worked are aggregated as all hours of all workers, no explanation is given for the varied nature of labour.Despite this limitation, the Centre for the Study of Living Standards (1998) and OECD Manual (2001) acknowledge partial factor labour productivity as the most readily available

and widely used measure of productivity. Since labour is the most important factor of production, labour productivity reflects the influence of all factors that affect productivity. The OECD manual suggests that the quantity of labour input in the production process is best measured by total number of hours worked. This approach has the tendency to accommodate variations in overtime, absence from work or shifts in normal hours.

On the issue of workers (skilled and unskilled) unequal contributions to the production process, Diewert (2001), argued that using number of workers as a measure of labour input may not be an accurate measure because of the effect of law of diminishing returns and that hours of work contributed by extremely talented workers may not be of the same weighting with that of untalented workers. However, to handle this labour contribution differentials, it was suggested that if a measuring constant-quality labour input be used, this implies that for a measure of total labour input, each labour input of different quality can be weighed with the "share that each type of labour occupies in the total labour compensation". Further suggestion puts it that "aggregation of undifferentiated labour input across detailed industries can provide some form of implicit differentiation." (OECD Manual, 2001 and Schreyer, 2001).

Noor (1992) in his study of the variability of labour productivity in building trades observed that the extent of consistency in the construction industry in which a task is executed permits for the application of construction labour productivity as a partial factor productivity measure. He also observed that the working materials and tools used by masonry trades in the construction industry are fairly homogenous.

2.2.1Summary

The discussion and analysis revealed that there is no one single measure of labour productivity. The choice is dependent upon the purpose of the productivity measurement. In this research, the measure of labour productivity adopted or used is that given by equation 2.7. The single or partial productivity measures are responsive in that it is easier to pinpoint a problem when used as a diagnostic tool. This type of measure of productivity is appropriate in achieving the objectives of this research in that it facilities the calculation of cumulative productivity and baseline productivity, which is the best performance a contractor can achieve for a particular design of project work. Also it has the advantage of tracing the labour requirement per unit of physical output.In this research the labour productivity data obtained from block, concrete, plastering and tiling activities on a number of projects will be used to test relationships between output variability and performance.

2.3 MEASUREMENT AND MONITORING TECHNIQUES OF SITE LABOUR PRODUCTIVITY.

There are two methods of checking construction site labour productivity. The first approach comprises the continuous time study which involves direct continuous observation of site workers at work and work sampling which is monitoring work process by sporadic observations of site labour at work. The preference of a method in the measurement and monitoring of labour productivity rests on the intention of the exercise and availability of resources.

The labour productivity used in this study is expressed (equation 2.7) as the work hours (labour time inputs) over quantity of work done (output). From the foregoing expression, it means that two measurement considerations are required for the study which is measurement or monitoring of outputs and inputs. The measurement of output may not be demanding

compared to that of the inputs. It involves the physical measurement of output of tradesmen on job site by using measuring tape. The output produced must be work done during the sampled input time. The calculation of the time inputs by site operations may be more demanding. It involves using any of the methods described in the following section.

2.3.1 Determination of Labour Inputs.

2.3.1.1 Work Study

This is the general terminology covering all approaches of method study and work measurement utilised to ensure best use of resources in site operations (Peer, 1986). This is illustrated in Figure 2.1.

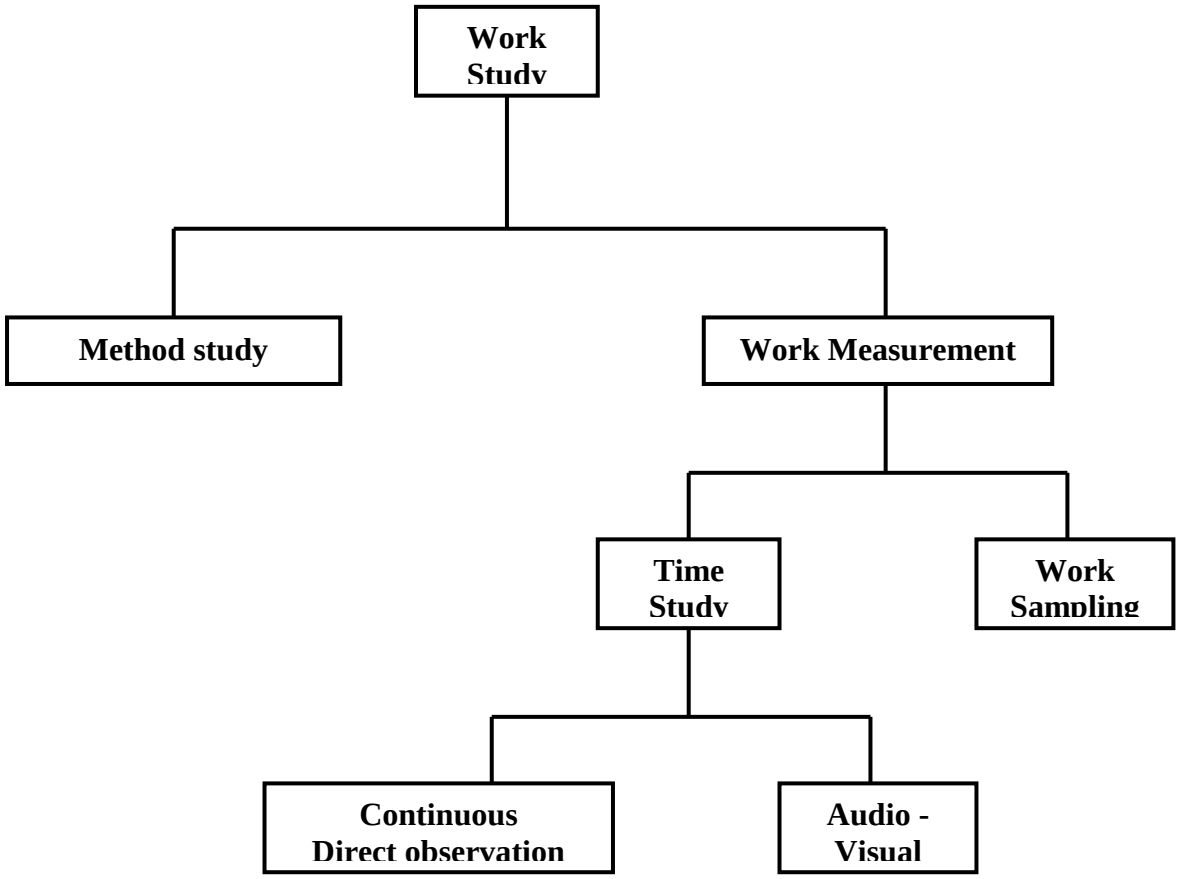

Figure. 2.1. The composition of Work Study.(Source: Peer, 1986).

2.3.1.2 Method StudyIn the case of method study, it centers on the proficiency of the operational method used. The information obtained from the study is used to evaluate the proficiency of work method employed otherwise alternative method of operation is put in place or employed.The construction of charts or diagrams is the major technique to the study of work methods. The rule here is to communicate to the workers through the language of pictures. The charts are in form of process diagram, employee-tools diagram, concurrent movement diagram, and task diagram. The study is done in combination with time study or standard time data. The choice of which diagram technique to use depends on the task's activity level namely, production process, the worker at a fixed workplace, a worker interacting with machines and a worker interacting with other workers.

2.3.1.3 Work Measurement

The aim of work measurement is to determine the time required by a qualified worker to carry out a job at a defined rate of working. The two known and commonlyused work measurement techniques for measuring work or time inputs are time study and work sampling. Other methods include predetermined time standards and standard data. The time study and work sampling techniques form the major component parts of work measurement. The choice of technique depends on two factors; the nature of the work and the level of details required (Peeradaech 2007)

The data generated from work measurement study assist construction managers to schedule work and allocate capacity, provide an objective basis for motivating the workers and measuring workers' performance, bid for new contracts and evaluate performance on existing ones, and provide benchmarks for improvement. In addition it helps benchmarking team to regularly compare company's standard with other best practices elsewhere.

(a) Continuous Time Study: Direct observation time study: The continuous time study is recorded manually or by direct observation with the aid of stopwatch or visual aids. The observation is carried out by observing the activities of the skilled and unskilled workers on site throughout the day. This is done by the researcher or his trained assistants. The observer needs to carry the timing device and recording sheets to make entries. The entries are made of data time sheets designed purposely for the study. This is done to ensure consistency and that each study or observation recorded is of the same format. Also to ensure that all relevant data are captured and retrieved as and when required. There are various designs of data collection forms, which vary according to the ideal layout of the study – (Kanawaty, 1992).

The forms have two parts, those used at the point of observation and those used after the site observation which may be referred to as study summary sheet. The filling–in of all the relevant information from direct observation is important in case there is a need to refer to it later. Kanawaty, suggested basic information to be obtained in time study. They include.

I. *Information to enable the study to be retrieved and identified quickly when needed.*
II. *Information to enable the product or element being measured to be accurately identified.*
III. *Information to enable the location where the operation is taking place to be identified.*
IV. *Information to enable the operation to be identified*
V. *Duration of the study*
VI. *Working conditions (Kanawaty, 1992)*

Besides the above information, the observer records data of observation, crafts (gang) observed, area of work covered and work category performed. This piece of information allows the researcher to sort information by day, by craft and location. During observation, the observer interacts with the workers and makes notes for factors influencing productivity

positively or negatively using the craftsmen questionnaire survey. These notes prove useful when making recommendations to project owner and contractors at the conclusion of the study (Jenkins and Orth, 2003).

As regards the issue of number of operatives a single observer can monitor or observe, Noor (1992) identified five operations for a single observer from previous studies which means that where a large labour force is to be observed additional observers would be engaged. One of the limitations of direct observation is that is expensive. It is effective in studying activity that is repetitive short-cycle in operation but may be highly costly in non repetitive operations (Peer, 1986).

(b) Video – Tape Recording (VTR) Method: The use of mechanical devices has been widely made to collect information by way of indirect means. Eye camera, Pupilometric camera, Psycho-galvanometer, Motion picture camera and Audiometer are the principal devices so far developed and commonly used by modern big business houses, mostly in the developed world for the purpose of collecting the required information (Kothari, 2004).

Thesemechanical devices are used for various purposes depending on the examination being carried out. Eye cameras are designed to record the focus of eyes of a respondent on a specific portion of a sketch or diagram or written material.Pupilometric cameras record dilation of the pupil as a result of a visual stimulus.Psychogalvanometer is used for measuring the extent of body excitement as a result of the visual stimulus.Motion picture cameras can be used to record movement of body of a craftsman while performing an operation. Productivity is monitored by time-lapse photography. The physical movements can easily be recorded by the motion picture camera which is referred to as audio-visual

camera. The time interval between pictures determines the extent of details in which the work is recorded. Noor(1992) observed some difficulties with this productivity mechanical device. It has high initial cost and inclined to system failure which could result to loss of data. To overcome these deficiencies, he recommended the use of video-tape recording. This has the advantage of low operation cost and gives better pictures in a situation of poor lighting.

(C)**Work Sampling:** It is defined as a "technique of finding the percentage rate of a particular activity by statistical sampling and random observations (Peer, 1986). Work sampling is a work measurement technique used in the determination of the amount of time a worker uses on a task (Russell and Taylor, 2009). The technique is used to determine ratio-delayed that is the "percentage of time a worker or machine is delayed or idle". It is also used to examine works that are not cyclic in nature. Work sampling involves making intermittent observations of the activities to be studied. Its original application found its root in the textile industry in the United Kingdom. It is referred to as a "snap-reading" method because of its snapshot recording of observations of the sample being examined.

Work sampling observations are carried out either randomly or at fixed intervals and it should be without prejudice. Each sampling tour must offer each worker equal chance of being observed while at work. On the issue of inaccuracy of results when samples are few, this is handled by taking large samples or larger number of observations. The greater the number of samples, the more accurately will the findings of the sampling approximate to the real conditions.

The effectiveness of activity sampling technique has been proved and tested by other researchers. Jenkins and Orth (2003) used work sampling technique to investigate work

performance on an industrial construction project; they found it to be an effective method in evaluating site productivity problems and determining a baseline for examining future investigations.

Thomas (1991) in his study of labour productivity and work sampling identified the level of involvement of the skilled workers on a nuclear plant and concluded that this level of industry among skilled workers has no significant relationship with labour productivity. In spite of this, he proposed that findings from work sampling study should be used to provide significant interactive information in sizeable and complex projects.

The work sampling method has the benefit of being used to monitor labour input across various trades at the same time. It is cost effective in relation to continuous observation methods. It has the flexibility of being adjusted to meet required levels of accuracy and it helps to aggregate important information during project operations. However, the major weakness of work sampling is that the end result offers information on the labour time input and none on the output (Thomas, 1991).

Data collection in activity sampling method involves regular monitoring by observers or research assistants observing the labour force. Observations are carried out at randomly chosen periods during work hours excluding period of break times or change over periods. Similar to continuous observation, all basic information is recorded on the data collection form such as the labour size, foreman, work areas and activity being covered. On completion of the sampling exercise the data collected are synthesized and processed using a statistical instrument. Afterwards the various variables such as total labour hours, the time spent on

each activity and percentage variations are analysed. Also the mean of the value added activity and standard deviation of the entire process can be determined for the study.

There are various types of work sampling. Peer (1986), proposed an Improved Fixed–Internal Sampling technique (FS). Recording of the time input on the data collection form is done by drawing horizontal line on the time space to represent the time input. The size of workers is indicated by a figure on the line. The advantage of this type is the reduction in the time used for collecting the results of the observations.

Another method is the five-minutes rating technique. In this method, the number of the crew or gang should determine the duration of the observation. For instance, a crew of seven operations should be observed for seven minutes. The observation interval should be at least 30 seconds except in a situation where the crew of operatives is large, in which case the interval can be adjusted. The five-minutes rating method allows for workers to be credited if an operative is "engaged in work for a period of time greater than 50% during the observation" the major advantage of the method is that it can be used for all operations irrespective of whether it is repetitive or non-repetitive (Noor, 1992).

(d) Daily Visit Data Collection Method: The daily visit data collection method has been successfully used in collecting both input and output data for research purposes (Noor, 1992; Thomas *et al.,* 2002). In this method each research assistant visits the site daily to collect or record data at least twice on each of the building trades being investigated. In the morning records are taken on the starting time and number of operatives working in each trade section. The research assistant later visits to interact with the foreman on site and to take records of the input and output data, by so doing the research assistant is able to monitor or cover three

to four sites that are at close proximity. All the information obtainedis entered in the daily data collecting sheet (Table 2.1). This method provides the opportunity for the observer to interact with the foreman and the site workers to collect information on certain factors affecting productivity such as shortage of material, delays, sequencing problem and others.

The daily visit method of collecting data is a simple and effective method of monitoring productivity on building construction sites. It has the advantage of being used to measure multiple gang size. It is used to collect productivity data on labour inputs and outputs. Its accuracy of measurement has been found to be equal with continuous observation method if length of delays of 15-21 minutes is allowed (Noor, 1992). Also this method has been found to be less labour intensive than the activity sampling and continuous observation methods and it was suggested by Noor, as a ready tool for contractors to monitor construction labour productivity. It also allows for sharing of productivity data among researchers.

2.3.1.4. Types of Input Times: Total, Available and Productive Times.

The time input measurements for labour productivity are categorized into three parts. Talhouni (1990) Thomas *et al.* (1990)and,Bennet and Omerod (1994) explained labour productivity measurement in three perspectives of time input: which are total time, available time and productive time. Total time was defined as total paid time which excludes normal break time. Available time isexplained to mean total time minusunavoidable delays such as meal breaks and weather. While productive timeis available time minus avoidable delays.

The ratio of total time/output could be said to define the overall labour cost of the project. In this perspective avoidable delays are not excluded in the estimate. It is the universal figure often required by the estimator for thepurposes of tendering and monitoring contractor's profit and performance.

Productivity measure using the available time can be productive where there is good site management of reducing the frequency and duration of disruption.Productivity measure based on available time is used to assess site troubled by inclement weather and provides the platform on which claims for delay and disruption are made.

Productivity measured using the productive time/output time signifies the actual time input of a workman and it is used to evaluate the influence of internal factors, such asquality of the labour,on labour productivity.

Practically, it is the most detailed level at which site labour productivity can be economically and practically measured without the continuous presence of an observer. This measure is used primary as an investigative tool in an attempt to isolate, understand and quantify the large variety of factors that can influence site labour productivity. In this research the input time employed is the total time which measures the global figure often required by the estimator for thepurposes of tendering and monitoring contractor's profit and performance. This agrees with the objectives of this thesis. The total time as applied in this work is the time spent on the task multiplied by the crew size.

2.3.2 Determination of Outputs

The measurement of output is very significant to labour productivity computation. To achieve this, daily outputs have to be measured and matched with corresponding daily input resources. Output data collection is measured physically on site. The work measurement techniques discussed in the previous section do not take into account the output measurement except the daily visit method. Researchers have modified the input data collection forms to include output measurement. In their study of labour productivity, Abdel-Razek *et al.* (2007) used a modified direct observation technique to measure both time inputs and outputs as shown in Appendix vii. In the data collection form, output data measurement was included.

The form was designed to make provision for the measurement of time inputs, number of crew, foreman on site, type of activity being measured, and the dimensions of the element under observation (daily quantities). With this type of modified data collection form, the researchers were able to calculate easily the study attributes such as daily quantities, man-hours per day and daily labour productivity.

2.3.2.1 Conversion Factor

The use of conversion factor or mensuration indices is a common practice in productivity research where different types of materials are used for the same purpose. These differences are taken care of by using converting factors. The determination of mensuration indices for different sizes of materials in the building trades has some procedures. Firstly, is the establishment of the common base of measurement to which the conversion of all other outputs will be done. In most cases the common type of material is chosen as the predetermined standard unit. "Thus if output in dense concrete blocks of dimensions (450x225x225mm) are laid in stretcher bond are the greatest, it is chosen as the standard unit of output. Outputs in the other types of material are then converted to equivalent outputs based on the standard unit of output." (Noor, 1992). This means that all outputs in relation to their quantities are converted to the predetermined standard unit of measurement.

The procedures for the establishment of mensuration factors from data set are as follows

(1) Separate the work days in which work was done with only one material type.

(2) From (1) compute the average daily productivity for each of the material types including the one chosen as the standard unit of output.

(3) The mensuration factor for a material type is defined to be the ratio of the average daily productivity for the material obtained from two to that of the material type

chosen as the standard unit. It was suggested that the results can be compared with that obtained from estimating manuals.

$$Conversion\ factor_{ij} = \frac{Unit\ rate\ for\ the\ item\ in\ question_i}{Unit\ rate\ of\ the\ standard\ time_j} \quad (2.8)$$

Where *i* = item number; and *j* = standard unit number.

The assumption behind conversion factors is to compute equivalent quantity. It can be easily verified that irrespective of mix of quantities attained, the conversion factor does not alter the hours worked and also conversion factor is similar to monetary exchange rates (Thomas and Raynar, 1997). Therefore, to calculate the equivalent quantities, the following equation is employed,$Equivalent\ quantity_i =$

$$\sum_{i=1}^{k}(conversion\ factor_i \times actual\ quantity_n) \quad (2.9)$$

Where *i* = denotes the item being measured; and *k* = total quantities worked during day one.

2.3.2.2. Conversion Factor for Concrete Elements

There are certain factors that affect concrete work on site in terms of transporting, placing and compacting. This means that productivity rates for each concrete element will differ from one another depending on where the concrete element is located in the structure. Also methods employed in the construction process, such as method of placing, transporting and compacting concrete will affect the labour output. Therefore, the assumption here is that the methods are same for all studied projects. The pre-determined standard unit is established using statistical median. Based on this assumption the labour outputs for transporting, placing and compacting concrete for all concrete elements per one labourer expressed in man hours over output are summarised in Table 2.1.

Similar to the concrete trade which has different areas of operations more than one type (size) of material was used in the floor tiling trade. The common floor tiles used were approximately 300mm square.

Table 2.1Labour outputs for transporting, placing and compacting concrete based one labourer

Concrete Elements	Labour Outputs Man-hrs/m^3	Conversion Factors
Foundations	3.5	**0.259**
Beds	4.0	**0.296**
Suspended slabs	7.5	**0.556**
Columns	13.5	**1.000**
Beams	13.5	**1.000**
Walls	13.5	**1.000**
Staircases	15.5	**1.148**

Source: Saman, 1985;Ross *et al.*, 2007

2.3.2.3. Conversion Factor for Tiling Trade

During the tiling operations, the crew worked with different sizes of tiling material ranging from 600 x 600mm to 250 x 250mm. This affected output rates for the gangs. The type of tile for which outputs were greatest was the 300 x 300mm tiles. Therefore, this type of floor tile was taken as the common unit for computing the tiling conversion factor. It should be noted that the calculation of converting factor for tiling trade is similar to that of concrete trade except that the data used for computation were not obtained from existing manual. This was due to the fact that the floor tiles have different various sizes which are not common and thus output rates were not available in the estimating manuals. Therefore, the conversion factors were calculated from the data collected as shown in Table 2.2.

This approach of calculating mensuration indices may likely be susceptible to imprecision in instances when the data sample contains a small proportion of data points in which work was done with one material type (Noor, 1992). Having a large data set tends to check inaccuracy.

Table 2.2 Converting Factor for Computing Equivalent Quantities of Tiles

S/N	Type and Size of Tiles	Area of Tile (m^2)	Output per Square metre	Conversion Factor
1	600 x 600mm	0.360	2.77	**0.25**
2	600 x 300mm	0.180	5.55	**0.50**
3	450 x 450mm	0.203	4.93	**0.44**
4	300 x 300mm	0.090	11.11	**1.00**
5	250 x 250mm	0.063	15.87	**1.43**

Source: Author's analysis of data 2012.

$$CF_{ft} = \frac{Outputof Noncommontiles_{nt}}{Outputof commontiles_{ct}} = \frac{P_{nt}}{p_{ct}} \quad (2.10)$$

Where CF_{ft} = Conversion factor of floor tiles.

P_{nt} = Output of Non common tiles.

P_{ct} = Output of common tiles.

2.4 IDENTIFICATION OF FACTORS INFLUENCING LABOURPRODUCTIVITY.

Labour productivity is anintricatefact which is affected byvaried factors (Enshassi *et al.*, 2007). Many of studies have been carried out by researchers to improve construction labour productivity using factors analysis andclassification methods (Abdel-Razek *et al.*, 2007).A number of studies have discovereda range of factors that affect labour productivity on construction sites. Maloney (1983) pointed out that the level of labour productivity is as a result of the driving, induced and restraining forces acting upon the workers and that these

factors act positively and negatively. Enshassi *et al.* (2007) corroborated this fact by suggesting that the adoption of these positive factors and elimination of the negative ones will enhance the improvement of labour productivity. Other attempts have been made in the past by researchers to improve labour productivity through various studies. Iyagba and Ayandele (1999) identified positive and negative factors affecting labour productivity in three cities of Nigeria, using correlation analysis. They concluded that the strategy for improvement was to encourage and incorporate the positive factors that affect labour productivity into the system while the factors that negatively affect productivity should be discarded or removed from the organization's work environment.

Thomas (1991), and Ayandele (1999) identified the following factors as having influence on productivity of construction workers, project (Type, scope, layout and complexity), Time frame, construction methods, weather conditions, skills of the workforce, work practices, length of work day, availability of material, incentives, degree of supervision, enabling environment, Government regulation and organisational size and maturity.

Yates and Guthathakurta (1993) cited in Ameh and Odusami (2002) observed that productivity is related in part to management (proper planning, realistic scheduling, adequate coordination, suitable control); labour (union agreement, restrictive work practices, absenteeism, turnover, delays, availability, level of skilled artisan, and use of equipment); government (regulations, social characteristics, environmental rules, climate and political influence); contracts (fixed – price, unit cost and cost – plus fixed fee); owner characteristics; and financing.Heap (1987) highlighted management short comings that are capable of reducing efficiency and productivity as:

1. delayed vague or inadequate instructions
2. delays in delivery of material, tools or equipment
3. provision of poor tools and equipment
4. unbalanced work gangs
5. Use of wrong methods
6. Bad advance planning or allocation of work tasks.
7. Failure to delegate authority from senior to lower level supervisors.

The ability or efficiency of a worker is dependent on his capacity for work.Thomas *et al.* (2002) investigated the possibility of reducing variability to improve performance using lean construction principle, they were able to identify poor and short sightedness of management, and nature of project as some factors militating against labour productivity and good project performance.

Ameh and Odusami (2002) in their study of factors affecting labour productivity in the Nigeria construction industry identified common site problems inhibiting productivity on site. Low wage level tops the list with a relative index of 0.69, others factors include lack of materials, unfriendly working atmosphere, supervisor's incompetence, interference between operatives, instruction delays, changing crew members, absenteeism of gang members, inspection delays, lack of proper tools and repeat work which is the least in the ranking with a relative index of 0.28.

Olomolaiye *et al* (1989) investigated labour productivity on construction sites in Nigeria.They recommended the need to establish output figures or values on various construction sites using time study techniques. It was suggested that method study and

research findings should be circulated to construction firms including indigenous ones. This was to enable the best or most productive working practice be adopted by operatives which will result in increased output with little labour inputs. Lim and Alum (1995) explored factors affecting productivity in the construction industry in Singapore. Their investigation showed that the critical problems affecting productivity were: difficulty with recruitment of supervisor; difficulty with recruitment of workers; high rate of labour turnover; absenteeism from work. In their study of factors affecting productivity of craftsmen in Indonesia, Olomolaiye *et al* (1996) identified five critical factors: lack of materials: rework; absenteeism; lack of equipment; and inefficient tools. In a similar study, Olomolaiye *et al* (1989) found that the six most significant factors in Nigeria are lack of materials, rework, lack of equipment, supervision delays, absenteeism, and interference. He however stated that factors influencing construction productivity are rarely constant and may vary from country to country, from project to project and from task to task within the same project, depending on circumstances.

2.4.1. Classification of factors affecting construction productivity

According to United Nations report (1995) cited in Enshassi *et al* (2007), in a normal situation two major sets of factors affect the site labour productivity requirements. Organisational and execution continuity. Organisational continuity is explained as the physical constituents of work, specification requirements, design details etc, while execution continuity refers to the work environment and how effectively a job is organized and managed. The report further noted that management aspects include weather, material and equipment availability, congestion, and out-of- sequence work.

Heizer and Render (1990) classified influence factors on productivity into three groups; labour characteristics factors; project work conditions factors; and non productive activities. Kane *et al* cited in Enshassi *et al* (2007) classified factors influencing site productivity into two main groups: technological factors and administrative factors. The technological factors include those related mostly to the design of the project; the administrative group factors relate to the management and construction of the project. Kene *et al.* further broke down the technological factors into sub groups, such as construction methods and procedural factors equipment factors, labour factors and social factors.

Olomolaiye *et al* (1998) identified factors affecting labour productivity as external and internal, the external factors were explained to include nature of the industry construction, client knowledge of construction procedure, weather and level of economic development. Internal factors are those originating within the firm and they include management, technology, labour and labour unions.Dileep (2008) stated that many factors affect productivity and some of these factors are classified under five main groups.

i. General Environment: These are economic, availability of capital, raw materials, degree of competition, sociological including beliefs (Religion), attitudes and mode of behaviour:
ii. Technical factors: These include method and techniques of production, degree of mechanization and scale of operation.
iii. Human Aspects: under these groups are factors of skill and knowledge level of operatives, education, training and motivation.
iv. Organisational factors: management practices, trade unionism, Job stress, Job dissatisfaction, absenteeism and labour turnover.

v. Environmental factors: These factors cover the physical work environment, facilities and ergonomics.

Enshassi *et al* (2007) identified forty five factors affecting labour productivity in the construction industry. These factors were classified further in their study into tencategories as follows;

a. Site material / equipment factors
b. Supervision factors
c. Headship factors
d. Capacity factors
e. Period factor
f. Human power factor
g. Scheme /Task factors
h. Exogenous factors
i. Incentive factors
j. Security factors

2.4.2 Summary and inferences

On the issue of improving labour productivity in the construction industry, some of the reviewed works of previous researches have provided support for this research. It was observed thata number of construction labour productivity studies have been undertaken, only few have addressed improving labour productivity in developing countries (Leman 1995, Enshassi *et al.*,2007). The following excerpt fromOfori-Kuragu, Baiden, and Edum-Fotwe's study encapsulates the productivity improvement concept,

> *Improving productivity yields cost and quality advantages over competitors. This occurs: when output increases faster than input (managed growth); when there is more output from the same input (working smarter); when more output can be attained with a reduction of input (the ideal); where the same output is achieved with less input (greater efficiency) or when output*

> *decreases but input decreases more and the decrease in input is proportionately higher than the decrease in output (managed decline). Productivity is a multi dimensional term whose meaning may be determined by the particular context in which it is used. In practice, the transformation processes in a firm may be fed with several different types of input such as labour, capital, material and energy. The corresponding output may be more than one thus making the calculation of productivity difficult. (Ofori-Kuragu, Baiden, and Edum-Fotwe, 2010).*

Some of the studies of previous researches have proved to be very useful and have provided insight into the identification of numerous factors affecting productivity on construction sites. They include the identification of management impact on productivity of construction workers (Ayandele, 1999); the discovery of indirect and direct factors affecting labour productivity using correlation analysis (Iyagba and Ayandele, 1999);the development of relative index values for eleven common site problems inhibiting productivityby Ameh and Odusami (2002).

However, group factor classifications and analyses were not considered in their works. Several approaches have been adopted in relation to the classification of factors affecting construction productivity. Kane *et al.* cited in Enshassi *et al.* (2007) classified factors influencing labour productivity into three groups. These groups appear to be too broad with no consideration for group importance. The work of Enshassi *et al.* (2007) filled the gap in factors classification in relation to group importance. Although their work was detailed comprising 45 factors grouped into 10 classifications, the aspect of belief factor group was not considered. This factor was however identified by Dileep (2008).

It can be seen from literature findings that the list of all factors affecting productivity are numerous. Noor, (1992) asserted that the scope of a study determines the extent to which the effects of all these factors would be applied. However, he suggested that the study of the

effects of all factors on labour productivity be restricted to critical or significant factors which are likely to affect productivity. Previous work by Thomas and Yiakoumis (1987) cited in Noor (1992) attempted to deal with this difficulty, restricted their study to the significant factors which are likely to affect labour productivity on site. With the application of factor analysis method they identifiedinventory of thirteen common factors which had the most significant effect on productivity. These factors included:

i. The make-up of the gangs.
ii. The occurrence of "delays".
iii. The characteristics of site location.
iv. The extent of administrative control at hand on site.
v. The kind of payment system.
vi. The altitude at which work is done.
vii. Training outcomes because of repetition.
viii. Degree of dexterity and incentive of the workers.
ix. The nature of contract agreement.
x. The value of "workmanship" needed.
xi. The extent of automation of the work process.
xii. Labour proceeds and "absenteeism among the operatives".
xiii. Continuity in the work of skilled workers.

Horner*et al*(1989) from their preliminary results of a major labour productivity monitoring programme identified the following thirteen main or critical factors affecting productivity.

a. Skill of Labour Force
b. Buildability
c. Quality of Supervision
d. Method of Working

e. Incentive Scheme

f. Site Layout

g. Complexity of Design Information

h. Gang Size And Composition

i. Length of Working Day

j. Availability of Power Tools

k. Absenteeism

l. Total Number of Operatives On Site

m. Proportion of Work Subcontracted

Some of these critical factors mentioned above overlapped with the significant factors identified by Enshassi *et al* (2007). The factors were drawn from the group classification. They include:-

i. Lack of Labour Experience

ii. Poor Supervision

iii. Payment delay

iv. Material Shortages

v. No Holiday(working 7 days a week)

vi. Alteration in drawing /specification

vii. Working within a confined space

viii. Accidents

ix. Weather changes

x. Lack of tools/equipment

From these sequences of inferences this research intends to identify and usethe most significant factors, drawn from literature, likely to affect labour productivityin the study sites. Significantly, the research methodologies of previous studies were based principally on factor

analysis and ranking of factors affecting labour productivity on site. Olomolaiye *et al* (1998) had earlier recommended the need to develop or establish empirical output values through appropriate productivity measurement methods. The resulting findings should be communicated to construction firms including indigenous ones with the aim of improving workforce management thereby increasing work flow output with little labour inputs. Therefore, mere identification and ranking of positive and negative factors affecting labour productivity on site is not enough to generate empirical data, create innovation and the spirit of competition necessary for growth and development among contractors.The aim of this research is to measure, apart from the identification ranking of critical factors, the effect of work flow variability of labour productivity with the intension to regulate it in order to improve productivity and system performanceof building contractors on site in the study area.

Considering previous work done on factors affecting labour productivity, there are numerous factors found in literature that are likely to affect labour productivity on building construction site. Some of these factors are either external or internal which stem from within the organisation. Client, statutory authorities and government agencies have their share in generating factors that could impede progress of work on construction sites. To identify, isolate and analyse the influence of each of these numerous factors on labour productivity is certainly beyond the scope of this work. Thomas and Yiakoamis (1989) and Noor (1992) approach, of determining factors which have the most significant effects on productivity, was adopted in this work.

The lists of significant or critical factors found in literature(Thomas and Yiakoumis, 1987; Horner *et al.,* 1989; Olomolaiye *et al.,* 1989; Ameh and Odusami, 2002; Enshassi *et al.,*

2007)are shown in Table 2.3, from which the common critical factors of the study were determined.

Table 2.3COMPARISON OF CRITICAL FACTORS AFFECTING STIE LABOUR PRODUCTIVITY

Thomas and Yiakoumis 1987	**Horner *et al.* 1989**	**Olomolaiye *et al.* 1989**	**Ameh and Odusami 2002**	**Enshassi *et al.* 2007**	**Common Factors**
The makeup of the gangs	Skill of Labour force	Lack of Materials	changing crew members		Crew Composition
Degree of dexterity	Buildability	Rework	Supervision incompetence	Lack of labour experience	Lack of Experience
Characteristics of site location	Quality of supervision	Lack of equipment	Harsh working environment	Poor supervision	Supervision
Payment system	Method of working	Absenteeism	Low wage level	Payment delay	Payment system
Management Decision	Incentive scheme	Supervision delays	Lack of materials	Material shortages	Material shortages
	Site layout/distant	Interference	Lack of tools	Lack of tools	Lack of equipment
Absenteeism	Complexity of design information		Absenteeism	No Holidays	Absenteeism
Extent of automation	Gang size and composition		Accidents	Accidents	Accidents
Occurrence of delays	Length of working day		Inspection delays		delays
Value of Workmanship	Availability of power tools		Interference		Interference
Height at which work is done	Absenteeism			Working within confined space	Site conditions (i) Height (ii) Distance of materials (iii) confined space
Training outcomes because of repetition	Total number of operatives on site		Repeat work	Alteration in drawing/specification	Rework
Continuity in the work of skilled workers	Proportion of work subcontracted		-	Weather Change	Weather Condition

Source: Author's analysis 2012

2.5 CRITICAL FACTORS AFFECTING LABOUR PRODUCTIVITY

a. Lack of labour experience
b. Material shortages
c. Occurrence of delays
d. Poor supervision marked with excessive waiting
e. Rework and fatigue
f. Distance of materials to work location
g. Characteristics of site location
h. Payment system (daily, output or sub)
i. Size and composition of the gangs
j. Height at which work is done
k. Accidents on site
l. Lack of tools/equipment
m. Absenteeism among the site labourers
n. Weather changes/conditions
o. Confined working space
p. Interference from other workers

2.5.1 Lack of labour experience

Lack of labour experience has a very high negative effect on labour productivity. This assertion is supported by the findings of Enshassi *et al*(2007) in their studies on factors affecting labour productivity in building projects. The results of their study showed that lack of labour experience is the most important factor negatively affecting productivity. Enshassi *et al*(2007) noted that experience improves both the mental and natural capabilities of labour which invariably increase labour productivity.

2.5.2 Material storage

Lack of materials refers to problems encountered due to inaccessibility of items or excessive time expended to acquire them (Abdul-kadir *et al*., 2005). Material shortage from previous studies has been identified as the most important of all the factors negatively affecting labour productivity (Yates and Guhathakurta, 1993; Lim and Alum, 1995; Olomolaiye *et al.,* 1996).

Shortage of material, where it is experienced, slows down site works. Ali *et al*(2010) identified poor material planning, inefficient communication, unreliable suppliers and late delivery as factors responsible for shortage of materials on site. Shortage of materials resulting from poor material planning could surface in the course of a project execution due to mistake at planning stage relating to when the materials are expected to be used in the work. This may cause delay and affect productivity negatively. Dunkelberger(2009) cited in Ali *et al*(2010) stated that the success or failure of a business is directly related to the ability to communicate. The consequence of inefficient communication is misunderstanding between contractor and supplier. This could result in the supply of inadequate, early or late supply of materials which could affect the progress of work adversely. Dada *et al*(2003) cited in Ali *et al*(2005), referred to unreliable supplier as a factor whereby the quantity of material delivered by the supplier is less than the quantity ordered. This also means that the supplier is not able to deliver materials as and when due. This factor shows that unreliability on the side of the supplier will lead to shortage of materials on site and delay the completion time of the project.

2.5.3 Lack of equipment and tools"Lack of equipment refers to frequent breakdown of major equipment, shortage of spare parts, improper service and maintenance, slack use of machinery or deliberate sabotage by operators" (Ali *et al.,* 2005).

Wendle (2008) cited in Ali *et al* (2005) pointed out that the construction industry faces equipment shortages because of theft. Equipment and tools on construction sites are frequently stolen thereby causing shortages. Shree (2007) identified the high cost of renting construction equipment and tools as a contributing factor to the inability of contractors to hire construction equipment when needed. The increasing cost creates financial difficulty to the contractor thereby making the contractor to suffer from equipment and tools shortage on site.

2.5.4 Occurrence of delays

Delay occurs as a result of certain factors such as inspection time, supervision time, change order by consultants and work variations and alteration of drawings and specifications. Lost productivity and efficiency of labourers always occur when delays happen (Branble and Callahan, 2000). Other factors causing delay include acceleration of schedule pressure to complete work and construction mistakes. This will lead to rework and increase in work content for the workers.This situation directly reduces productivity.

Noor, 1992 identified nine major causes of delay which are inclement weather conditions, labourer strikes or disputes, equipment unavailability, unavailability of material, incidence of accidents, lack of adequate design information or work instructions, sequencing problems, performing remedial work and irregularity in late starts and early quits.

2.5.5 Supervision

Good supervision of site works ensures that sequence is accomplished according to work programme. Poor knowledge and the inexperience of site supervisors in planning, scheduling and procurement hinder work progress (Abdulkadir *et al.,* 2005). They also attribute most rework activities to lack of ability of the supervising team to harmonize discrepancies among

architectural, electrical, mechanical and structural drawings. Failure on the part of supervisors to harmonize these impedes work progress on site. Enshassi *et al*(2007) observed that absenteeism of supervisor results in delay of inspection of ready work, which in turn, leads to delay in the commencement of new work. This affect site labour productivity negatively.

2.5.6 Incidence of Accidents

Accidents on construction sites are classified in three categories (Sanders and Thomas, 1991)

(i) The death of an injured worker on site as a result of accident, could lead to total stoppage of work on site.

(ii) The injured operative being hospitalized as a consequence of site accident has the tendency of decreasing labour productivity of the gang.

(iii) Minor accidents caused by nails and steel wires affect productivity negatively to a small extent

Violation of safety precautions, insufficient lighting, bad ventilation, working at high places, non engagement of safety officer on construction sites and noise have been identified as factors contributing to frequent accidents on site (Enshissi *et al.,* 2007).

Noor (1992) established the fact that there is correlation between productivity and safety in his work and suggested that good planning strategies ahead of construction activities will reduce the occurrence of crisis situations in terms of safety.

2.5.7 Absenteeism

Absenteeism and turnover of labour in the construction industry have some effects on labour productivity (Noor, 1992). Construction sites where the rate of absenteeism and turnover of labour force is high, the tendency of training new workers to fit into the work will also be

high. This act of training new operatives and the time required to get them become acquainted with their new task affect productivity negatively.

2.5.8 Characteristics of Site location

The characteristics of a construction site in terms of its layout and the types of operations involved could have an effect on productivity (Noor, 1992). On construction sites where workers and machines are able to move freely, the possibilities of delay and disruptions are reduced compared to sites where movements are restricted. A site in which access is restricted could result in material double handling. This situation has the tendency to increase labour time and cost thereby affecting the labour productivity for the work activities being constructed.

Other factors under the characteristics of site conditions that could affect productivity include height at which work is executed and distance of materials to work location. Working at a great height, such as storey buildings, without appropriate hoisting equipment affects productivity (David and Ben, 2002). Where this happens, the likelihood of lifting materials manually is certain, which will increase labour input and thus reducing productivity.

2.5.9 Payment system

According to Noor (1992) there are types of payment systems generally employed in the construction industry. These payment schemes relate the method of employment. The first payment system of employment involves the direct engagement of gangs by the main contractor, which means that the workmen are under the payroll of the contractor. The second system is when the workmen are employed directly by a specialist sub contractor and lastly is the self employed system. Where operatives are directly employed they are paid basic wage

according to their levels of experience. To increase productivity in a wage system, bonus schemes are introduced by employers. Bonuses are paid to workmen if they are able to achieve a predetermined level of work set by their employers and if not, a flat rate wage is paid. Labour sub-contractors also hire labour on behalf of the main contractors in this system and the gangs are paid by the sub contractor for services rendered.In the self employed system, the gangs are hired and fired on a daily basis or paid on what is called tasks work basis depending on the nature of work or in some cases specific jobs such as block work are done on counting basis.

The question that may be asked here is that, to what extent have these payment systems affected productivity? Noor(1992) stated that, there have been differing results on the effect of the type of payment scheme on productivity. Whitehead (1990) in the study of 12 selected construction sites in Britain concluded that there was no correlation between productivity and the type of incentive scheme used or adopted. Duff.*et al*(1987) argued that in some certain instances incentive schemes may provide a psychological motivation rather than natural motivation for increased performance. Entwistle and Reiners (1958) cited in Noor (1992) found out that the effects of financial encouragement in the building industry for house building was 20% higher for sub-contracted labour than for those constructed with direct labour. However, they stated that the choice of labours system depends on the nature of work and the prevailing factors.

2.5.10 Size and Make Up of Gangs

A gang is explained to mean a tradesman and one or two labourer assistants. The duty of the labourer is to support the tradesman with respect to the provision of materials and other services as required by the tradesman. In order to ensure efficiency, adequate number of

assistants must be given to the tradesman. Adjustment of crew size or gang affects gang performance in terms of productivity.

2.5.11 Interference

Enshass *et al*(2007) in their study of factors affecting labour productivity in building projects in the Gaza strip discovered that interference has an average impact on labour productivity. They also pointed out that the interference between gangs and workers is caused by mismanagement of construction sites. Steel fixers were identified to suffer most of interference. For instance, where the carpenters have not completed the formwork, steel fixes will have to wait before fixing the reinforcement rods.

2.6 LEAN PRODUCTION PRINCIPLES

Lean Construction is to a great extent an adaptation and implementation of the Japanese manufacturing principles within the construction process and in doing this, lean construction assumes that construction is a kind of production albeit a special one (Bertelsen, 2004)

Lean construction is a new way to manage construction. The objective principles and techniques of lean construction taken together form the basis for a new project delivery process(Farrar *et al*., 2004). Unlike current approaches to manage construction including design-build and programmatic improvement efforts (partnering and total quality management TQM), lean construction provides the foundation for an operation based project delivery system. This concept found its roots in the Toyota Production System, which is a new way of designing and making capital facilities, which makes possible significant improvements on complex, uncertain, and quick projects (Howell and Ballard 1997). Howell and Ballard reported that the Toyota Production system was developed after the Second

World War when ToyotaCompany was insignificant in size. The company was faced with the challenge of producing variety of cars for a small market and had only a small capital base. Therefore a production system was required that was capable of short production time, rapid change between kinds and models of automobiles, and the smallest amount of work in production process possible. Therefore, Engineer Ohno and other Japanese engineers began to develop the principles of lean production (as opposed to mass) as they redesigned the Toyota production process. Their relentless pursuit of perfection led to the new form of production now call lean.

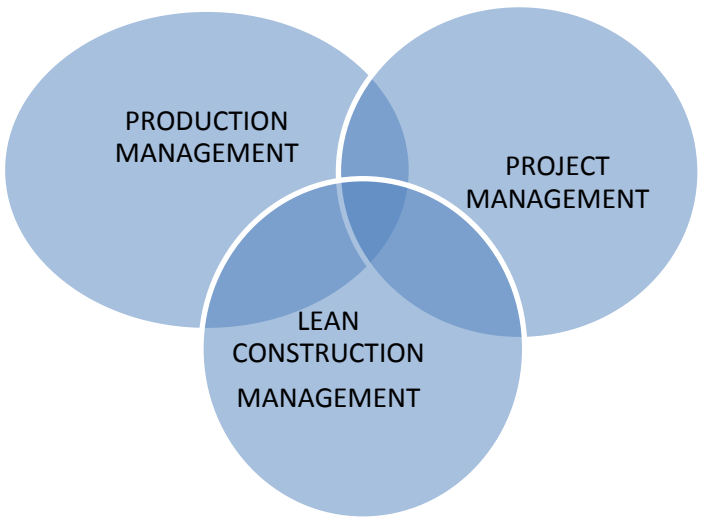

Figure 2.2 Venn Diagram of Production, Project and Lean managements
(Koskela and Ballard 2006)

2.6.1. The New Production Principles and Practices

Most lean approaches in construction are focused in the lean construction concept. The academic discourse in lean construction is to challenge the conventional understanding of

projectsmanagement based on theories of economics, and adopt project management based on theories of production (Koskela and Ballard 2006, Ballard and Howell 2004). Figure 2.2 illustrates the interrelationship between production management, project management and lean construction management.Some researchers have stated that lean construction is similar to the current practices in the construction industry; both practices pursue meeting customer needs while reducing waste of every resource (Howell and Ballard, 1998; Salem*et al.*, 2005).

However, the difference between the current practices and lean construction is that lean construction is based on production management principles, and it has better results in complex, uncertain, and quick projects. Therefore, it is imperative to understand the principles and practices of lean. The most frequently cited definition of lean principles found in literature according to Hook and Stehn (2008) is that of Womack *et al* (1996); it is defined as,"state value, pinpoint the value flow for each product, make the product move along without interruptions, let the customer draw value from the producer and followexcellence".
The Construction Industry Institute report authored by James *et al.* cited in Salem and Zimmer (2005) developed a study by presenting the theory behind lean thinking.They presented a set of conclusions and recommendations in support of lean practices having potential for improving construction productivity. The principles identified were; reducing lead time, eliminating non-value adding activities, and reducing variability and are facilitated by methods such as pull scheduling, simplified operations and buffer reduction. They reported that, tools that have been created to aid these methods include value stream mapping, just-in-time, and continuous improvement. The authors concluded and recommended five major lean principles applicable in the construction industry, which are;

1. Customer focus
2. Culture/people

3. Workplace standardization
4. Waste elimination
5. Continuous improvement

However, the sub-principles that stem from these major principles were rated and assessed for applicability. The report suggests that these could be used as a guide for creating a construction organisation that moves closer to the ideal of lean production. Koskela (1992) identifies eleven "heuristic" principles for what is now known as the "New Production Philosophy"applicable in the construction industry as:

i. Reduce the share of non value-adding activities
ii. Increase output value through systematic construction of customer requirements
iii. Build continuous improvement into the process
iv. Reduce variability
v. Reduce cycle times
vi. Simplify by minimizing the number of steps, parts and linkages
vii. Increase output flexibility
viii. Increase process transparency
ix. Focus control on the complete process
x. Balance flow improvement with conversion improvement
xi. Benchmark (Koskela 1992)

According to Ballard (1994 and 1998), Tommelein(1998)and Thomas *et al*(2002), the principles of lean constructioninclude:

a. Practice just-in-time (JIT).
b. Use pull-driven scheduling.
c. Reduce variability in labor productivity.
d. Improving flow reliability.

e. Eliminate waste, and simplify the operation.

f. Benchmark Operations.

2.6.2 Factor-resource model

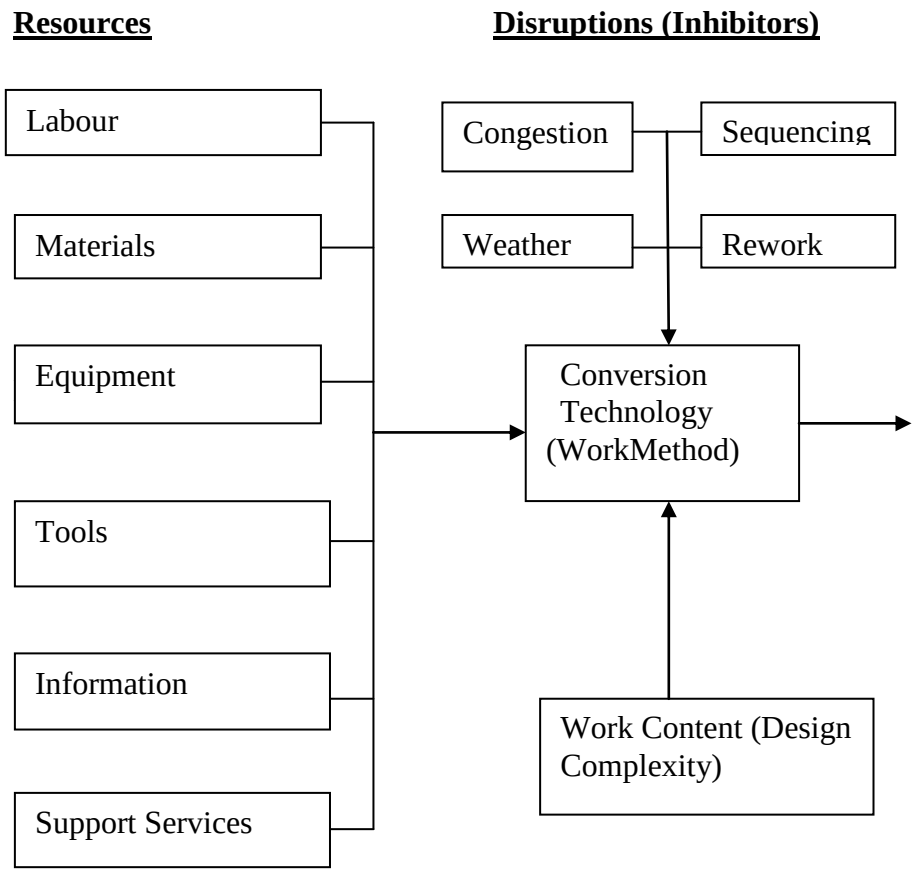

Figure 2.3 Factor-resource Models
(Source Thomas *et al.*, 2002)

2.6.3 Theoretical Framework for the Study

The theoretical framework of the study is structured to support the theory of the research. It explains or reveals the existence of a problem, therefore the theoretical framework of this study serves as a basis for undertaking this research. The purpose for this framework is to enable the researcher to conceptualize obviously the variables of the research.

The lean management thinking proposed a theory that suggests the achievement of a better cost and labour performance by reducing variability (Koskela, 1992: Thomas *et al.,* 2002). The testing of this theory forms the basis for conducting this research. The study therefore examines the relationship between productivity variability and project performance particularly on job site labour performance. This is carried out by using productivity data from selected cement based site activities from building construction sites. The main points emphasized in the above theory are illustrated in Figure 2.4.

The Figure 2.3 explains the framework for investigating the relationship between variability and performance. The factor-resource model proposed by Thomas *et al* (1990); Sanders and Thomas (1991) was adopted and modified to form the theoretical framework for this research. This model can be used to compare variability in inputs and outputs.

2.6.4 The theoretical model for this study has six steps:

Step 1: Contains inputs resources such as labour, materials required for the production, tools for the work and all necessary information and support services.

Step 2: Conversion machinery involves processing of all input resources into output quantities. This is made possible by employing appropriate work methods with the assumption that all input resources are made available at the right proportion and at the right time. All factors and design complexities capable of hindering the conversion process are managed at this level.

Step 3: For efficient production there must be appropriate conversion machinery put in place, adequate resources and non adverse influence of any productivity factors and design complexity on the output.

Step 4: Labour Productivity has been identified as the key factor in production. This contains the collection of productivity data from the conversion process which is the ratio of input values and output values.

Step 5: The productivity data gathered in step 4 are synthesized and observed for variability which is equally regulated for improving labour performance.

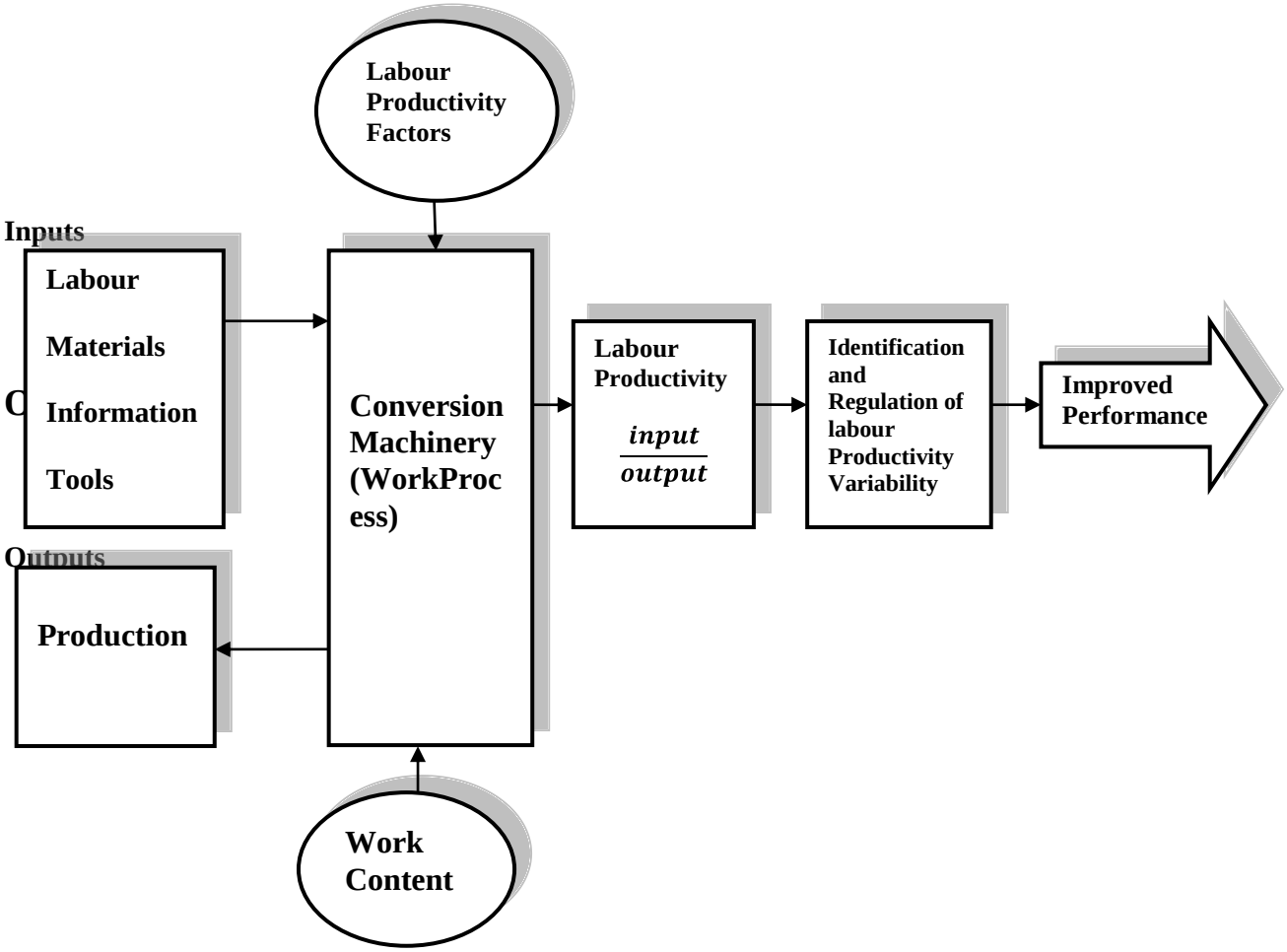

Figure 2.4 Theoretical Model Proposed for this Study

Step 6: This is the ultimate goal of all the previous steps discussed. The variability level is compared with project waste index which is the performance index used in the study.

2.6.5 Lean Production Concepts in Construction

Theapplication of lean production principles in construction was necessitated because of the continuous decline in profit margins of construction projects. This prompted construction contractors to search for ways of eliminating waste and increasing profit (productivity) (Mastroiann and Abdelhamid 2003). According to Salem *et al* (2005), numerous approaches have been developed to improve efficiency and effectiveness of construction processes. Lean construction techniques offer the promise to minimize, if not completely eliminate, non value-adding work. Since the early 1990's, the construction research community has been analysing the possibility of applying the principles of lean production to construction. Koskela (1992) introduced the concept of understanding construction as production. The international group for lean construction (IGLC) has made significant contributions to the formulation of theoretical foundation for lean construction by abstracting the core ideas of lean production and applying them to the management of construction processes. Paez *et al*(2005) stated that the nature of operation, planning, and execution of projects are the key categories that emphasize the differences between manufacturing and construction. There are important differences between lean construction and current practice. In both approaches a design brief is prepared, the design developed and engineered and materials purchased, fabricated and installed. Under lean construction, the work in each of these activities is different and lean construction adds two essential concepts; works structuring and production control (Howell and Ballard 1997).

Design in current practice tends to be sequential, first primarily about what is to be built with no considerations for the future or periodic constructability reviews. According toHowell and Ballard in lean principles, the pressure for zero time delivery demands concurrent design of product and process. Process design is the consideration of how the work is to be done; it

structures the flow of work. This includes decisions about how the project will be broken into pieces and how the work in each piece will be coordinated with others. Work structuring requires input from those organisations whose performance is interdependent. This means some key procurement decisions will be made far earlier than in traditional practice, even design/build. Conte (2002) andHowell and Ballard (1997) agreed that production control applied over the life of the project is a second distinguishing feature of lean construction. Production control until recently has been developed and applied in manufacturing as distinct from construction. Production control consists of comprehensive production planning, material coordination, workload control, work order release, and production unit control. The construction industry uses different terms and a different conceptual model than manufacturing. Due to these fundamental differences between construction and production processes, the tools of lean production cannot be directly applied to manage construction processes and a new set of tools is required.According to Ballard (2000), the last planner system of production control, introduced in 1992, which emphasizes the relationship between scheduling and production control, is one of the most completely developed lean construction tool.

Construction industry, according to researchers, is a slow progressing industry with frequent problems such as low productivity, insufficient quality, time over-runs and poor safety which hinder customer delivery value (Senaratne and Wijesiri, 2008). The initiating works of Koskela (1992; 1993) introduced lean construction as an approach to address these problems. According to him, all activities can be divided into conversion and flows. Conversion activities produce tangible outputs whilst flow activities bind such conversion activities during the delivery process of the outputs. Although all activities expend cost and consume time, lean construction argues that only conversion activities add value and these should be

made more efficient, whereas, non-value adding flow activities need to be reduced or eliminated.

Alarcon (1995), further explained that traditional thinking of construction focuses on conversion activities and ignores flow and value considerations. In particular, waste is generally associated with waste of materials in the construction processes while activities such as inspection, delays, transportation of materials and others are not recognized as non value-adding flow activities that may lead to waste. Womack and Jones (2003) cited in Senaratne and Wijesiri (2008) described waste as any human activity which absorbs resources, but creates no value. Thus, by eliminating waste, activities can become 'lean', which provides more with fewer resources. Serpell *et al* (1995) in their work of characterization of waste in building construction projects revealed that considerable amount of waste lies in flow processes of construction. According to findings by Koskela (1992), these wastes in flow processes of construction such as non-conformance quality costs "consume 12% of total project cost; "poor materials management causes 10-12% of total labour cost; time used for non-adding activities amounts to $^{2}/_{3}$ of total project time; and lack of safety amounts to 6% of total project cost. Thus, the value hindrance by wastes in flow processes of construction is quite evident – which, then, triggers the necessity to implement a concept such as lean construction.

2.6.6. The Concept of Waste in Flow Activities:

Koskela (1992) stated that there has not been a systematic attempt to identify wastes in flow activities (flow wastes) by the construction industry practitioners until lean construction concept was introduced. Senaratne and Wijesiri (2008) suggested that if flow waste is identified as a major weakness in a particular industry,lean construction can be regarded as a

suitable option for consideration. Previous studies on Lean Concepts have revealed different types of flow waste. The original seven wastes defined by Ohno (1988) are:

(i) **Transport** (moving products that are not actually required to perform the processing)

(ii) **Inventory or stock** (all components, work in process and finished product not being processed)

(iii) **Motion** (people or equipment moving or walking more than is required to perform the processing)

(iv) **Waiting** (waiting for the next production step)

(v) **Over production** (production ahead of demand)

(vi) **Over processing** (resulting from poor tool or product design creating activity)

(vii) **Defects** (the effort involved in inspecting for and fixing defects).

Koskela (1992) has identified wastes in construction processes as number of defects, rework, number of design errors, omissions,number of change order, safety costs, and excess consumption of materials. Further, Alarcon (1995) has recognized a variety of wastes relating to work methods, materials, time, labour, operational planning and equipments. Serpell *et al*(1998) cited in Senaratne and Wijesiri (2008) further identified work immobility and fruitless work within the constructive time as waste.According to Cullen *et al* (2005) "lean thinking is lean because it provides a way to do more and more with less and less human effort, less equipment, less time and less pace – while coming closer and closer to providing customers with exactly what they want".

2.6.7. The Demand for Cultural Change

It has been observed that the environment of the construction industry has become increasingly demanding Johansen and Walter (2007). The processing of modern-day projects is almost certainly determined by an increasing technological and financial pressure along with a rising interest of the client to be involved in the process. Most construction firms adapt to the traditional ways of doing things. Palmisano (2006) cited in Grantham (2008) stated that change adoption is required if companies are to succeed in today's business environment, that successful change adoption requires both acceptance and support from organisational members. Schein (2004) defined culture as "a pattern of shared basic assumptions that has been learnt whilst solving problems, that has worked well enough to be considered valid and therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems".

According to Johansen and Walter (2007) the lean culture relates to this definition because the concept of lean has developed through the years and is now considered to be valid for structuring and development of organisations. They suggested a balanced whole system view emphasizing improved performance through a focus on the persons delivering value to customers. Mann (2005) puts it this way "focus on the people and the results will follow. Focus on the results, and you'll have the same troubles as everyone else- poor follow up, lack of interest, no ownership of improvements and diminishing productivity". This means that personal focus, involvement and motivation are imperative when applying lean principles and approaching a lean culture.

Lean thinking takes a project-as-production-system view as opposed to the current activity or contract centered perspective. In this way lean embraces the uncertainty and complexity of

construction and aims to assure that local improvements actually lead to results at the project level. But the shift from activity to system is a change of the mental model level that has important implications for implementation (Howell and Ballard 1998).

2.6.8. Areas of Lean PrinciplesApplicability in the Construction Industry.

Koskela (1992) served as a pioneer for research in lean construction. Since then, researchers working closely with practitioners have been investigating the theory, principles and techniques of lean project delivery. These efforts cover a range of project types,for instance, housing, commercial, and industrial projects) and project areas e.g. project definition, design, supply, assembly, and use (Thais and Cynthia 2007). Common *et al* (2000) identified four areas as being fundamental in developing a lean culture namely procurement, planning, control, and management. Within each area they recognized a number of techniques that were seen as being instrumental for the realization of lean construction. The techniques reported included design and build, last planner, look ahead planning, supply chain management and partnering. Recent studies by Johansen and Walter (2007) have revealed that Common *et al.*'s (2000) framework no longer sufficient. New insights have been gained into the development and application of techniques as well as into human aspects of lean construction. Taking into consideration the recent studies and development in lean construction, the conceptual framework has eight areas namely, management, design, procurement, supply, planning control, behavior, collaboration and installation as shown in Figure 2.5

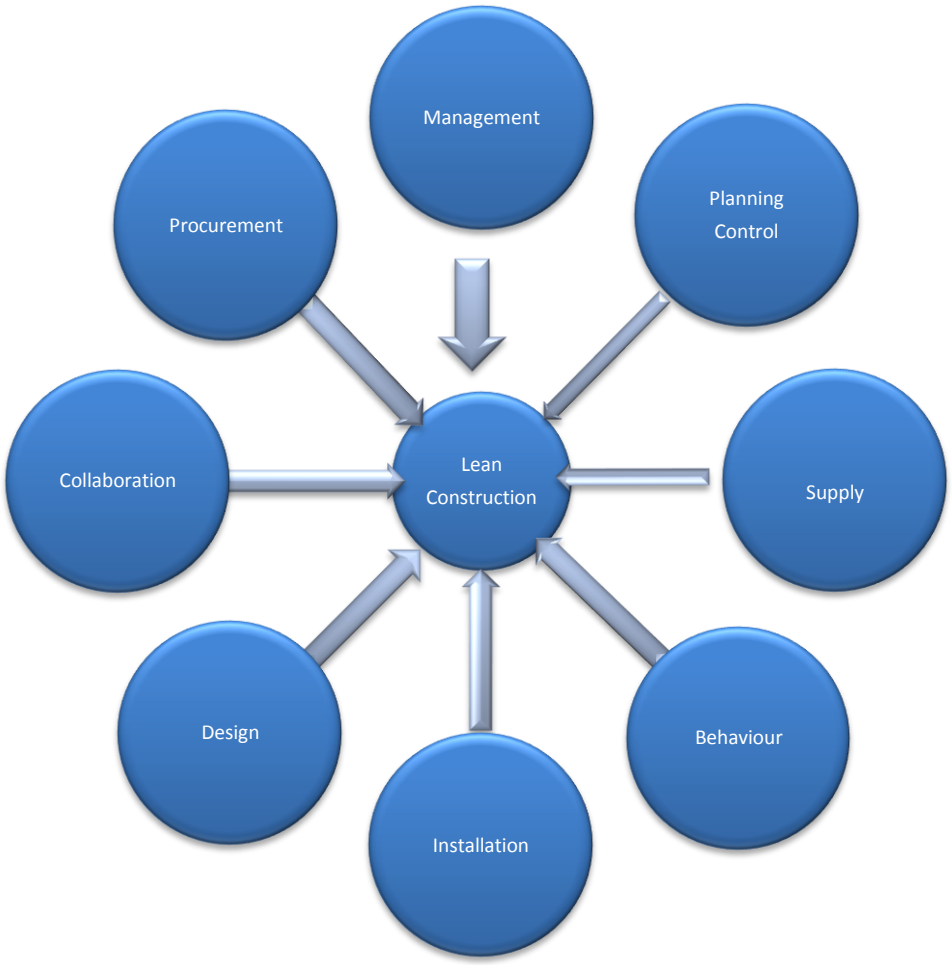

Figure.2.5Areas of Applicability of lean principles in the construction industry.
(Source:Johansen and Walter, 2007)

2.6.9. Some Management Techniques Employed in Lean Construction

Howell and Ballard (1998) cited in Salem *et al* (2005) indicated that lean construction is similar to the current practices in the construction industry; both practices pursue the aim of meeting customer needs while reducing waste of every resource. However, the differences between the current practices and lean construction is that, lean construction is based on production management principles and it has better results incomplicated, undefined and speedy projects. Some of the management tools employed in lean construction are explained in the glossary.

2.6.9.1 Last Planner System of Production Control

The last planner system can be explained as a means for changing"what should be done into what can be done, thus forming an inventory of ready work, from which weekly work plans can be formed" (Alarcon and Colderon 2003). As indicated by Ballard (2000), "last planner system is a technique that shapes work flow and addresses project variability in construction". The best planner is the person or group accountable for operation planning, that is, the structuring of product design to facilitate improved work flow, and production unit control, which is the completion of individual assignments at the operational level. The basic elements of last planner system are master schedule, reverse phase schedules (RPS), Six week 1ookahead (SWLA), weekly work plan (WWP), percent plan complete (PPC), constraint analysis and variance analysis as shown in Figure 2.6. These elements help to set up an effective programme planning structure through a pull method which shapes work flow sequence, and rate; matches work flow and capacity; develops methods for executing work: and improves communication between trades (Salem *et al.,* 2005).

Last planner system (LPS) enables programme and production planning decisions to be made collaboratively of the lowest possible level in a whole range of one – off production settings – self development, ship building, yacht fit–out, one-off manufacture and construction(Koskela *et al.*, 2010). By promoting conversations between trade foremen and site management at appropriate levels of detail before issues become critical. Last planner system (LPS) is creating significant improvements in programme predictability, productivity, profit, safety and feelings of well being among project staff (Mossman 2005). The important role of the Last planner tool is to replace hopeful planning with practical planning by evaluating the performance of workers based on their ability to dependably achieve their obligations or

commitments. The goals of last planner are to pull activities by reverse phase scheduling through team planning and optimize resources in the long-term.

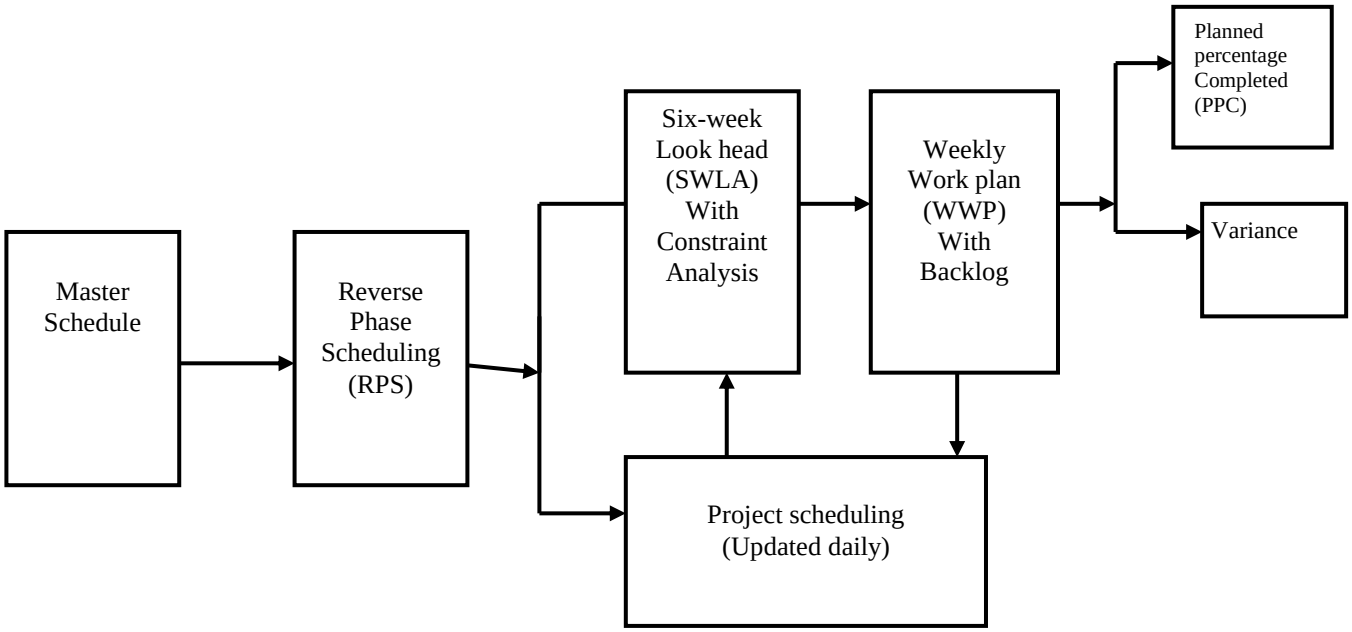

Figure 2.6. The Sequence of Last Planner Process
(Source: Salem et al., 2005).

2.6.10 Benchmarking Concept and Types

(a) **Concept:**Benchmarking has been identified as one of the principles of lean construction(Osman and Abdel Razek, 1996). Benchmarking therefore can be defined as a systematic and continuous measurement process; a process of continuously measuring and comparing theoutput of one organisation to the output of another organisation anywhere in the world to acquire information which will assist the organisation to improve its operation or productivity (Koskela, 1992; Madigan, 1997). In other words, benchmarking is said to be the continuous process of measuring products, services and practices against the toughest competitors or those recognized as industry leaders (Camp, 1989). From this definition, benchmarking measurement can be applied to products, production, process, services (labour) and practices. "The term benchmarking involves measurement which can be achieved by

comparing internal and external practices and recording the significant differences to highlight the best practices that must be executed to realize superiority" (Straker, 2006).

Furthermore, benchmarking is the act of identifying the highest standards of excellence for products, services, or processes (best practice), and benchmarking improvements to attain the level of those best practices (Elmuti and Kathawala, 1997). Therefore, benchmarking concerns the measuring of an organization's performance against key business activities, and then using lessons learnt to make targeted improvements in the particular organisation. According to Chinyo and Boyd (2003), the quest for targeted improvement drives and promotes innovations in organisations. They argued that the scope of benchmarking is very wide; it can be utilized to benchmark the whole activities of an organisation. Also it can be applied to specific activities in the organization "specially those aspects where high under-performance have been identified".Benchmarking can be internal, external, strategic, classic, traditional, process, performance, functional or combination. The idea behind each is the same: todiscover, compute,contrast, carry out gapexamination, change and apply newthoughts. Fisher (1995) cited in Abdul – Razek *et al* (2007).

Thomas and Zavrski (1999a) have developed a site based standard for measuring the labour productivity of construction activities called theoretical (conceptual) paradigm for worldwide benchmarking of labour productivity. This model was an analytical approach to contrast labour productivity in one project to that of another. Therefore benchmarking has become an important research function in national and global construction market (Abdel – Razek *et al.*, 2007). The application of these benchmarks can lead to evaluating the labour productivity and identifying the best and worst performing projects. Figure. 2.7 shows components of the conceptual benchmarking model for a single project evaluation.

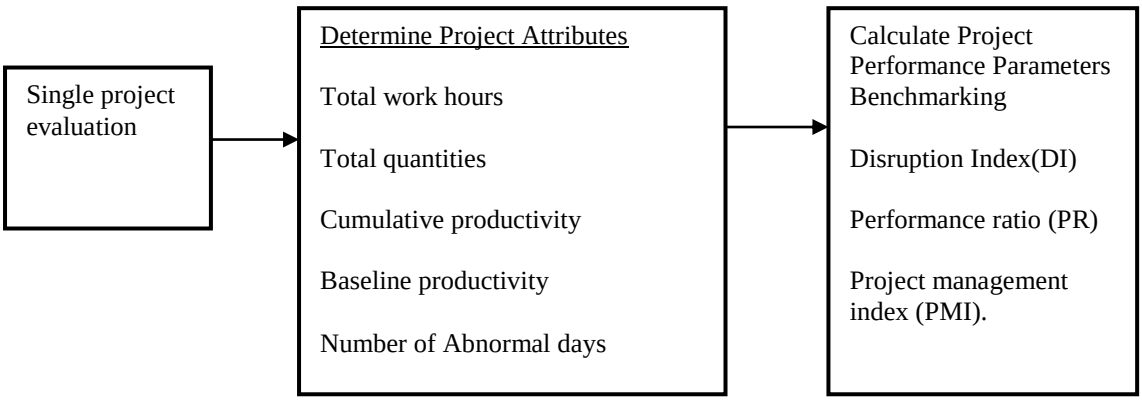

Figure 2.7. Single Project Evaluation
(Source: Abdel – Razek *et al.*, 2007)

(b) Types of Benchmarking: Benchmarking originated in the manufacturing industry as systematically and continuously measuring and comparing the firm's business and management processes against best practice in the same field (Harris and McCaffer, 2001). Its development could be traced back to early 1900s as shown in Figure 2.8, also indicated are the developmental phases of types of benchmarking over time. Benchmarking is a method of measuring performance level. It is a means for improving process, and a "technique for strategic management". Organisations adopt benchmarking as a means to accomplish set goals and increase their "performance based on a comparison" of firm's output with regards to processes, products and services (Kozak, 2004, cited in Chen *et al.*, 2008).

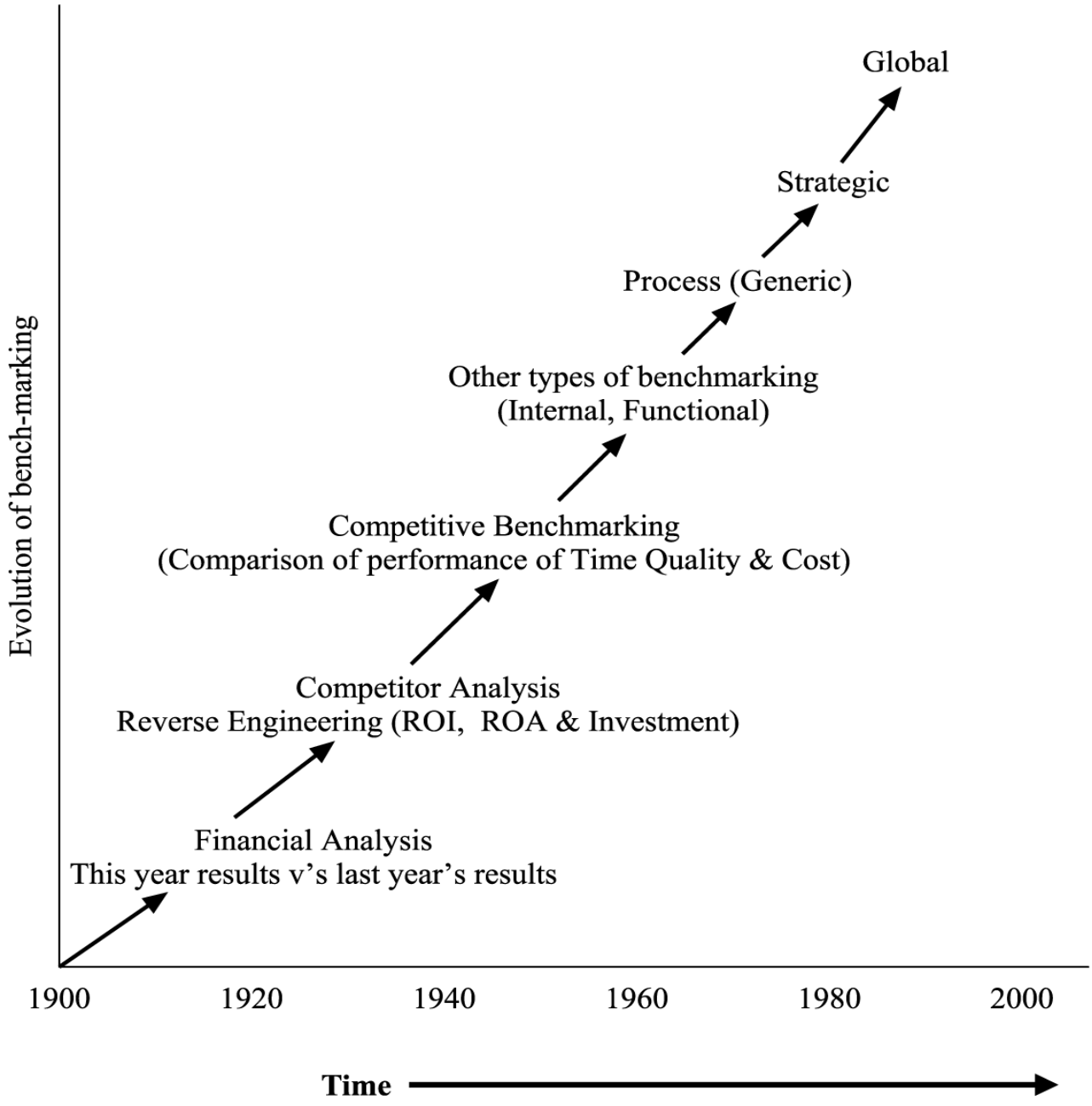

Figure 2.8 Development of Benchmarking
(Source: Anderson and McAdam, 2007)

Benchmarking can be applied to a wide range of activities within an organisation but the purpose and effectiveness of usage may differ between companies or firms. As a result of its various areas of application, benchmarking has a number of terminologies. The most widely adopted accepted terms are that of internal, competitive, functional and generic

benchmarking (Camp, 1995; Hinton *et al.*, 2000; Chen *et al.*, 2008).Many other researchers have expanded upon these four main categories of benchmarking to include "result and Process" benchmarking, "problem-based" and "process-based" benchmarking, compulsory and voluntary benchmarking and strategic and operational benchmarking (Trosa and Williams, 1996; Camp, 1995; Helgason, 1997; Bowerman *et al.*, 2002). Other terminologies also exist which include lateral benchmarking, implicit benchmarking and co-operative benchmarking. In their studies they concluded that the multiplication of terminologies is of no value since it does not assist to "understand the purposes held for benchmarking".

It was observed from a previous study conducted by Holloway *et al* (1999) that many firms or companies preferred competitive type of benchmarking. The findings showed that the percentage of companies using each of the four main benchmarking types varies thus: Internal benchmarking 25%, Competitive benchmarking 42%, functional benchmarking 25%, and Generic benchmarking 8%. From this result, it shows that competitive benchmarking is the most widely used type while generic benchmarking is the least used type. Straker (2006) concluded that "when looking to improve, companies will naturally look to their competitors to attempt to close the performance gap".

(i) Internal benchmarking: Internal benchmarking is "where a firm aims towards identifying improvement areas within the structure through comparing its business operations with those of others who do it better, thereby setting new targets to meet (Sherif, 1996).

Harris and McCaffer (2001) explained internal benchmarking as comparing a firm business and management processes against similar internal units in the same organization. Furthermore, internal benchmarking occurs when a firm benchmarks against similar operations within the firms. Internal benchmarking assumes that "there are different work

practices within different parts of an organization and that some sections practices may be more efficient and effective than others (Straker, 2006). Internal benchmarking can be of immense value in large companies performing similar work in different sites or locations. Increased performance could be achieved by using internal benchmarking as a means of identifying areas of potential improvement. Internal Benchmarkinglooks for associates from within the same company. The main benefits of internal benchmarking are that sensitive data and information are more accessible, general data is readily available, and less time and resources are needed.

Internal benchmarking has other internal advantages which include documentation of company "own processes." This serves as benchmarking for any future analysis that may be carried out on any other type of benchmarking. (Francis, 2003) Also reliable data can be easily generated when internal benchmarking is employed. However, Straker (2006) observed that "practices found within one's own company may not be best practice". Also that "there may be internal problems if certain departments are unwilling to share information and data" because of the desire to maintain lead over other departments.Straker, noticed that it is a difficult exercise to employ a totally objective comparison through internal benchmarking and cultural differences between departments and organizations in different locations.

This type of benchmarking stands for a main stride towards establishing well defined measures and measuring systems within the organization.This is to better understand its own processes, resources and tasks (Sherif, 1996). The main elements of internal benchmarking are shown in Figure 2.9. Internal benchmarking provides useful database and learning experience for organisations benchmarking and it also serves as starting point for further benchmarking.

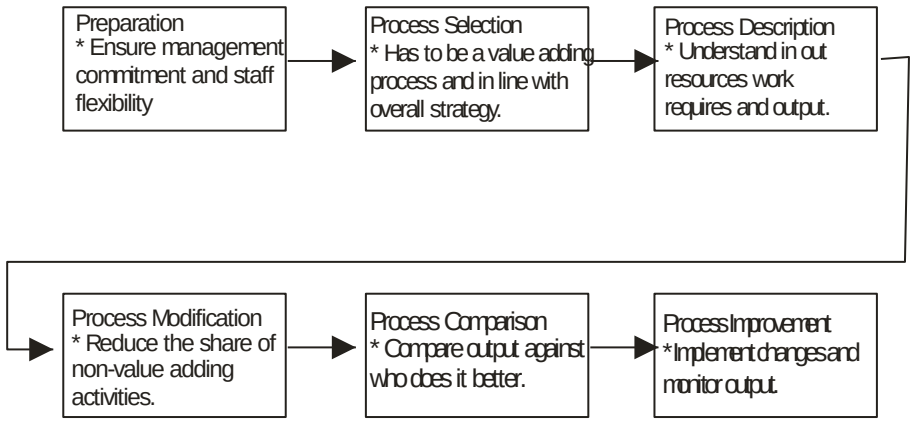

Figure 2.9 Main elements of internal Benchmarking
(Source: Sherif, 1996).

(ii) Competitive Benchmarking: Competitive benchmarking is benchmarking which is "concerned with the selection and implementation of managerial and technological breakthroughs, developed by other industries to generate significant improvement in construction productivity (Sherif 1996). Comparison in this case is among the rival firms operating in different environments with the main aim of achieving best practices. This is done principally by measuring proficiency against "quality of production, productivity, cost level, safety and delivery tune criteria" (Harris and McCaffer 2001).

Competitive benchmarking is when production or production processes are benchmarked against highest standard of excellence for products, services or processes. Furthermore, it deals with the measurement of a company performance in some key business areas, and then using lessons learnt to make intended improvements in a specific firm (Chinyo and Boyd, 2003). Naturally, any business concern will desire growth and will want to know its place in relation to other competing organisations. Competitive Benchmarkingis used when establishments take into account their positions with respect to performance distinctiveness of essential manufactured goods and services. Benchmarking partners are drawn from the same

segment. Therefore, knowledge of the work practices of other firms will assist to "improve those work practices where performance is low". Competing organisations should learn from one another and share information which may potentially improve performance (Camp, 1995; Straker, 2006).

Benchmarking in a competitive environment requires the identification of the business gap, seeking for betterideas and knowledge from other firms. Francis (2003) noticed a major setback of competitive benchmarking which is the unwillingness of competition to share information which may destroy their leading advantages. The success of competitive benchmarking depends on availability of information, willingness of competitors to release information and cooperation (Zairi and Leonard, 1994 cited in Straker, 2006).

(iii) Functional Benchmarking: Functional Benchmarking is when a company focuses its benchmarking exercise on a single function to improve the operation of that particular function (Straker, 2006). Furthermore, functional benchmarking according to Cox and Thompson (1998) could also mean "comparison of practices of organizations with similar process in the same function but outside the industry. Value based (2011) explains functional benchmarking as benchmarking similar processes within an industry this could involve more number of benchmarking or comparing parties and may also include non-competitors. Functional Benchmarkingis used when establishments seem to benchmark with partners from different business areas of activity in order to find ways of improving like functions or work processes.

(iv) GenericBenchmarking: Generic or parallel industry benchmarking is comparing operations between unrelated industries value based (2011). Generic benchmarking is further described as comparing business processes of organisation regardless of the industry sector to

which they belong" (Kelly, 2008). "With generic benchmarking there is no search for direct comparability, instead an attempt is made to learn from others who have innovative and exemplar processes" (Straker 2006). Process benchmarkingis used when the focal point is on improving detailed significant processes and operations. Associates are sought from best practice establishments that carry out related operations or provide similarservices. Generic benchmarking is employed for the purpose of carrying out comparison of functions or processes of the same production "regardless of industries (Syuhaida and Aminah, 2009). In generic benchmarking, processes are measured and compared against those firms believed to be leaders or have best practices. It helps to identify potential solution to the defined problem statements in an organization by seeking how other companies in other industries have dealt with similar issues. As a matter of fact, generic benchmarking focuses strictly on the process. "The approach is to consider that organisations are run on their processes and that many of these processes must have similar requirements, no matter what type of operation the company performs" (Francis, 2003). Other types of benchmarking are;

(v) Strategic Benchmarking:is used to improve overall performance by examining the long-term strategies and approaches that have enabled great performers to succeed. It involves considering core competencies, developing new products and services; changing the balance of activities; and improving capabilities for dealing with changes in the background environment.

(vi) External Benchmarking:seeks outside organisations that are known to be best in their field. External benchmarking provides the chance to learn from those who are known to be best in class, although it is important to remember that not every best practice solution can be adopted by others.

(vii) International Benchmarking:seeks partners from other countries because the best organisations are located in other parts of the world or there are too few benchmarking partners within the same country to produce valid results.The American Productivity and Quality Center (1993) captures benchmarking as the practice of being humble enough to admit that someone else is better at something, and being wise enough to learn how to match them and even surpass them at it".

The whole essence of benchmarking exercise could be seen in the above definition which comprises the following;

(a) **Measurement,** of self and the benchmarking peers performance extent, both for consideration and for recording improvement.

(b) **Comparison,** of performance extent, procedures, traditions etc

(c) **Learning,** from the benchmarking peers to effect improvements.

(d) **Improvements,** which is the final purpose of benchmarking scrutiny (Andersen *et al.,* 1998).

2.6.11 The Need for Benchmarking

Benchmarking accelerates the need for change in attitude and behaviour in an organisation where it is practiced. It is a mechanism for "improvement and change". Benchmarking helps an organisation to search for industry best practices that will bring about superior performance by examining the performance and practices of other firms (Andersen and Petterson, 1995).

For benchmarking to be successful there must be the need for available data for effective comparison and setting of a baseline. It also requires the provision of realistic and achievable

targets coupled with the appropriate handling of the challenges of operational complacency. The exercise allows for the identification of areas of weakness and indicates what needs to be done to improve. Furthermore, it allows the operatives to visualize the improvement as a strong motivator for change. It can also help create an atmosphere conducive for continuous improvement and changes, and creates a sense of urgency from improvement (Amanda *et al.,* 2011). Apart from the above needs benchmarking exercise has the following benefits to an organisation.

a. *Identify its position with respect to the global market.*
b. *Identify potential areas of growth, raise attentiveness to performance and create a greater openness about strengths and weaknesses.*
c. *Learn new ideas from others and generates confidence in developing and applying new methods.*
d. *Increase productivity and reliability of its operations.*
e. *Identify emerging technologies and practices that are entering their sphere of business.*
f. *Identify weaknesses, which have remained unknown to management.*
g. *Update its goals and reduce cost of operations.*
h. *Provide quality goods and services to customers more quickly (Chinyo and Boyd, 2003).*

2.6.12 Previous Benchmarking Models

Researchers have developed different models of the benchmarking process. There are a number of models describing the different steps that constitute a benchmarking investigation. However, the development of benchmarking model requires simplicity, clarity, emphasis on organisation and planning, customer focus and consistent approach through the organisation. The style should be data, process, people and strategy driven (Camp, 1995).

(a) Camp's Model: Camp (1995) developed a ten step process as shown in Figure 2.10, grouped into four phases of planning, analysis, integration and action.The first phase consists of three steps mainly, identification of benchmark partner, determination of data collection method and collection of data. The second phase has two steps which are determination of

competitive gap and project future performance. The third phase contains two steps of communicating the result and establishing functional goals while the last phase has three steps, which involve developing action plans, implementing plans and monitoring results, and 'recalibrate" benchmarks.

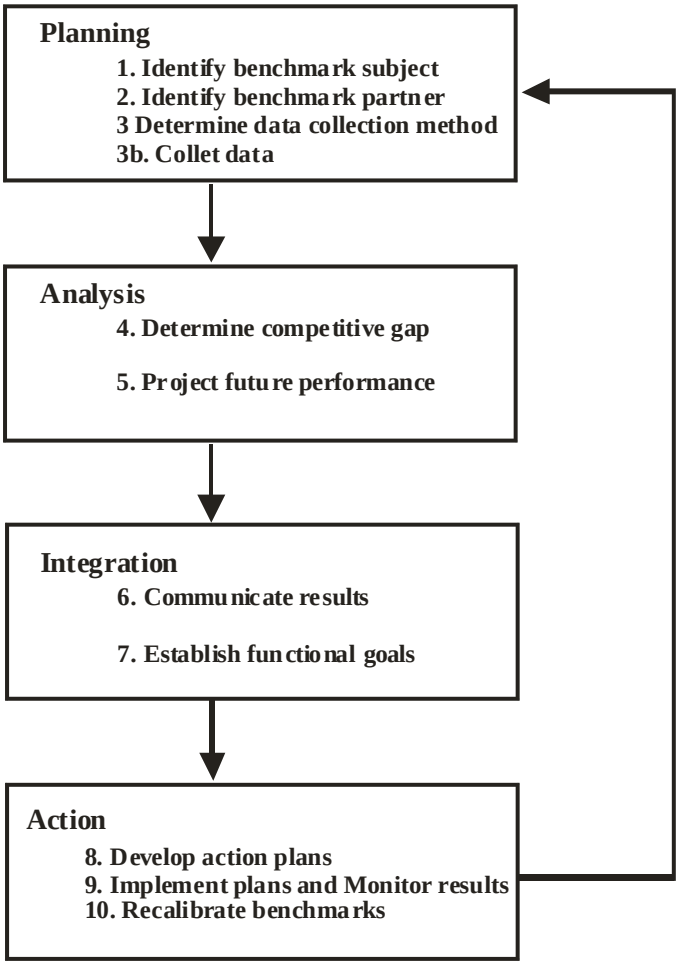

Figure 2:10 Camp's Ten Steps benchmarking Process
(Source: Camp, 1995)

In the ten steps process, Camp allocated three steps to the first phase which involves what to benchmark, who to benchmark and sourcing for benchmarking data. For an organisation to be able to carry out a successful benchmarking, it must establish well defined measures and measuring systems within the organization so as to understand its own procedures, resources and tasks (Sherif, 1996).Although camp's model may contain ten steps, other models have

fewer steps. According to Bhutta and Hug (1999) the number of steps is not imperative provided that a "Simple, logical sequence of activity is followed". However, Straker (2006) suggested that heavy emphasis should be placed on planning and organisation. The last step of camp's process is recalibrating". It contains the process of adaptation of benchmarking principles within the organisation and the application of this principle for continuous improvements purposes. This is the ultimate purpose of benchmarking.

(b) Andersen's Model: The conduct of benchmarking investigation may be slightly different from one project to the other, but the underlying principle and objective of improving the organizations business processes remain the same (Andersen *et al.*, 1998). Andersen (1995) developed a model called benchmarking wheel as shown in Figure 2.11

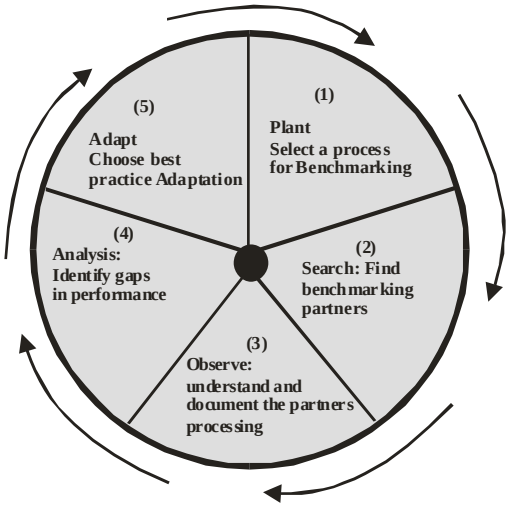

Figure 2.11 Andersen's benchmarking wheel
(Source: Andersen, 1995)

Andersen's model has five phases, each phase covering a natural part of the benchmarking investigation. The phases are planning, searching observing, analysing and adapting. In Andersen's five phased model, planning comprises the identification of essential success

factors and choosing a process for benchmarking. Further analysis of this phase showed that it contains recording the process and working out the operational measures. Phases two and three contain one item of activity each,which are searching for benchmarking partners and recording of observation made on the operation of partners respectively. The fourth part of the benchmarking wheel identifies gaps in performance while the fifth phase is all about implementation.

A close examination of the two models discussed above shows that they have certain common characteristics except for the emphasis given to searching and observation of benchmarking partners in the model of Andersen (1995). These were not highlighted as major steps in the benchmarking process of Camp's but as components of the first phase. Communicating the benchmarking results to all the operatives in the organization helps in achieving "support, commitment" and sense of belonging (Ahuja, Yang and Shankar, 2010). The aspects of communication and commitment were not stressed in Andersen's model.

(c)<u>Spendolini Model:</u> Spendolini (1992) proposed a five step model which are stated thus (see Figure 2.12)

i. Determine what to benchmark
ii. Form a benchmarking team
iii. Identify benchmarking partners
iv. Collect and analysis benchmarking
v. Take action

In Spendolini's model he allocated the forming of benchmarking team to stage two. This is important at planning stage, so that team members are given roles and responsibilities without any ambiguity on the objective of the task at hand (Straker, 2006). Knowledge of

benchmarking principles was pointed out as one of the key conditions for the selection of team members at both ends of the organisations (Holloway *et al.,* 1998). In camp's and Andersen's models, this aspect of forming benchmarking team was not stressed. In the study conducted (Vasilash, 1994 cited in Straker, 2006) it was recommended that two or three was the optimum number of persons to undertake benchmarking investigation depending on the complexity of the task.

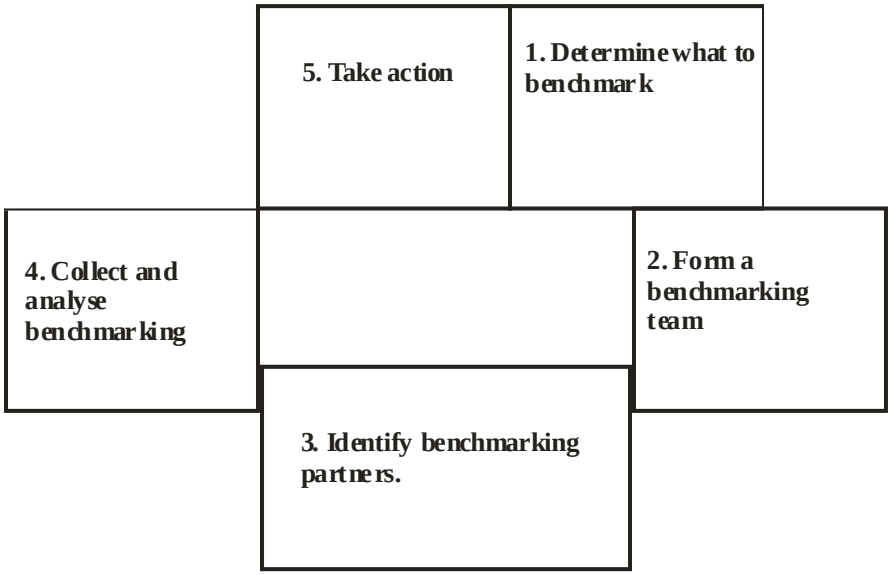

Figure 2.12. The five Steps of benchmarking Process
(Source: Spendolini, 1992)

(d) Love and Smith Model: Love and smith (2003) developed a three-phase approach of benchmarking (self assessment of organization against best practice in the industry), bench learning (determining organisational learning approach and benchaction (practical execution of findings through the education of operatives). Although the contents of this three-phase model are found in the models of Camp (1995) and Andersen (1995), it is a compressed benchmarking process.

The benchmarking learning phase which is also referred to as analysis phase, permits the transfer of the benchmarking idea from operational measurement to operational management approach (Costa *et al.*, 2006 cited in Ahuja *et al.*, 2010).

The benchAction phase contains the combination of integration, action and maturity phases which can produce improvement in the construction industry within a "receptive environment". This should be the prerogative of the industry to produce a friendly atmosphere in the industry in an attempt to establish results of the benchAction. Costa *et al* (2006) suggested the formulation of benchmarking associations as forums for individuals to learn from the best practices within domestic "support network". Also such clubs should form the platform for organisations to share their experiences, gaps and methods of operation. This formation of benchmarking clubs is very essential for the purpose of knowledge transfer.

(e) Ahuja, Yang and Shankar's model: Ahuja *et al* (2010) in their study proposed benchmarking process similar to previous studies (Fong *et al.*, 1998 and Love and Smith, 2003) with some modifications as shown in Figure 2.13. The modified process included four phases of

1. Benchmarking and Bench measurement
2. Bench Learning
3. Bench Action
4. Bench Monitoring

The elements of bench measurement and bench monitoring were included in the adapted model. These were not part of Love and Smith's benchmarking process; however the introduction of benchmarking offers the opportunity to evaluate the efficiency of the Organisations in implementing their strategies for the task at hand. In Ahuja *et al.*'s model

the first phase of the benchmarking and bench measurement has three steps comprising, rating of organization, performance measurement and identifications of trends and gaps in practice.

Benchmarking phase incorporates qualitative study of the findings of bench measurement which includes "study gaps in practices and trends identified at the benchmarking stages. Bench learning phase prepares the solution package to surmount the disparity in practice and other identified matter. These deeds form a component part of the bench Action stage. At this point communication at the industry level and firm level is emphasized for effective implementation of the process (Camp, 1995). Ahuja *et al* (2010) suggested ways of communicating benchmarking results as follows:-

a. *At industry level, national bodies should create awareness about the process through forums like seminars and conferences and communicate its importance to the organisation*

b. *Benchmarking clubs should be initiated for interaction between the different organizations*

c. *Formal rating system like ISO certification should be initiated in the industry to increase participation by the organizations.*

d. *At the organization level communication of the benchmarking process results and suggested action to operatives in addition to middle level managers or supervisors is very significant for successful implementation of suggested actions in the organisation* (Ahuja *et al*., 2010).

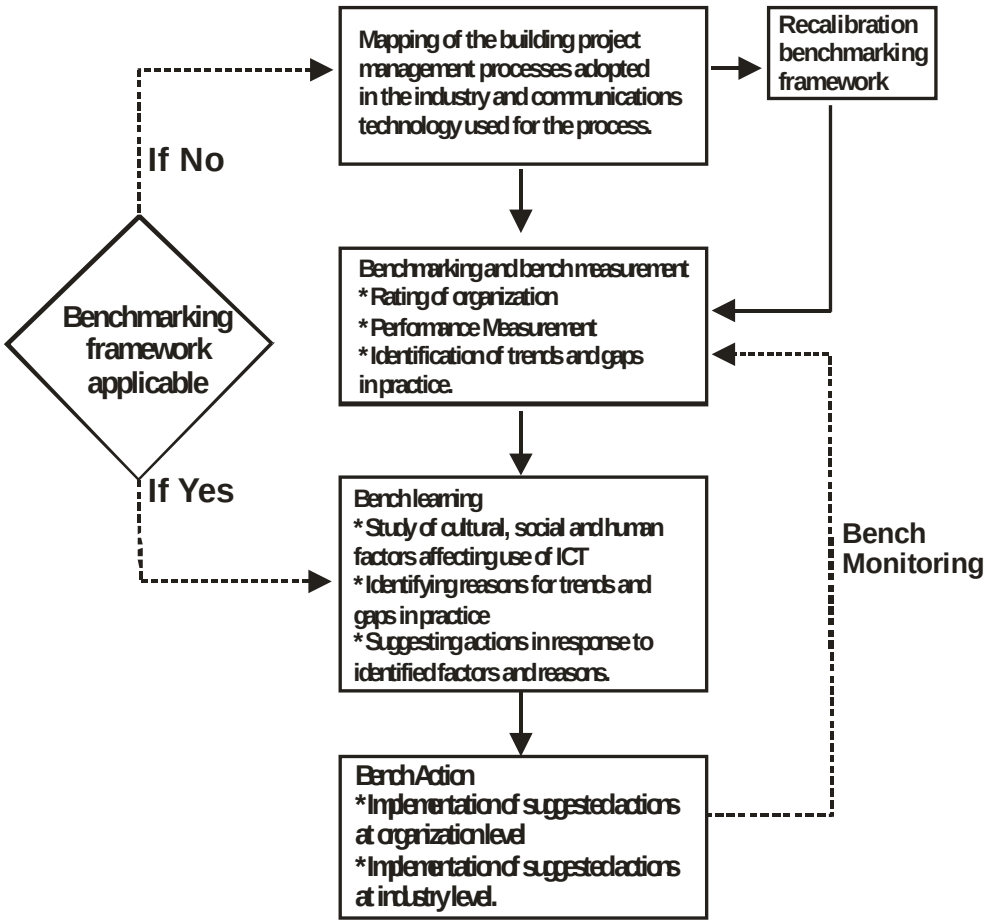

Figure 2.13 Ahuja *et al.'s* Benchmarking Process
(Source: Ahuja *et al.*, 2010)

Bench monitoring is the last flow activity that involves continuous or regular benchmarking and bench measurement exercise. From the model; benchmarking is set in motion after the bench action activity. The model identifies the applicability of existing framework. If framework is valid or relevant the bench learning process is conducted otherwise the project variables (project management process and information technology employed) should lead to recalibration of the benchmarking structure (Figure. 2.13).

"The model developed by Camp, and the subsequent modifications made on the model, has been shown to be the most commonly used of the benchmarking processes" (Straker, 2006).

Camps model has more features than others, which were well highlighted and classified into four phases.Ahuja *et al.*'s model contains four phases with some of the essential features over lapping with camp's model except for the introduction of benchmarking framework applicability in the model which has capacity for periodic review. Holloway *et al* (1998)"reject the notion that there is single best way of developing processes". This means a combination ofprocesses is a possibility from the reason highlightedabove. Therefore, Ahuja *et al.'s* model was adopted in this study with some modifications to accommodate the components of the conceptual benchmarking model of Thomas and Zavrski (1999). The adoption and modification of the model is shown in Figure 2.13.The major feature of the proposed model is the incorporation of analytical metrics to measure reliability of data and performance quantitatively.

Andersen *et al* (1998) classified benchmarking information into quantitative and qualitative. The quantitative data analysis is employed to measure the gap disparities in project execution at operational level while the qualitative data is utilized to create learning information about good or poor performance levels. Holloway *et al* (1998) expressed their preference for quantitative to qualitative measures "due to the ease of measurement and the simplicity of identifying gaps. Although, these measures do not give insights into why the sampled projects performed well or poorly, they give absolute values. The reasons for low or high performance were identified through the use of survey instrument (Enshassi *et al.*,2007). Quantitative values are easily analysed using developed software packages. Recent practiceby researchers is the application of mathematical and statistical" methods to evaluate benchmarking such as scorecard, scatter chart, radar chart and bar chart. (Chen *et al.*, 2008).

A Development of Conceptual Framework for the Study

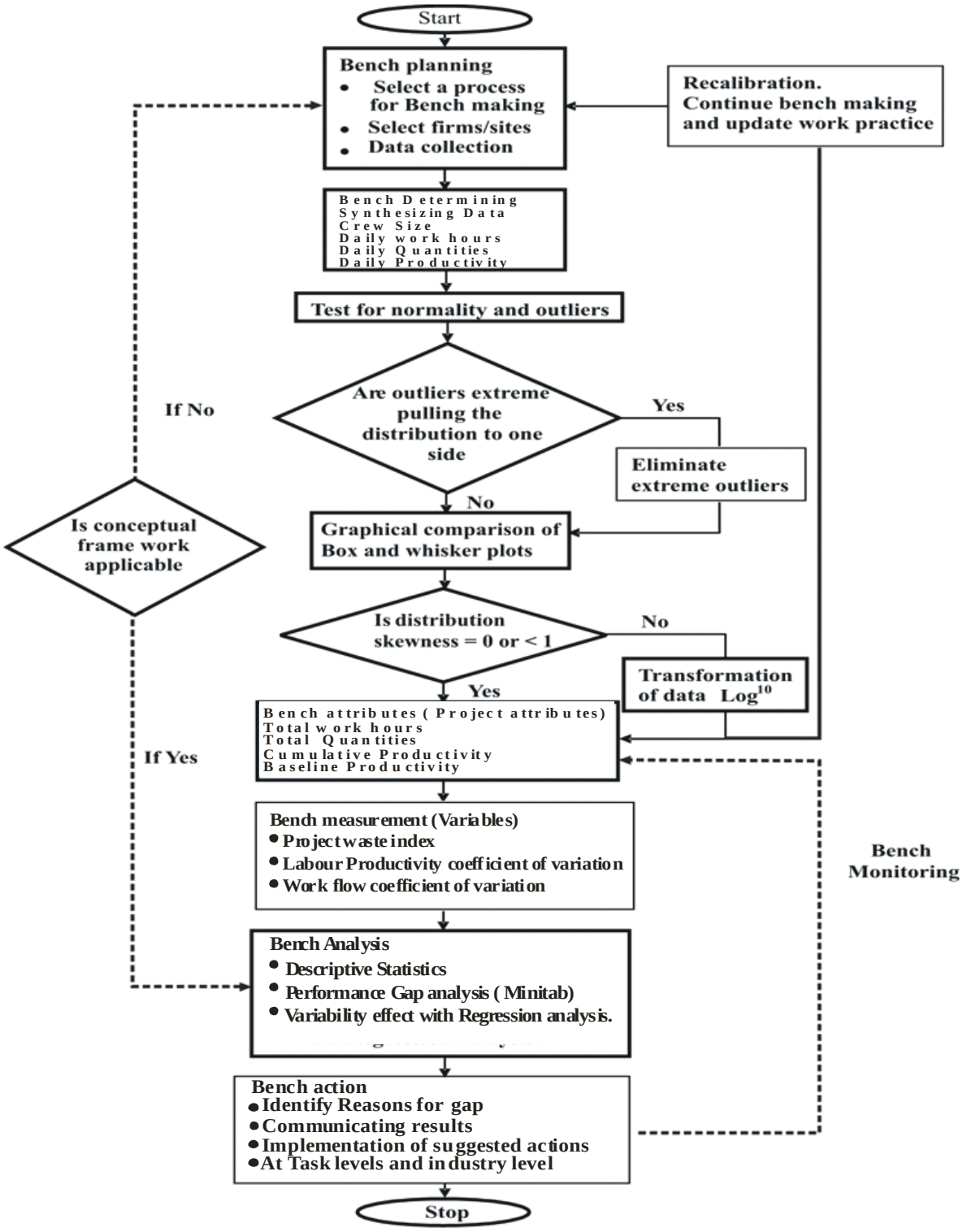

Figure 2.14 Development of a Conceptual Model for the study

2.6.13. Previous Studies on Lean Principles to Construction.

Lean construction is a concept still new to many construction industries in the world. According to Ballard and Howell (2003) countries such as UK, Australia, USA and Brazil have gained significant benefits by the adoption of lean construction concepts.

Ballard (2000) reported an extensive implementation of lean concept which included last planner system and look ahead process – by a contractor handling a laboratory building project for Stanford University. The mean PPC for the period of the study was 71% which compared favourably to work flow reliability achieved through previous application of last planner system to projects.

Senaratne and Wijesiri (2008) identified ten types of flow wastes and eight types of causes of flow wastes, frequently prevalent in the Sri Lankan construction industry. It was observed that a majority of flow wastes and their causes identified were controllable. They concluded that the study proved that lean construction is suitable in Sri Lanka as an option to eliminate waste problems in the construction industry.

"Managing variability and benchmarking of labour productivity are important dimensions of lean thinking"(Abdel – Razek *et al.*,2007). In their study of masonry work in eleven construction sites in Egypt it was observed that there was a strong relationship between variability and performance. The coefficient of variation (CV) of the studied projects ranged from 38.23 to 217.23. Three of the projects had CV values less than 65 while others had CV values greater than 100. The higher the CV the more the project experienced abnormal work day's (variability of daily labour productivity). They concluded that better workflow, better planning and better information, and feedback system are factors thatcould lead to

reducedvariability. The project waste index (PWI) which is indicative of the contribution of project management to the cumulative labour performance on the project was computed. The values ranged from 0.202 to 4.23. Seven of the projects had PWI values greater than 0.5, indicative of poor performance. The study revealed that there were difficulties in managing workforce. The reasons for idle time were due to lack of materials, poor communication and inadequate supervision factors. Some of the projects fell behind scheduled. It was also observed that four of the projects preformed well, with PWI value lower than 0.5. The study also identified good planning and control systems for time, cost and quality, adequate supply of resources and good information and feedback system as factors for the good performance.

Alarcon and Calderon (2003) reported the implementation of changes in the project planning systems, based on lean construction principles using some core concepts developed in the last planner system (LPS) in some selected Chilean construction companies. Their study revealed that within two years of implementation the average PPC measures increased from initial measures of 50% to 64%. The main causes for non-completion were detected during implementation. The lessons learned from this analysis and its corresponding corrective action provided continuous improvement capabilities to the system. Furthermore, with the introduction of 'plan control',computer support systems developed by (choo *et al* cited in Alarcon and Calderon, 2003), the PPC rose to a significant level of about 70% average.

Enshassi *et al* (2007) studied the measurement of masonry labour productivity for nine project sites in Gaza strip, Palestine using a consistent benchmarking approach. The project waste indices were computed for the nine projects which is a reflection of the contribution of the project management to the cumulative labour performance on the projects. According to Thomas *et al* (1999a), the lower the project waste index (PWI) value, the better is the project

management's influence on overall performance. The PWI values computed for the project studied ranged from 0.1002 to 0.7928. It was observed that six of the projects had PWI values lower than 0.4 which is an indication of good performance, while two of the projects had PI value of 0.79 and 0.61 which showed poor performance. The poor performance was due to lack of resource availability together with improper planning and lack of following procedures factors (continuous improvement mechanism).

2.6.14 Synopsis on the above review

A survey of the literature revealed several primary contributions to the theory and practice of lean production principles. Some of the researches provided encouragement for this dissertation. In construction the application of lean production model stems from the discussion of Koskela's research (1992), which emphasized the importance of the production processes flow, as well as aspects related to converting inputs into finished products as an important element to the creation of value over the life of the project. Many other researchers(Ballard and Howell, 1998; Alarcon and Calderon, 2003; Bertelsen, 2004; Salem *et al.*, 2005) have expanded this concept and provided evidence of it applicability in the construction industry. The pioneering work of Koskela (1992) opened up streams of researches into lean construction principles. The core lean concepts were identified and translated from the manufacturing production management into construction language (Shingo, 1984; Koskela, 1992, 1993; Ballard and Howell, 1994a). To operate these core concepts in the construction industry a new set of management techniques were developed (Paez *el al.*, 2005). The last planner system of production control was introduced in 1992 but developed by Ballard, and Howell (1994b). In the application of these tools, previous researches revealed substantial improvement in productivity for those who improved plan reliability to the 70% level. Howell and Ballard (1994)studieson the last planner technique

showed that the use of formal and flexible production planning procedures is the first step to keep the production environment stable. The technique emphasizes the use of daily production plans, constrains analyses, Look ahead and percentage of planned and completed items. Thomas *etal* (2002) asserted that, with the last planning technique, the percentage planned tasks (PPC) is measured to show changes in planning reliability. However, they argued the extent to which a larger PPC improves project performance. According to them, there is limited evidence showing that productivity performance for crews with a PPC above 50% is 35% better than that of crews with a PPC below 50%. This remains unclear. Also while these techniques have proven useful, El Mashaleh *et al*(2001)believed that their application has no methodology that could relate the activity and project level accomplishment to firm's accomplishment.

Abdel – Razek *et al* (2007) suggested that better labour and cost performance can be achieved by reducing variability and measuring benchmarking. However, all the previous studies on benchmarking were done on non homogenous projects (Thomas and Zavrski, 1999; Abdel – Razek *et al* (2007; Enshassi *et al.*,2007). Thomas and Zavrski, 1999a and1999b, developed the framework for international labour productivity benchmarks of selected construction activities. The application of these benchmarks can lead to evaluating the labour productivity and identifying the best and worst performing projects. Therefore, from these series of inferences it could be said that the exploration of improving construction labour performance in Nigeria by applying two lean construction principles, namely benchmarking and reducing variability is a possibility.

2.7 DETERMINATION OF PROJECT BENCHMARKING ATTRIBUTES

2.7.1 Project Characteristics

Thomas *et al* (2002) and Thomas and Zavrski (1999b), explain the project characteristics as follows.

Total Work hours: Total Work hours are the summation of daily work hours in each project.

Total Quantities: Total quantities are the summation of daily quantities in each project.

Cumulative Productivity (whr/m^2): Total work hours (whr) over Total quantities (m^2).

Baseline Productivity: The baseline productivity is the best implementation a contractor can achieve for a particularproject.In other words, it is the best and most consistent productivity that the contractor achieved on a project.

Number of Abnormal Workdays: -According to Thomas and Zavrski(1999b) the indiscriminatechangeability in daily productivity figures when there are no disruptions is about twice the baseline productivity. Figures exceeding this boundary are usually the effect of transferable causes resulting from disruptions. An important measure of performance is the number of abnormal or disrupted days.

2.7.2 Project performance parameters (benchmarks)

2.7.2.1 Disruption Index

The first measure of labour performance (benchmarks) is the disruption index (D1). It is the ratio of the number of disruption workdays divided by the total number of observed workdays (Thomas and Zavrski, 1996; Enshassi *et al.,* 2007).

2.7.2.2 Performance Ratio (PR)

The performance ratio (PR) is the actual cumulative productivity divided by the expected baseline productivity (average values of baseline of all projects) Abdel – Razek *et al.,* 2007).

2.7.3 Performance

The word performance is the umbrella term of excellence and includes profitability and productivity as well as other non-cost factors such as quality, speed, cost, dependability and flexibility.(Tangen, 2005).The performance of any construction firm as an organisation is a function of the individual's performance. This is based on the assumption that the individual effort is tailored towards achieving the company's objectives. "In other words, that is what makes up a development in individual's performance has a multiplier effect in the firm's general performance" (Lema, 1996).

2.7.4 Profitability

Profitability has been defined as keystone of performance measurement systems with respect to corporate performance (Lema, 1996). But relating to improvement purposes, profitability does not have a direct impact on performance. Profitability is explained as the fruit of the actions and processes in operations. "It helps to identify the effects of monetary elements like inflation, price changes and currency effects and distinguishes them from true performance and productivity change" (Grunberg, 2004).

Profitability therefore can be defined as the ratio between revenue and cost. It is expressed mathematically by Bernolak (1997) cited in Grunberg(2004) as;

$$\frac{OutputVolume \times OutputUnitPrice}{InputVolume \times InputUnitCost} \quad \text{.... eq 2.10}$$

Tangen(2005) further defined profitability as the ratio between profit and assets. This is the overriding goal for the success and growth of any business. Tangen (2005) however cautioned that an increased productivity does not necessarily lead to increased profitability. He suggested that organizations should combine productivity and profitability ratios so that the true reasons for increased profits become clearer.

Profitability factor has been identified generally as outcome of what happened in a production process. This factor cannot fully explain what happened in the process in order to form a basis for future actions (Lema, 1996). This is viewed as a limitation by some researchers when financial indicator is employed as performance measurement.

2.7.5 Efficiency and Effectiveness

There is a link between the terms efficiency, effectiveness and productivity (Petersson, 2000 cited in Grunberg, 2004).Effectiveness is often described simply as "doing the right things, "while efficiency represents "doing things right" which means that efficiency centers on input and transformation process. Therefore, efficiency is defined as the ratio between resources expected to be consumed and actually consumed while effectiveness affects the output of the productivity ratio which could be defined as the ratio between actual output and expected output (Sink and Tuttle, 1989).

Effectiveness stands for the degree to which desired results are achieved; efficiency represents how well the resources of the transformation process are utilized. The interrelationship existing among the terms performance, profitability and productivity (PPP)

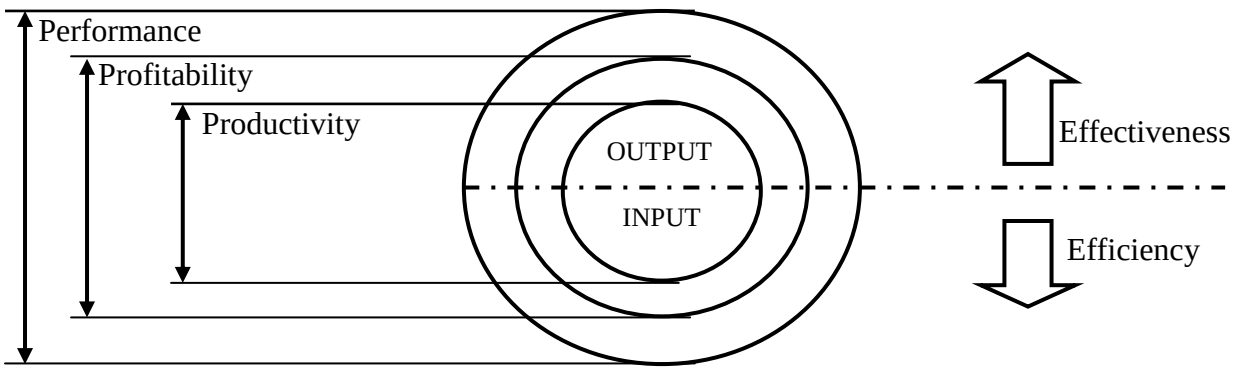

Figure 2.15: The Triple 'P' Model Relationship between the terms Performance, Profitability Productivity, Effectiveness and Efficiency.
Source: Tangen, 2005.

is well explained by Tangen's, 2005 Triple P-Model shown in Figure 2.15

2.7.6 Performance measurement

Construction jobsite performance can be measured in thatperformance measurement in any organisation is based on the assumption that there is a standard against which comparison can be made, this benchmark could be internally and externally based.Performance measurement has been described as the process of quantifying the efficiency and effectiveness of actions. "For a performance measurement system to be regarded as a useful management process it should act as a meansthat enables assessment to be made, provides useful information and detects problem, allows judgment against certain predetermined criteria to be performed and more importantly, the systems should be reviewed and updated as an ongoing process."(Benon and Milton, 2010).

Regular assessment of performance in an organization helps management with invaluable information to guide in decision making. The importance of regular performance assessment cannot be overemphasized. The exercise makes management to be competent, transforms average site managers to performers and supplies management with the better information on which right decisions and actions are taken. According to Alfeld (1988)contractors performance has two aspects, firstly accomplishment and secondly, method employed to accomplish the task.

Accomplishment here represents finished work of value to the job while method describes how the work was done for instance, the total member of blocks laid is an accomplishment; the number of labour man-hours represents the method. Therefore, performance can be defined as the ratio of accomplishment to methods.

It is also expressed as;

$$Performance = \frac{Accomplishment}{Methods} (2.11)$$

$$Performance = \frac{QTY\ (Value)}{Manhours\ (Cost)} = \frac{Output}{Input} \quad (2.12)$$

The above performance ratio reveals to us that a contractor can raise his competence by increasing the value of accomplishments while reducing the amount of time, energy and money spent on methods. Therefore "worthy performance occurs when the value of the accomplishment exceeds the cost of the method" (Alfeld, 1988). This means that contractors improve on their performance by investing resources in reducing the cost of the labour input (methods) required to accomplish a given tasks. The measurement of accomplishment helps to identify deficiencies in work methods. Construction performance is improved by management if such deficiencies are corrected. The definition of performance here is similar to that of productivity. This is explained by the Triple P model in Figure 2.14 that performance, productivity and profitability can all be expressed as ratios of output and input.

However, performance engineering defines productivity in a narrower context of jobsite labour man hours divided by quantity of work produced which is an important and very useful measurement of jobsite performance. This is a measure of only one performance dimension. Alfeld (1988), suggested that performance measurement should be related to a baseline or exemplar performance. This assertion was corroborated by Thomas and Zavrski (1999a), 1999b) and Enshassi *et al*(2007) that performance should be measured in relation to baseline productivity.

Lean concept identifies project management index (PMI) or project waste index as a useful tool to measure jobsite performance. According to Thomas and Zarrski, 1999a and 1999b, and Abdel Hamid*et al* (2004), PMI (Performance) is expressed mathematically thus:

$$PMI(Performance) = \frac{CumulativeProductivity - BaselineProductivity}{Expected\ Baseline\ Productivity} \quad (2.13)$$

This is defined as the ratio of the difference between the cumulative productivity and Baseline Productivity over expected Baseline Productivity. This is further discussed in thefollowing section.

2.7.7 Project Management Index (PMI): The project management index, sometime referred to as project waste index (PWI) is a dimensionless parameter that reflects the influence that project management has on the cumulative labour operations. It is expressed as the ratio of the difference between the cumulative productivity and baseline productivity over expected baseline productivity (Thomas and Zavrski, 1999a and 1999b). According to Abdel – Razek *et al*(2007) PMI is a measure of the difference between the actual and baseline productivity, it provides a measure of the impact of poor material, equipment and information flows, and inadequate planning. This makes it a measure of waste, which is one of the issues being addressed by lean construction. Reduced waste can lead to better flow and productivity. The lower the PMI value the better is the project management's influence on overall operation (Thomas and Zavrski, 1999b). Mathematically, the PMI eliminates the productivity influence of complex design.

2.7.8 Reduce Variability in Labour Productivity: Thomas *et al* (2002) stated that different strategies for managing construction variability emerge from lean thinking. Some

focus on reducing work flow variability with the intention of improving project performance by increasing throughput.While others employ the strategy of capacity management that is, using flexibility in responding to variability which has the capacity to improve operation by permitting rapid changes as needed. Thomas and Zavrski (1999b) concluded in their study that the variability in daily labour productivity is highly correlated to project performance. Also that variability in productivity appears to be a good determinant of good and poorly performing project. Thus the goal of lean construction as stated by Thomas and Zavrski (1999b) should be to improve performance by reducing variability in labour productivity. This variability in the daily labour productivity should be computed using the developed mathematical equations byThomas and Zavrski (1999a) discussed in chapter three.

2.7.9 Variability in Construction

All construction works experience variability or changeability at varying degrees. It is common even to a well managed construction project. It is universally believed by researchers as an inhibitor of performance. Variability can induce fluctuating and unexpected condition making objectives unstable and obscuring the means to achieve them(Thomas *etal.*,2002).

Variability in the management of construction work can be caused due to ineffective site supervision and other factors affecting site productivity (Abdel Razek *etal.*, 2007). It is also believed that the nature of a project, shortcoming of management to predict and establish effective defensive actions could induce various degrees of variability on a construction project.

Managing changeability on a construction project is a significant aspect of lean production management. Thomas *etal* (2002) believed in flexible capacity management as a tool to

manage variability because of its essential capability and receptiveness under varying situations.Productive variability in construction project isprincipally of two types,work flow variability and labour productivity variability. Both are seen by researchers as impeding system performance.

Horman and Kenley (1998) cited in Thomas *etal*(2002) asserted that the ability to reduce cycle time by the application of capacity management will improve flow reliability eliminate waste and simplify operations (which is the flexible approach to labour and resource management).

CHAPTER 3

RESEARCH METHODOLOGY

3.1. INTRODUCTION

The purpose of this introduction is to clarify the issues being addressed in this chapter. The research involves quantitative method of investigation. This chapter starts with a discussion on the research design which has two sections (i) Researchsurvey techniquewas discussed (ii) Research On-Site ProductivityData Collection – here issues bordering on the research process were addressed. Also a description of the research methods comprising two parts of data collection and analysis is presented.

Lastly in this chapter, a report of the pilot study conducted was presented which contains issues on choice of building trades, site characteristics, methods of data collection on the inputs and outputs, preliminary analysis and results of data collected and validity of instrument used in the research.

3.2. RESEARCH STRATEGIES

According to Hughes, (1994), "research studies in construction management differ significantly from other disciplines since the latter is not an academic discipline in its own right, with its own research techniques and theories, but rather builds upon theoretical models developed elsewhere in the Social Sciences". As such, the doctoral researcher must be able to decide upon the research methodology and formulate the adopted research strategy in such a way, so as to be in accordance with the aims and objectives of the study while at the same

time, ensuring an original contribution to an existing body of knowledge (Grix, 2001). In addition, irrespective of the adopted approach and the innovative characteristics, every scholarly endeavour must be conducted with a framework which is directed towards the achievement of validity and reliability for the results and conclusion emerging from the study, Lucko and Rojas (2010) cited in Panas and Pantouvakis (2010).The research strategy used for this thesis was carefully selected in line with the accomplishment of the researchobjectives and questions.

3.2.1Research Survey Technique

In order to answer the research question 1,the research strategy that lent itself to the investigation of this research question was the survey research. Surveys are classified according to their focus and scope. The focus in this research was to target stakeholders in construction management matters, therefore sampled survey was appropriate, which is a survey that studies only a portion of the population. The next task was to construct the instrument used to gather the data from the sample. Two options were available for use – interviews and questionnaire. Each has two options, thus providing different approaches to collecting data: (1) Personal interview (2) Telephone interview (3) Mailed questionnaire (4) Directly administered questionnaire. For the purpose of research question 1, directly administered questionnaire approachwas employed. This technique has high response rate (Anikweze, 2009). Also the survey was targeted at a group of people assembled at a place for a specific purpose e.g.construction sites and firms. Research questions 2, 3 and 4 were answered by using instrument for quantitative data gathering. The process is described in section 3.4.1.

3.3. RESEARCH METHODS

3.3.1. Method of Data Collection

A survey questionnaire was designed to gather data to address the researchquestion1 which is on significant factors affecting productivity. The two options available were; open- ended questions and closed – ended questions. The closed–ended option was adopted for this research in order to avoid the difficulty of coding and quantification inherent with open ended response questionnaire. Furthermore,the closed–ended alternative facilitates data analysis, estimation of validity and reliability indices for the instrument and is easier for the respondent to fill and demand less time to complete (Mogbo, 2003 and Donald *et al.,* 2002). The questionnaire was therefore structured, with fixed questions for the respondents to indicate to what extent a critical factor affects labour productivity. The questionnaires have two sections, the first section relates to the identification of the respondent while the second section boarders on the information on the critical factorsof labour productivity(Appendix I).

*3.3.1.2*On-Site Productivity*Data Collection*

The quantitative data for on-site productivity study was collected onselected building trades (blocks, concrete, wall plastering, wall tiling and floor tiling) for all the projects sampled. The research procedures involved the engagement of research assistants, trained on how to observe the workman and record observations in terms of input and output.

Data collection covers masonry block work, concreting, plastering and tiling activities in not less than 61 live projects for each of the trades from building contractors within the study area (Abuja). Daily visit method of observation of labour productivity was adopted. This involved personal observation of labour activities on cement based works on live projects. The strategy here was to visit the site daily and interact with the foreman and workers in order to record the dates, number of workers, starting time, closing time and measurement of

length/breadth of work done (quantities) of each worker. Entries were made on research instrument collection sheet designed for this purpose (See AppendixII). The values collected were analysed using lean benchmarking approach of calculating performance using Thomas *et al* (1999) mathematical model.

Ballard (2000) identified the problem of making the "worse appear better" which sometimes is associated with productivity studies. This is a situation where workers on site give false impression of commitment when being observed by researchers. This kind of attitude has the propensity to influence the research data. However, he suggested that the workmen should be convinced that the observation is not a measure of individual but of system performance. Mogbo (2003) took an exception to Ballard's suggestion. In order to prevail over the "Hawthorne" effect Mogbo suggested that the observer may ignore initial observations. This is because with time the group returns to its normal way of doing things having overcome the influence of the presence of the observer.

3.3.2 Population of the Study and Sampling Technique

Factors that restrain true random sampling in investigating research in the local indigenous business have been identified in literature (Olugbeoyega, 1995). One major setback is the non existence of comprehensive list of contractors and their current site locations which could aid the development of precise sampling frames. The Federal Ministry of Works has stopped registering contractors into different categories since 2007; this is in compliance with the Public Procurement Act, 2007. Where such list exists most of the contractors are not traceable. Another factor found to hinder accurate sampling is the unwillingness of prospective respondents. In this study only contractors actively involved in the construction of single storey buildings and willing to be part of the benchmarking club were selected for the study (purposive sampling).

The only available list to the researcher is the list of registered real estate developers. In the FCT there are 401 registered members (REDAN Office 2012). There were other contractors who registered with the main developers who were also undertaking construction works. The developers (builders) were involved in different types of construction activities such as mass housing projects of bungalow category, storey building housing projects and infrastructures. At the time of collecting samples some of the developers were not having projects at hand.In order to meet the objectives of the study the research samples were drawn from contractors constructing single storey buildings. The research team was allowed access into two hundred and forty four (244) construction sites, randomlydrawn from the available list of developers, to collect samples that is, from those that willingly accepted the request for data collection. This amounted to about 61 firms or sites for each of the trade investigated.A total of 3477 observations were obtained for all cement based activities from these sites thus giving the following breakdown; block work activity 1127, concrete work activity 778, wall plastering work 835 and floor tiling activity 737 observations.At the time of data gathering, it was observed that most of the firms were executing projects at various levels of completion.

The project locations were scattered all over Abuja principally in the phase 2 and phase 3 development areas were construction works relevant to the study were at their zenith. The areas involved are namely, Apo,Galadima,Garki,Gwagwalada,Gwarinpa,Jabi,Jahi,Kabusa,Kado,Kasana, Katampe,Kubua,Kuje,Lifecamp,Lokogoma,Mabushi,Maitama,Wuse,and Wuye.The computation on the adequacy and sufficiency of data points is discussed in section 3.5.7.

3.3.3 Techniques of Data Analysis

3.3.3.1 Importance Index

In order to evaluate the common critical factors affecting labour productivitythe respondents were given five options of levels to choose from, which showed the extent to which each factor affects productivity as follows:

- ☐ 1. AFFECTS WITH LITTLE EXTENT
- ☐ 2. AFFECTS TO SOME EXTENT
- ☐ 3. AFFECTS WITH AVERAGE EXTENT
- ☐ 4. AFFECTS WITH LARGE EXTENT
- ☐ 5. AFFECTS WITH VERY LARGE EXENT

This involved analyzing results (responses) using ordinal Measurement Scale. The agreement scale was assigned with numbers ranging from 1 to 5 from which the respondents were asked

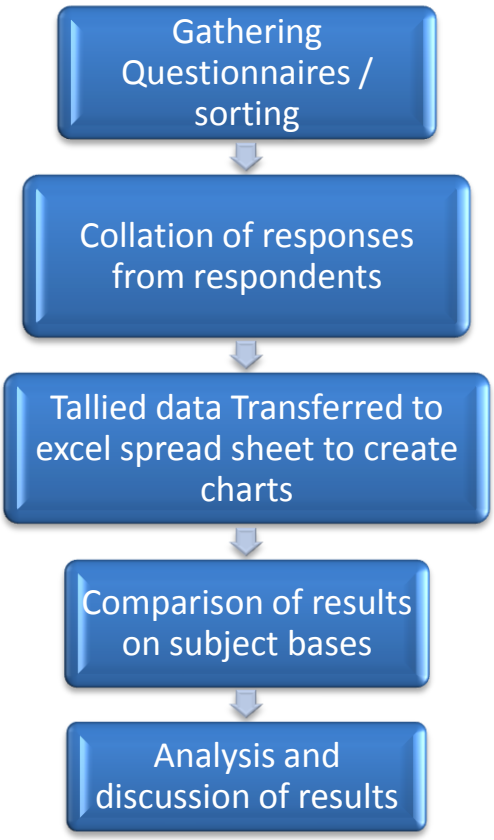

Figure. 3.1 Data Gathering and Analysis Flowchart forFactors Identification and Ranking

to rank the factors affecting labour productivity in their firms according to the degree of importance. A response of "affects with little extent" was given a weight of response 1, "affects to some extent" was given a weight of 2, "affects with average extent" was given a weight of 3, "affects with large extent" a weight of 4, and"affects with very large extent" was given the weight of 5. The relative importance index figures were computed for instance, if 100 responses were received of which for a particular productivity factor: 10 responded by "little extent"; 25 responded by "some extent," 15 responded by "average extent," 5 responded by "large extent,"and 45 responded by"very large extent" then the importance index for this factor would be calculated as shown in equation 3.2

For analyzing data by ordinal scale an importance index (I) was used (Enshassi*et al.*, 2007). The indexes were computed by the following equation (Lim and Alum, 1995)

$$Importance\ index = \frac{5n5 + 4n4 + 3n3 + 2n2 + n1}{5(n1 + n2 + n3 + n4 + n5)} * 100 \quad (3.1)$$

Where: n1 = number of respondents who ticked "little effect"

n2 = number of respondents who ticked "some effect"

n3 = number of respondents who ticked "average effect"

n4 = number of respondents who ticked "high effect"

n5 = number of respondents who ticked "very high effect"

$$Importance\ index = \frac{5*45 + 4*5 + 3*15 + 2*25 + 10}{5(10 + 25 + 15 + 5 + 45)} * 100 \quad (3.2)$$

$$= 70$$

The above computation gives importance index of 70. The following procedures were employed for analysis and synthesis of the administered questionnaires as in Figure 3.1:

(i) Gathering the documents (questionnaires) and sorting

(ii) Collation of responses from respondents

(iii) Tallied data transferred to Excel spreadsheet to create charts

(iv) Results comparison on subject bases.

(v) Computation and discussion of results.

3.3.3.2 Sample Size for Factors Identification and Ranking

A systematic random sample was used in the selection of firms, using the following formula (Hogg and Tannis, 1997 cited inEnshassi*et al.*, 2007):

$$m = \frac{Z^2 x P^* x (1-P^*)}{\varepsilon^2} \qquad (3.3)$$

$$n = \frac{m}{1 + \frac{m-1}{N}} \qquad (3.4)$$

Where m = sample size of unlimited population

n = sample size of limited population.

Z = the value of 1.96 for a 95% double-tailed probability.

P^* = the extent of variance between the element of population.

ε = maximum error of the point estimate.

$$m = \frac{(1.96)^2 x\ 0.5\ x(1-0.5)}{0.05^2} = 384.16 = 385 \qquad (3.5)$$

$$n = \frac{385}{1 + \frac{385-1}{401}} = 196.6 = 197 \qquad (3.6)$$

Sample size required = 197.

3.3.3.3. Benchmarking characteristics (Thomas et al., 1999 model)

Thomas and Zavrski (1999a), 1999b) expressed the projects attributes in the following forms.

$$\textit{Total work hours} = \sum \textit{Daily work hours} \quad (3.7)$$

$$\textit{Total quantities} = \sum \textit{Daily quantities} \quad (3.8)$$

$$\textit{Cumulative Productivity} = \frac{\textit{Total work done (h)}}{\textit{Total quantity } (m^2)} \quad (3.9)$$

Baseline Productivity: This is defined as the paramount performance a contractor can get from a particular model or design. To compute the baseline productivity values certain laid down steps were applied to the daily productivity figures for each project(Abdel-Hamid *et al.,* 2004 and Enshassi *et al.,* 2007).

1. Establish the figures for workdays that consist 10% of the workdays studied.
2. The number established in one above should be rounded off to the next highest odd number which should not be less than (5) five. This number, n, explains the size of the baseline division.
3. The contents of the baseline division are the n workdays that have the highest daily production or output.
4. The next step is to compute the summation of the work hours and quantities for these n workdays
5. The baseline productivity can now be expressed as the ratio of work hours and the quantities contained in the baseline division.

Number of Abnormal Workdays: This is also referred to as disrupted days. It is mathematical expressed as follows:

$$\textit{Disruption Index (DI)} = \frac{\textit{Number of Abnormal Work Days}}{\sum \textit{Number of Work Days}} \textit{(3.10)}$$

Performance ratio (PR) (Abdel – Humid *et al.*, 2004):

$$\textit{Performance Ratio (PR)} = \frac{\textit{Cumulative Productivity}}{\textit{Expected Baseline Productivity}} \textit{(3.11)}$$

Project Management index (PMI) or Project Waste Index (PWI) According to Abdel-Hamid*et al* (2004); Thomas and Zavrski, (1999a), 1999b) it is expressed as follows:

$$\textit{Project Waste Index (PWI)} = \frac{\textit{Cumulative Productivity - Baseline Productivity}}{\textit{Expected Baseline Productivity}} \textit{(3.12)}$$

Project Waste Index (PWI) has been identified in previous studies as a useful tool to measure performance (Thomas and Zavrski, 1998, 1999).

Variability in Labour Productivity

If n individual values xi in a set of data are represented by the symbols $x1$,$x2$, $x3$ . . . xi . . . xn then the mean $\bar{x}$ and the variance V(x) are given by

$$\bar{x} = \frac{1}{n}\sum x_i \qquad \textbf{(3.13)}$$

$$V(x) = \frac{1}{n}\sum (x - \bar{x})^2 \qquad \textbf{(3.14)}$$

Where $\boldsymbol{V(x)}$ = Productivity variation.

x = ur_{ij} = daily productivity (Unit rate) for workday ion Project j.

$\overline{x}$ = mean = Baseline Productivity.

n = number of workdays on project j.

This is the measurement or evaluation of levels of capacity flexibility in daily labour productivity (Thomas *et al.*, 2002) which is stated thus:

$$\textbf{\textit{Productivity Variation}} = \sqrt{\frac{\sum(ur_{ij} - Baselineproductivity_j)^2}{n}} \quad \textbf{(3.15)}$$

Where urij = daily productivity (Unit rate) for workday i on

Project j; and n = number of workdays on project j.

The coefficient of productivity variation (CPV) for each project is calculated as

$$\textit{Coefficient of productivity variation (CPV)}_j = \frac{PV_j \times 100}{(Baseline\ Productivity_j)} (3.16)$$

Where CPV_j = coefficient of productivity variation for $project_j$. Alternatively it can be computed as a ratio of the standard deviation to the mean.

3.3.3.4 Correlation

(a) Pearson's Product Moment: The product moment correlation coefficient, symbolized r, is the most widely used descriptive statistic of correlation. The technique is adopted when the two variables to be analysed are normally distributed (Anikweze, 2009).

Correlation is a mathematical technique for determining the relation between two sets of scores or data. The formula was developed by Karl Pearson to determine the degree of relationship between variables

$$\mathbf{r} = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{[n\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2]}} \quad \textbf{(3.17)}$$

where r is the Pearson product moment correlation coefficient, n is the number of individuals, $\sum XY$ is the sum of each individuals X times Y value, $\sum X$ is the sum of the scores for one set of measures, $\sum Y$ is the sum of the scores for the others set of measures, $\sum X^2$ is the sum of the squared X scores, and $\sum Y^2$ is the sum of the squared Y scores (Ted et'al 2003).

(b) Biserial Coefficient of Correlation

The Biserial r is designed for the situation in which both variables being correlated are normally distributed but one of the variables has been artificially dichotomized probably as a consequence of the only way in which data could be obtained. The formula for computing Biserial r is based on the principle that with zero correlation, there would be no difference between means for the continuous variable and the larger the difference between means, the larger the correlation (Anikweze, 2009).

$$r_b = \frac{M_{P-M_q}}{\sigma t} X \frac{pq}{y} \qquad \textbf{(3.18)}$$

where r_b is the biserial coefficient of correlation,M_p is the mean of X values for the higher group in the dichotomised variable,M_q is the mean of X values for the lower group, P is proportion of cases in the higher group, q is proportion of cases in the lower group, y ordinate of the unit normal distribution and σt is standard deviation of the total sample in the continuously measured variable X.

(c) Spearman's Rho Coefficient Correlation This isan ordinal coefficient of correlation, is used when the data are ranks rather than raw scores. The spearman is calculated by putting the pained ranks into the formula (Donald *et al.,* 2002).

The formula for spearman rho is expressed as (Murray and Larry, 2000)

$$r_{s} = 1 - \frac{6 \sum D^2}{N(N^2 - 1)} \qquad \textbf{(3.19)}$$

Where D denotes the differences between the ranks of corresponding values of X and Y, and where N is the number of pairs of values (X, Y) in the data.

3.3.3.5. Simple Regression Analysis Method

Regression is the statistical model used to predict performance or effect of one variable from another (Ted *et al.,* 2003). Regression analysis could be analyzed as simple regression analysis and multiple regression analyses. To develop a simple prediction model, a large number of data (n=50, with n>100) must be measured and a score on the independent know as predictor variable (X) and the dependent know as criterion variable (Y) are obtained for each. The measured data is replaced with a single line relationship which also can be represented mathematically. The purpose for finding this line relationship is to predict. This predictive tendency makes this analytical method appropriate for this work since the objective of the research is measure the effects of labour productivity variability on the job site performance for all the cement based buildingactivities investigated.

The fundamental concept of a regression analysis is the description of the relationship between two or more variables by computing a straight-line graph through the plotted data.

A two variable linear regression was used for this research, with the following mathematical expression.

$$Y = a + bx$$

Where Y = dependent variables

a = intercept

X= independent variable

b = Coefficient of X

The difference between the actual and the estimated value of Y for each case is called the residual that is the error in prediction and may be represented by the expression.

Residual = $Y - \overline{Y}$

The expression for a and b in equation above is as follows:

$$a = Y - b\overline{X} \qquad (3.20)$$

$$b = \frac{\sum(X-\overline{X})(Y-\overline{Y})}{\sum(X-\overline{X})^2} \quad (3.21)$$

Where X and $\ddot{Y}$ are the arithmetic means of the X and Y variables respectively.

Standard Error of Estimate and Prediction Accuracy

In order to evaluate the accuracy of the prediction equation or, equivalently, to determine the amount of prediction error associated with the predictions, it will be necessary to continue one or more of the statistics that reflect the average size of residuals. The R-Square statistic or its complement (1-R^2) indicates proportion of variation explained and unexplained, respectively. To base an assessment of prediction accuracy upon the absolute amount of explained or unexplained variation, standard error of estimate (S_{EE}) is used which is simply the standard deviation of actual Y values from the predicted Y values. It is expressed thus.

$$S_{EE} = \sqrt{\sum \frac{(Y-\bar{y})^2}{N-2}} \quad (3.22)$$

$$= \sqrt{\frac{SS_{res}}{N-2}} \quad (3.23)$$

whereSS_{res} is the residual sum of squares.

Significance Test for B

The significance of B can be tested either by examining the confidence interval or more conveniently, by evaluating the F ratio

$$F = \frac{\sum(Y-\bar{y})^2/_1}{\sum(Y-\bar{y})^2/_{(N-2)}} \quad (3.24)$$

$$\frac{SS_{reg}}{SS_{res}/_{(N-2)}} \quad (3.25)$$

where SS_{reg} is the regression sum of squares

Calculation of the sample coefficient of determination

The Coefficient of determination (R-square) may be interpreted as the percentage of variation in the dependent variable Y that has been accounted for or "explained" by the relationship between Y and X expressed in the regression line. Hence, it is a measure of the degree of association or correlation between the two variables Y and X. it is expressed thus:

$$R^2 = \frac{a\sum Y + b\sum XY - n\bar{Y}^2}{\sum Y^2 - n\bar{Y}^2} \qquad (3.26)$$

Therefore, from the above equation, the coefficient of correlation, which is the Multiple R can easily be estimated by computing the square root of the coefficient of determination, which is:

$$R = \sqrt{R^2} \qquad (3.27)$$

This value could be positive or negative indicating a direction of relationship that is either direct or inverse in nature.

3.3.3.6 Multiple Regression Method

Multiple Regression:- It is believed that using a single measure X is usually not very accurate for predicting a person's score on measure Y. Therefore, multiple regression model allows the researcher to predict score Y using several X scores. A multiple regression equation will have one intercept and several coefficients (bs) one for each independent variable. The general formula or equation is thus;

$$Y^I = b_1X_1 + b_2X_2 + b_3X_3 + c \qquad (3.28)$$

whereX_1 and X_2 are two independent variables and Y being the dependent variable, and c is the constant.

Multiple regression analysisis used "when the researcher has one dependentvariable which is presumed to be a function of two or more independent variables. The objective ofthis analysis

is to make a prediction about the dependent variable based on its covariance with all theconcerned independent variables" (Kothari, 2004).

Multiple regression analysisis required in this work to test the combined effect of construction output andlabour productivity on jobsite labour performance.

3.4 THE PILOT STUDY

Pilot studies were carried out to ensure the validation exercise and importance of the questionnaire to respondents. The research instruments were shown to mysupervisorsfor their input and vetting.Areas of improvement were in terms of its set-up anddesign, the question formulation, wordings and the overall content. Based on theircritique, modifications were madeto remove any vagueness andinconsistencies and the pilot study was conducted,based on the improved instrument in order to validate it. The draft questionnaire was revised to include the suggestions of these participants. In short, the questionnaire was validated through this process and provided the author with improvement opportunities before launching the main survey.

3.4.1 The Construction Sites for Pilot Study.

3.4.1.1 Characteristics of construction Location and site Trades Men

The sites chosen for the pilot study were single storey buildings under construction. A total of thirty building sites were selected for the study and permission sought from the contractors site supervisors. The buildings have varied floor areas ranging from approximately 240.56m^2 to 596.67m^2. Majority of the buildings sampled were located in the phases2 and 3 of development areas of Abuja where most housing projects are located. The material specifications for the buildings were the usual traditional blocks of 225mm sandcrete

principally used for both external and internal walls. In most of the projects 150mm sandcrete blocks were sparsely used except in toilet areas.

All concrete works were constructed in-situ. Structures being constructed with precast units were avoided since such method of construction was outside the scope of this study.

All the projects were designed to be rendered externally and plastered internally with cement mortar of ratio (1: 6). Tile finishing was specified as floor finishes and wall finishes for toilet/kitchen areas for all the projects.

The masonry groups under examination were directly engaged by the building contractors and had been on site working prior to the commencement of the productivity measurement. The gang size varied from one site to the other. The sizes were manageable for the observers to monitor.

3.4.2 Materials

(a) Blocks: There were principally two types of hollow sandcrete blocks in use at the sites studied. They were 225mm and 150mm blocks. The blocks have the following dimensions 450 x 225 x 225mm and 450 x 150 x 225mm. The 225mm thick blocks were used mainly for external walls and some of the internal partitions. The 150mm thick blocks were mainly used for internal partitions. All block works were laid in 25mm thick stretcher bond in cement mortar ratio of (1:6). Also all blocks used for the construction of the buildings were vibrated blocks purchased form blocks moulding industries supplied to sites. No blocks were produced on site.

(b) Concrete: Concreting work was carried out in foundation, bed, columns, lintel, beams and slabs. The extent of work also entails mixing of concrete components (cement, sand, aggregate and water), transporting and placing.

(c) Wall Plastering: This constitutes a plastic substance of cement and sand normally in (1:4) applied to vertical walls. The average thickness of plaster is 12mm. Mixing is done manually by site helpers engaged to assist the plasterers.

(d) Floor Tiling: This is a thin burnt-clay plates used for floor finishing. The extent of work involved in tiling included screeding and laying of tiles with cement paste. Tiles exist in a variety of sizes and types.

3.4.3 Site working Equipment

Material delivery equipment or plants such as fork lift were not used in any of the sites. In some of the sites concrete mixers were used mainly for mixing concrete while mortar mixing was being done manually. Block materials were being delivered manually to the masons or bricklayers work stations while in some of the sites the services of wheelbarrows were employed. All setting and cutting of blocks were done by the bricklayer's spirit level and hand trowel tools respectively.

3.4.4 Data Collection Techniques

3.4.4.1 Productivity Monitoring

The data collecting techniques used for the productivity monitoring was the daily visit method. The observations and measuring methods were made as discretely as possible to avoid "Hawthorne" effect (Mogbo, 2003). Also all questions and interactions with the site operatives were done with minimum disturbance.

3.4.4.2 Daily Visit Method

A format of the daily data collection sheet used in the direct activity observation is shown in Appendix ii.As much as possible every work done by each gang was noted on the daily

recording sheets including times spent on the activities. This modified daily data collection sheet allowed for recording the direct work by the site operatives, time for accomplishing such task, the number of crew or gang involved (skilled worker or unskilled worker). The sheet allowed the observers or research assistants to monitor and note critical factors of productivity affecting work men on site.

At the end of each operation for the building trades, which varied from one site to the other, the daily data gathering sheets were retrieved from the observers by the researcher for onward extraction of the daily input and output quantities. These values were entered into the data collation or summary form. This recording form provided for the computation of the daily labour productivities, baseline days and abnormal days.

3.4.4.3 Summary Discussion of data analysis for 30 Indigenous Pilot Projects Studied

The summary of data analysis for all thirty indigenous projects investigated is shown in Table 3.1 with values for total work hours, total quantity, total work day,average daily output, cumulative productivity, baseline productivity and abnormal days The total work hours for all projects range from 544hrs to 1976hrs, while the total output range from 474.80m^2 to 2406.30m^2. It was observed that project 2 had the highest value of average daily output of 130m^2 of block work while project 9 had the lowest value of average daily output of 24.99m^2 of block work. These do not necessarily represent the best and worst outputs in quantitative terms. Expressing the output into labour input per hour, project 2 was found to have masonry work output of 1.44m^2 per hour whileproject 9 had 0.79m^2 of masonry work per labour input per hour. Considering project 30, the average daily output achieved was 81.24m^2 of block work and 48.1 hours labour input. The hourly output was computed to be 1.69m^2 of block work per hour,which is the highest hourly output of all the projects studied.The reason

observed for this considerable or significant effort was the application of flexible capacity management practices which involved the adjustment of crew size and shortening work hours.

Some of the projects investigated experienced abnormal days which range from 1 to 13 days. Project 6 had the highest number of abnormal days of 13days which resulted in a high disruption index(DI) of 0.7222 as shown in Table 3.2 further examination of this table revealed that one project witnessed 8 abnormal days, two projects had 5 abnormal days, another two projects experienced 4 abnormal days, one project experienced 3 abnormal days,four projects witnessed 2 abnormal days and six projects had 1 abnormal day. The remaining projects experienced zero abnormal days. The disruption indices for all projects were computed by dividing each abnormal day with the total work days. Eleven of the projects had zero disruptive indices which is an indication of good performance while those with high value of disruptive indices showed poor performance.

Table 3.1 Summary of data analysis for 30 Indigenous Projects for Pilot Study

S/n	*Project Code*	*Total Work hours (hr)*	*Total quantity (m^2)*	*Total work days*	*Average Daily output (m^2)*	*Cumulative productivity (whr/m^2)*	*Baseline prod (whr/m^2)*
1	Project1	1505.50	1394.80	17	82.05	1.079	0.804
2	Project 2	1620	2340.30	18	130.00	0.692	0.571
3	Project 3	935	967.01	19	50.90	0.967	0.729
4	Project 4	1479	1797.48	16	112.34	0.823	0.703
5	Project 5	948	795.22	14	56.80	1.192	0.942
6	Project 6	1589.50	850.50	18	47.25	1.869	1.468
7	Project 7	1674.50	1141.40	16	71.34	1.467	1.110
8	Project 8	1376.00	754.20	15	50.28	1.824	1.587
9	Project 9	600	474.80	19	24.99	1.264	0.940
10	Project 10	1819	1389.58	15	92.63	1.309	0.978
11	Project 11	1154.50	1056.50	15	70.43	1.093	0.872
12	Project 12	1752	1588.50	19	83.60	1.103	0.931
13	Project 13	1946.50	2406.30	20	120.32	0.809	0.723
14	Project 14	1200	1015.74	17	59.75	1.181	0.918
15	Project 15	1275	1301.20	19	68.48	0.980	0.795
16	Project 16	969	889.70	14	63.55	1.089	0.916
17	Project 17	912	983.80	20	49.19	0.927	0.865
18	Project 18	544	522.89	14	37.35	1.040	0.744
19	Project 19	1292	1542.9	18	85.72	0.834	0.691
20	Project 20	1530	1214.2	17	71.42	1.260	0.999
21	Project 21	1504.50	1528.9	20	76.45	0.984	0.847
22	Project 22	1479	836.20	14	59.73	1.769	1.401
23	Project 23	1480	1065.00	14	76.07	1.390	1.070
24	Project 24	1296	2010.10	20	100.51	0.645	0.564
25	Project 25	1952	1229.60	19	64.72	1.588	1.547
26	Project 26	1587	1566.50	20	78.33	1.013	0.806
27	Project 27	1488	1577.80	18	87.66	0.943	0.850
28	Project 28	1976	1232.10	19	64.85	1.604	1.353
29	Project 29	1576	2137.00	20	106.85	0.737	0.652
30	Project 30	962	1624.88	20	81.24	0.592	0.473

Source: **Researcher's data analysis 2011**

Table 3.2 Computation of Project Waste index (PMI) and Performance Ratio (PR)

Project Serial Number	*Cumulative Prod. (whr/m^2)*	*Baseline Prod. (whr/m^2)*	*Project Waste index (PMI)*	*Performance Ratio (PR)*
Project1	1.079	0.804	0.2963	1.1627
Project 2	0.692	0.571	0.1304	0.7457
Project 3	0.967	0.729	0.2565	1.0420
Project 4	0.823	0.703	0.1293	0.8868
Project 5	1.192	0.942	0.2694	1.2844
Project 6	1.869	1.468	0.4321	2.0140
Project 7	1.467	1.110	0.3847	1.5808
Project 8	1.824	1.587	0.2553	2.0140
Project 9	1.264	0.940	0.3491	1.3620
Project 10	1.309	0.978	0.3567	1.4106
Project 11	1.093	0.872	0.2381	1,1778
Project 12	1.103	0.931	0.1853	1.1886
Project 13	0.809	0.723	0.0927	0.8718
Project 14	1.181	0.918	0.3054	1.2726
Project 15	0.980	0.795	0.1994	1.0560
Project 16	1.089	0.916	0.1864	1.1735
Project 17	0.927	0.865	0.0668	0.9989
Project 18	1.040	0.744	0.3190	1.1207
Project 19	0.834	0.691	0.2317	0.8987
Project 20	1.260	0.999	0.2813	1.3578
Project 21	0.984	0.847	0.1476	1.0603
Project 22	1.769	1.401	0.3965	1.9063
Project 23	1.390	1.070	0.3448	1.4978
Project 24	0.645	0.564	0.0872	0.6950
Project 25	1.588	1.547	0.0441	1.7112
Project 26	1.013	0.806	0.2230	1.0916
Project 27	0.943	0.850	0.1002	1.0162
Project 28	1.604	1.353	0.2705	1.7284
Project 29	0.737	0.652	0.0916	0.7942
Project 30	0.592	0.473	0.1282	0.6379

Source: **Researcher's data analysis 2011**

3.4.5 The Sample Size Determination

There are different methods of calculating sample size from a population. The general thinking is that the larger the sample size the greater the likelihood that the sample is representative of the population. Noor (1992) cautioned that one should not be confident that the sample is representative of the population until the level of confidence associated with an estimate of population parameter is evaluated. Since the prediction of the population is done from the sample statistic, it is important that the sample should be sufficiently large to ensure representation of the population.

The determination of sample size depends on the level of accuracy or precision the researcher desire to attain. For the purpose of this study, 95% confidence limits are set for the investigation or 5% level of significance. The t-test method was appropriate for this study because of its simplicity of use and usage at any point in time during data collection. This is stated as

$$\mu \pm t^* \frac{\sigma}{\sqrt{n}} \qquad (3.17)$$

The equation can be further expressed as;

$$t^* \frac{\sigma}{\sqrt{n}} = 0.05\mu \qquad (3.18)$$

Then fixing the mean and standard deviation of the sample into the above equation, that is if the mean is assumed to be x and standard deviation to be y. then the equation becomes

$$t^* \frac{\sigma}{\sqrt{n}} = 0.05 \frac{X}{Y} \qquad (3.19)$$

The figure obtained from the above equation is then compared with the corresponding value in the t-tables with 95% two – tailed probability to compute the appropriate sample size. However, it should be noted that the fundamental assumption in this computation is that the samples or data are normally distributed. Therefore, a check is necessary to confirm the normality conditions. This is achieved by testing for the data skewness and normal distribution plots.

3.4.6 Normal Distribution and Skewness Test

Frequency distribution of samples or data sets exhibit various types of shape when tested for normality. When the distribution is symmetrical, the two halves of the distribution are perfectly the same. The skewed distribution plot occurs when it is pulled out of symmetry by extreme scores or outliers. The presence of extreme scores made the distribution to be positively or negatively skewed which may give values of skewness within the range of ≤ l or above one. This is generally taken as the accepted level of skewness for normal distribution (Noor, 1992). When the skewness and kurtosis are extreme, transformation becomes a necessity. However, the decision to transform data depends on the severity of the departure from normality (Sheridan and Lyndall, 2001).

Noor (1992) further proposed that distributions which are slightly skewed to the left or right with skewness of ≤ l can be taken as being practically normal. The work of Spooner (1974) cited in Noor(1992) corroborated the choice of ≤ l as an acceptance level of skewness for normal distribution. Lema (1996) asserted that this acceptance of≤ l is too “simplistic” and therefore recommended that further normality or validation test be conducted to ascertain the state of the distribution.

It should be noted that all extreme scores or outliers causing skewness in the normal distribution plot were treated by removing them from the data set in order to eliminate their

effects on the normality of the samples. AbouRizk (1992) and Lema (1996) concluded that positive skewness is common to construction activities with occasional situations where symmetric or negatively skewed distributions wereencountered.

3.4.7 Test for Sufficiency of Sample Size

The data set for the pilot study was 524 data points for masonry work on block work from 30 construction sites. The daily productivities of masonry work were computed from the site data obtained on the daily work hours (input) and daily quantities (output).

The daily productivity data were subjected to normal distribution test to check for adequacy of the sample. The following results shown in Table 3.3 were obtained.

Table 3.3 Normal Probability Statistics with Outliers for Blockwork Activity

Statistics	Results
N (Data points)	**524**
Mean (Daily productivity)	**1.242whr/m^2**
Median	**1.077whr/m^2**
Std deviation	**0.606**
Skewness	**2.896**
Range	**6.279**

Source: researcher's data analysis 2011

It was observed from the above result that the skewness was 2.896 which is far from the normal range of ±1. This showed that the data distribution is not normal. It was also noticed that there were the presence of some outliers in the plot as indicated in Figures 3.1 and 3.2, which made the plot not to fit a straight line graph.

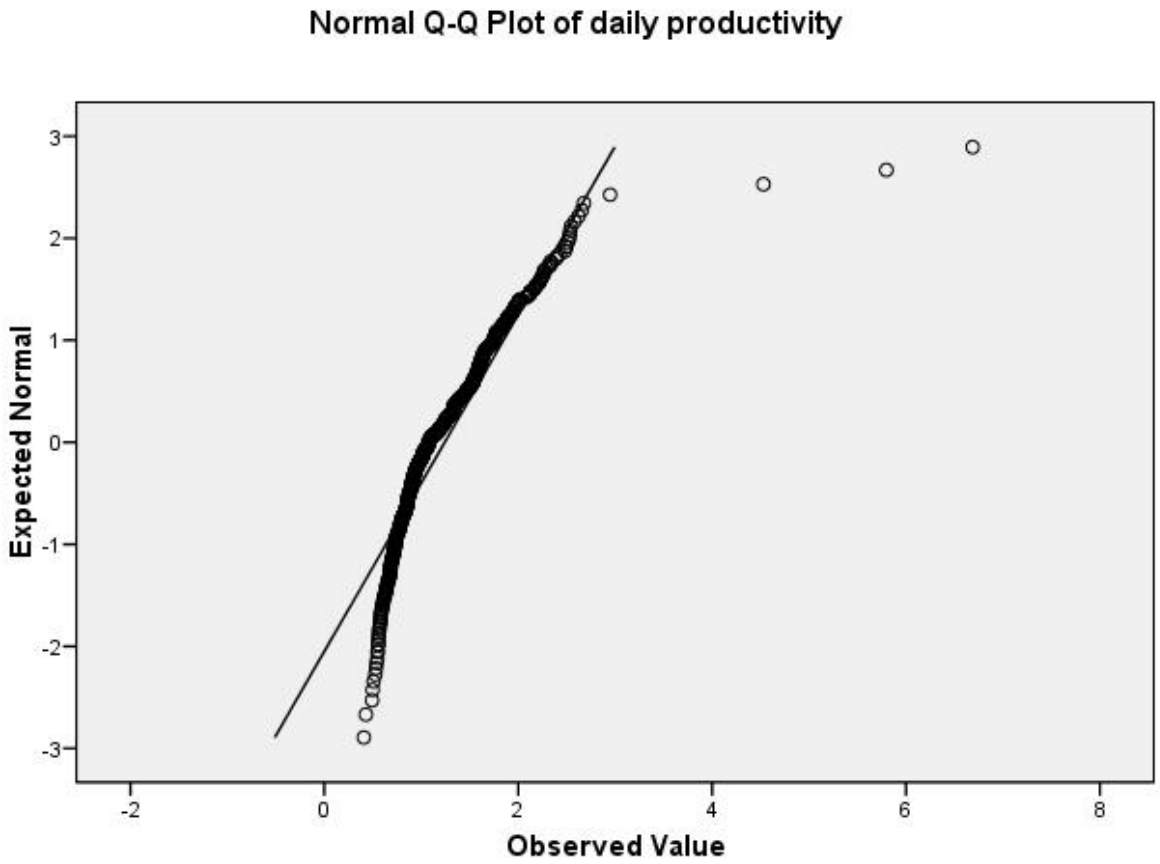

Figure 3.2Normal Probability Graph for Block laying Daily Labour Productivity Containing Outliers

The analysis was repeated with the exclusion of the extreme data and the normal probability plot for the daily labour productivity became normal as shown in Figure. 3.2. The following statistics shown in Table 3.4 were obtained from the analysis.It should be noted that the exclusion of the extreme data reduced the data points to 518.

Table 3.4 Normal Probability Statistics without Outliers for Blockwork Activity

Statistics	Results
N (Data points)	**518**
Mean (Daily productivity)	**1.208whr/m^2**
Median	**1.074whr/m^2**
Std deviation	**0.488**
Skewness	**0.765**
Range	**2.214**

*Source:***Researcher's data analysis 2011**

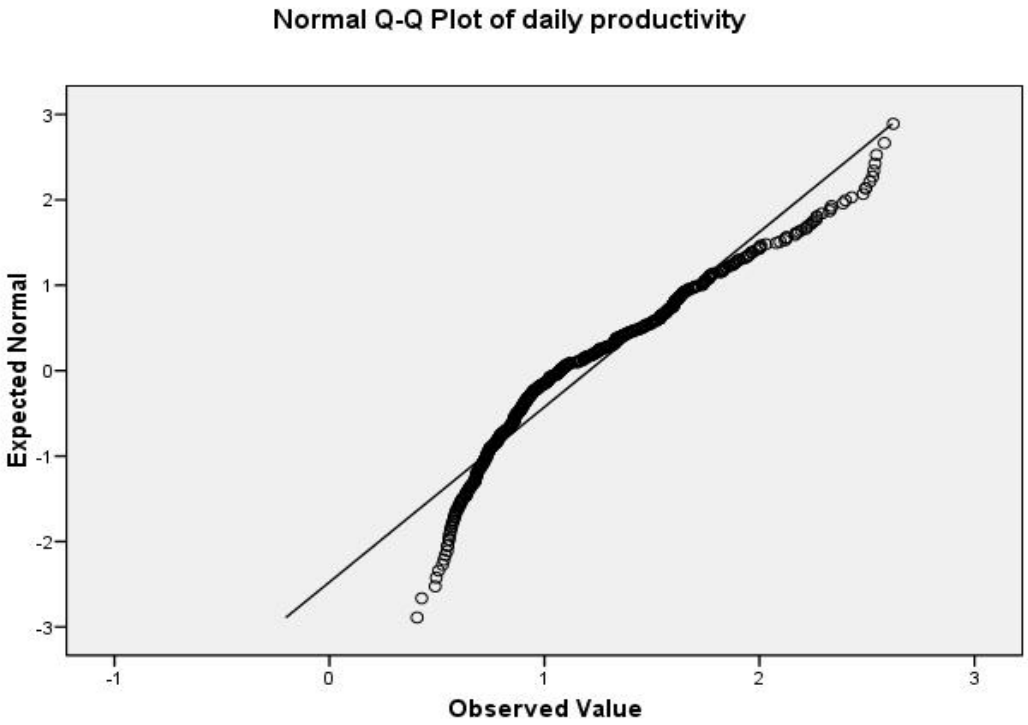

Figure 3.3Normal Probability Graph for Masonry Daily Labour Productivity without Outliers

The skewness value dropped from 2.896 to 0.765 which is within the acceptable normal range of ±l. In order to compute the sample size for the investigation the values for the mean

1.208whr/m^2 and standard deviation 0.488whr/m^2 were substituted into the sample size population equation, the following was obtained;

$$t^* \frac{\sigma}{\sqrt{n}} = 0.05\mu \qquad (3.20)$$

Where; $\frac{\sigma}{\sqrt{n}} = standard\ Error$

$= 0.02144$

$= t^*0.02144 = 0.05 * 1.208$

$t = 2.817$

$\frac{2.817}{\sqrt{n}} = 0.124$

therefore the sample size of,

$$n = \left(\frac{2.817}{0.124}\right)^2 = 516\ samples$$

516 observations would be adequate. Although from the above analysis 516 observations were found to be adequate, 518 data points were collected for masonry work for the pilot study. This means that the data used was adequate and will allow accurate predictions about the population parameters to be made and inferences drawn.

3.4.8 Measuring Variability in Data Set

Variability helps to measure the degree of dispersion of data. It measures how scores or data are clustered or scattered around the central value. It describes distribution in terms of variation, spread, dispersion or scatter of data, (Donald *et al.*,2002). The most commonly used are range, variance and standard deviation.

3.4.8.1 Range Method

This is the simplest of all variability measures. It is found by computing the difference between the highest and the lowest data in the distribution with one (1) added to the result. It is expressed mathematically as

$R = (X_h - X_L) + 1$ (3.21)

Where R = range

X_h = highest value of data in the distribution

X_L = lowest value if data in the distribution.

This method has some limitations. The computation is based only on two values which may mislead the researcher. Extreme values or outliers could be used for the computation thus making the outcome unreliable. It was suggested that its use be restricted to inspectional purpose or alternatively it should be used in conjunction with the other methods of variance and standard deviation.

3.4.8.2 Variance Method

Variance is explained to mean the summation of the squared deviations divided by the number of data or sample.

It is expressed mathematically as

$$\sigma^2 = \frac{\sum x^2}{N} \quad (3.22)$$

Where

σ^2 = variance

$\sum$ = sum of squares

X = deviation of each score from the mean$(x - \bar{x})$, otherwise known as the deviation score.

N = number of data points.

Because each of the deviations is squared, the assumption here is that the original unit of measure is changed. Instead of single unit of measurement, it is measured in metre square (m^2).

3.4.8.3 Standard Deviation Method

The most widely use of variability measurement is standard deviation. One advantage of this method is that it measures the data in the same unit of measurement as the original data. It is defined as the square root of the mean of the squared deviation scores. The value resulting from this computation can be expressed as the ratio of the mean to given a measure of variability known as coefficient of variability, Cv, expressed as a percentage. It has the advantage of being used to compare variability among differing magnitudes of productivity values within and among data sets. It is best used on data sets that are fairly normally distributed with skewness close to zero.

A mere practical method of variability measure that takes into account the original units of measurement of data and allows comparison to be made within and among data sets is the standard deviation method. In this research, the sample of data will be evaluated using this method because of the earlier mentioned advantage.

3.4.9 Variability in daily productivity of block work based on total time.

Figure 3.4 shows the statistics for variability in daily productivity of masonry work.The mean coefficient of variation for all projects was calculated to be 40% and the skewness was observed to be 0.765. The range to median ratio was computed to be 2.06.

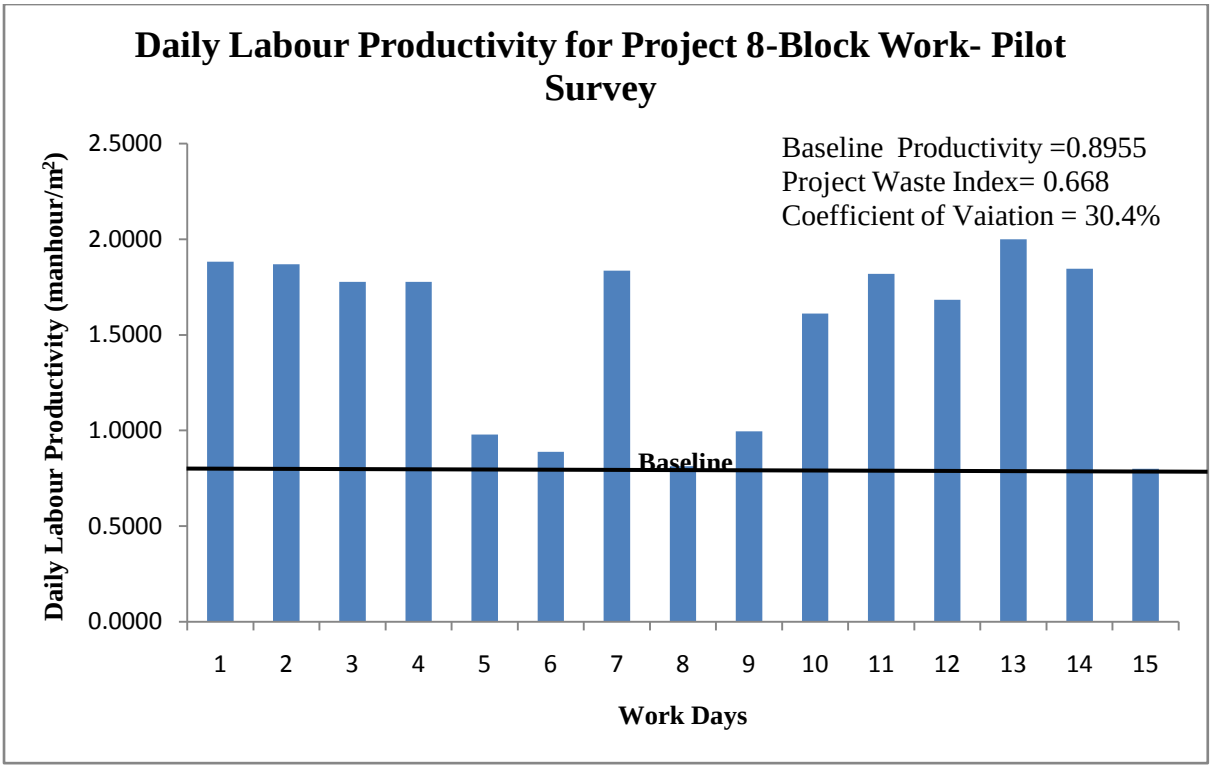

Figure 3.4Relationship of daily labour productivity, baseline productivity and performance (Project 8)

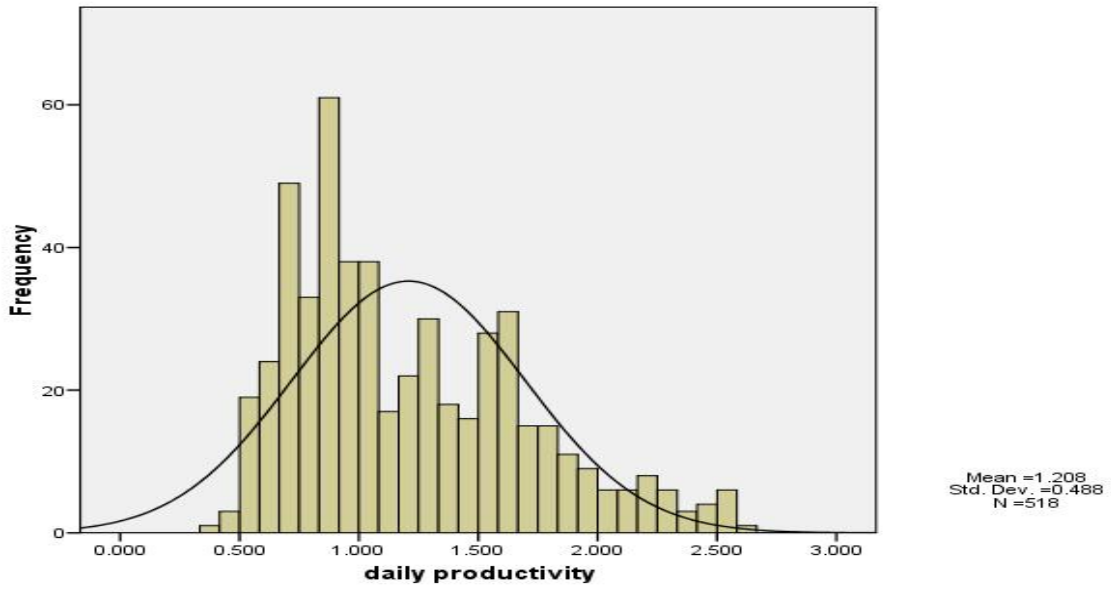

Figure 3.5 **Normal Probability Curve fordaily productivity Data for Block Activity.**

3.4.10 Normality for Cumulative Productivity by Projects

The data for cumulative productivity was tested for normal probability plot. This was to ascertain whether the data is normally distributed along a straight line graph and having a skewness within ±1. This type of test gives reliability on the data set.Figures 3.5 and 3.6 show plots for normal distribution for cumulative productivity for masonry data for all projects sampled. Figure 3.5 shows the absence of extreme outliers in the distribution plot. The data set of 518 was aggregated into 30 masonry projects from 30 firms. The mean and the standard deviation were computed to be 1.175man-hr/sq.m and 0.367man-hr/sq.m respectively. The graph is linear and the skewness of the data was found to be 0.321. The value shows that the data satisfies the condition for normality.

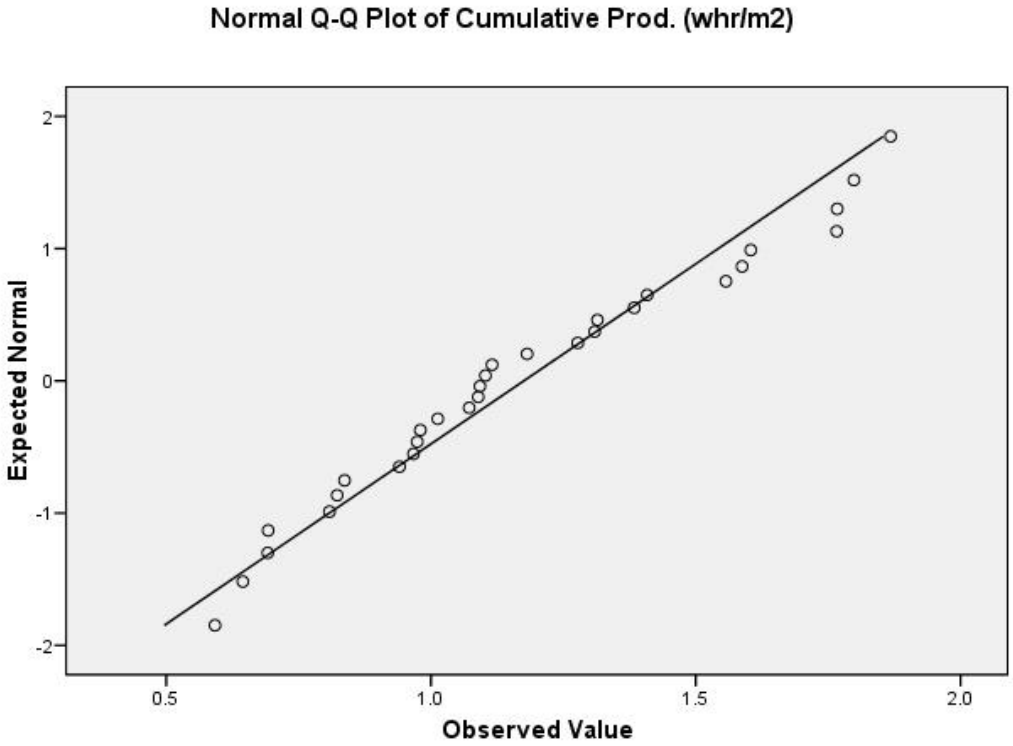

Figure 3.6 Normal Probability Graph for Masonry Cumulative Labour Productivity.

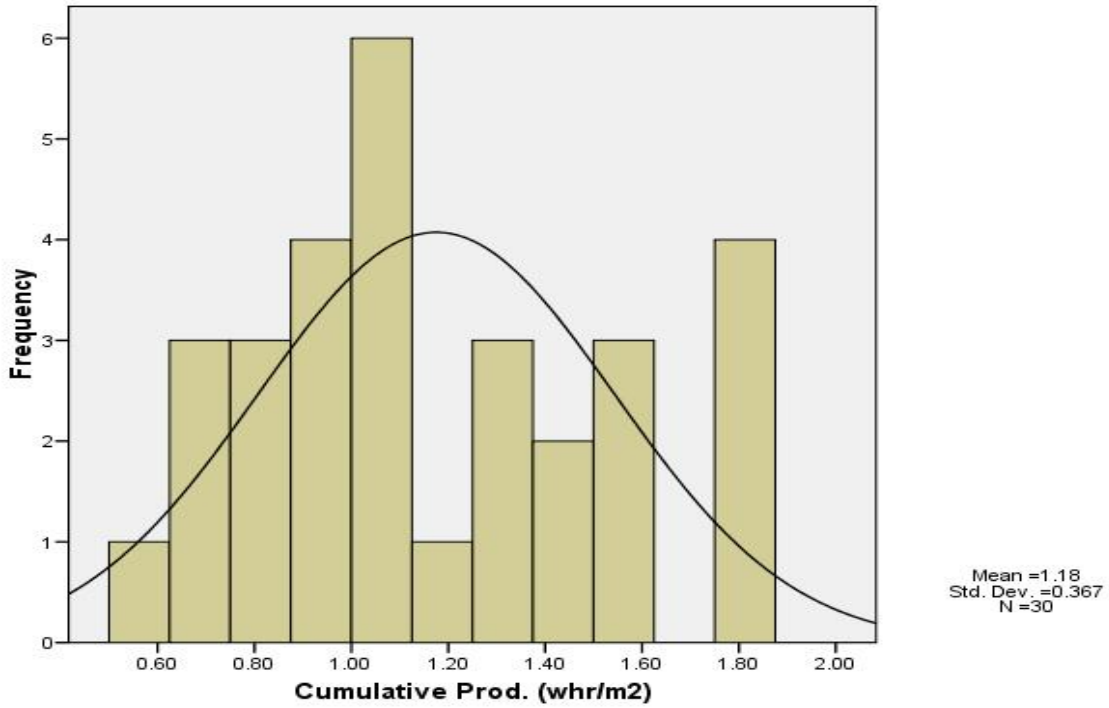

Figure 3.7.Normal Distribution Graph for Masonry Cumulative Labour Productivity.

3.4.11 Pilot Study Early Results from the Analysis of all Building trades

(a) Block work activity: The Coefficient of Variation Cv, for block work was found to be 40.40%, as shown in Table 3.5, which is quite significant. A test of relationship between coefficient of variability of labour productivity and project performance was conducted. The result showed a weak correlation of 0.309. This means that variability in labour productivity has a marginal effect on project performance for masonry work at pilot study level.An expansion of the data set may likely improve this relationship.

Table 3.5 Pilot Study Summary of Analysis

Statistics	Block work	Concrete	Wall Plastering	Floor Tiling
N (Data Points)	**518**	**353**	**375**	**359**
Mean (daily productivity)	**1.208**	**12.702**	**1.231**	**1.290**
Median	**1.074**	**13.213**	**1.189**	**1.249**
Std Deviation	**0.488**	**4.373**	**0.487**	**0.475**
Skewness	**0.765**	**- 0.070**	**0.238**	**0.004**
Range	**2.214**	**15.71**	**1.650**	**1.70**
Coefficient of Variation (COV)	**40.40%**	**34.43%**	**39.56%**	**36.82%**
Correlation (r) between cov and project waste index	**0.309**	**0.479**	**0.766**	**0.557**

Source; Researcher's analysis of Data 2011

(b) Concrete work Activity: The pilot study result for concrete work crew gangs showed some positive outcomes. The research instrument designed for this purpose was employed to gather 353 data points. The normal probability statistics showed a skewness of -0.070 with a negative sign. This indicates that the median value is greater than the mean of the population hence the negative skewness. The coefficient of variation Cv, for concrete work was found to be 34.43%.A test of relationship between coefficient of variability of labour productivity and crew performance was carried out. The result showed a correlation coefficient of 0.479** which was quite significant at the 0.01 level. This suggests that variability in labour

productivity may have a significant effect on crew performance for concrete work if larger data set is employed in the main analysis.

(c) Wall Plastering Work Activity: The outcome of the pilot study for wall plastering wasexplicit. Also the same research instrument was utilized to obtain data for analysis. Thenormal probability statistics showed a skewness of 0.238 which waspositive. This indicates that the median value is less than the mean of the population. The coefficient of variation Cv, for wall plastering work was found to be 39.56%.A test of relationship between coefficient of variability of labour productivity and crew performance was conducted. The result showed a correlation coefficient of 0.766** which was quite significant at the 0.01 level.This implies that variability in labour productivity has strong significant effect on crew performance for wall plastering work at pilot study stage.However, using the same research instrument, a larger data set could be employed in the main analysis to substantiate this relationship.

(d) Floor Tiling Work Activity: The consequence of the pilot study for floor tiling wasdefinite. The same research instrument was made use of to obtain data for analysis. Thenormal probability statistics showed a skewness of 0.004 which was a positive skewness. This indicates that the median value is less than the mean of the population. The coefficient of variation Cv, for floor tiling work was found to be 36.82%.A test of relationship between coefficient of variability of labour productivity and crew performance was conducted. The result showed a correlation coefficient of 0.557** which was significant at the 0.01 level.This implies that variability in labour productivity has a significant effect on crew performance for floor tiling work however, a larger data points could be used in the main analysis to improve thisoutcome.

3.4.12 Content Validity of Instruments

The instrument employed to gather data on the qualitative and quantitative aspects of the research provided adequate coverage of the objectives of the study. The instrument covered desired areas of the qualitative and quantitative studies which include knowledge, application, experience and site management capability. The findings as reflected in section 3.5.11 are consistent with those found in the previous studies (Grantham 2008). The multiplicity of data sources among all levels of site operatives provided internal and external validation. Consistency and thus reliability in the instrument utilized was ensured through the use of the interview protocol. In case of the qualitative survey all respondents were questioned using the same rules by answering the same close ended questions.The instrument is devoid of the opportunity of expressing personal perceptions and opinions.Although the respondents were initially given two options to express their perceptions, this was latter discarded because of the divergent nature. This presupposed that external sources of variation are removed and possible error reduced to minimum.

CHAPTER 4

DATA PRESENTATION, ANALYSIS AND DISCUSSION OF RESULTS

4.1 INTRODUCTION

This chapter contains the presentation of data, the analysis of data and discussions. The first part of data presentation involved descriptive presentation of composition of respondents. This section also has the summary of the**i**mportance index (I) ranking of common critical factors affecting labour productivity tabulated. The second section contains the statistical analysis and discussion of selected construction activities. The analyses and discussions were subdivided into four areas thus; block work, concrete, wall plastering and tiling activities.

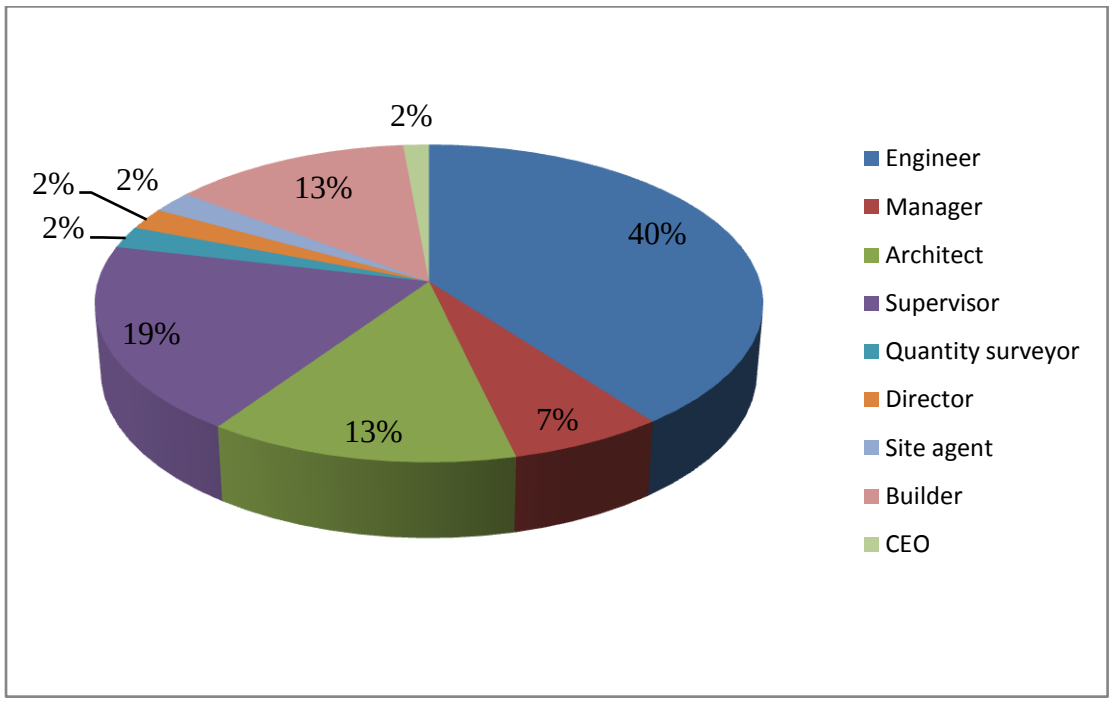

Fig 4.1 Composition of Respondents
Source:***Researcher's data analysis 2012.***

The goal of this survey was to securethe views of a range of stakeholders in the field of building construction on the critical factors affecting labour productivity on building sites that have been predominately identified in literature (Table 2.3 section 2.5). Respondents were

requested to assess each factor on a Likert scale of 1 to 5. A total of 138 responses were received out of 200 questionnairesadministered, which amounts to a response rate of 69 per cent. The composition of all respondents is shown in fig 4.1. Site engineers weretopmost on the list of respondents with 40% response rate while quantity surveyors, directors and site agents had response rate of 2% each.

Table 4.1Importance Index (I) Ranking of Common Critical Factors Affecting Labour Productivity

Factors	Affects with little extent	Affects to some extent	Affects with average extent	Affects with large extent	Affects with very large extent	N	Index	**Ranking**
Lack of labour experience	16.00	24.00	17.00	48.00	31.00	136.00	67.94	1
Material shortages	18.00	22.00	27.00	34.00	34.00	135.00	66.52	2
Lack of tools/equipment	19.00	14.00	21.00	51.00	30.00	135.00	64.00	3
Occurrence of interruptions	15.00	34.00	24.00	35.00	25.00	133.00	63.16	4
Poor supervision marked with excessive waiting	29.00	19.00	24.00	36.00	25.00	133.00	61.35	5
Accidents on site	26.00	32.00	17.00	36.00	27.00	138.00	60.87	6
Rework and fatigue	15.00	39.00	33.00	30.00	17.00	134.00	59.25	7
Absenteeism among the site labourers	31.00	34.00	21.00	30.00	21.00	137.00	56.50	8
Distance of materials to work location	23.00	40.00	27.00	36.00	11.00	137.00	55.91	9
Weather changes/conditions	24.00	48.00	24.00	17.00	19.00	132.00	53.79	10
Characteristics of site location	24.00	49.00	27.00	29.00	9.00	138.00	52.75	11
Payment system (daily, output or sub)	43.00	28.00	19.00	28.00	14.00	132.00	51.21	12
Confined working space	36.00	33.00	35.00	30.00	2.00	136.00	49.56	13
Size and composition of the gangs	39.00	38.00	22.00	25.00	7.00	131.00	48.24	14
Height at which work is done	35.00	43.00	35.00	19.00	3.00	135.00	46.96	15
Interference from other workers	41.00	41.00	30.00	15.00	3.00	135.00	40.61	16

Source:**Researcher's data analysis 2012**

4.2 FINDINGS AND DISCUSSION

In order to provide a degree of importance for each critical factor, an important index value was computed for each of the factors as shown in Table 4.1.The result showsthat the most important factor affecting labour productivity is lack of labour experience; this is closely followed by shortage of materials on site. Next to this are lack of tools / equipment, variation in drawing and specification during project execution, poor supervision, accidents,rework and fatigue, absenteeism, distance of material to work station, weather conditions, characteristics of site location, payment system, confined working space, gang formation, height at which work is executed and interference from other workers.

The surveyed contractors ranked “lack of labour experience” as the first factor among others with important index of 67.94 as shown in Table 4.1.By this ranking it shows that lack of labour experience has a very high negative effect on labour productivity. The position of this factor was supported in theearlier study by Enshassi *et al*(2007)which found out that the experience of skilled workers on site affect labour productivity either negatively or positively.

4.3STATISTICAL ANALYSIS AND DISCUSSION OF SELECTED CONSTRUCTION ACTIVITIES

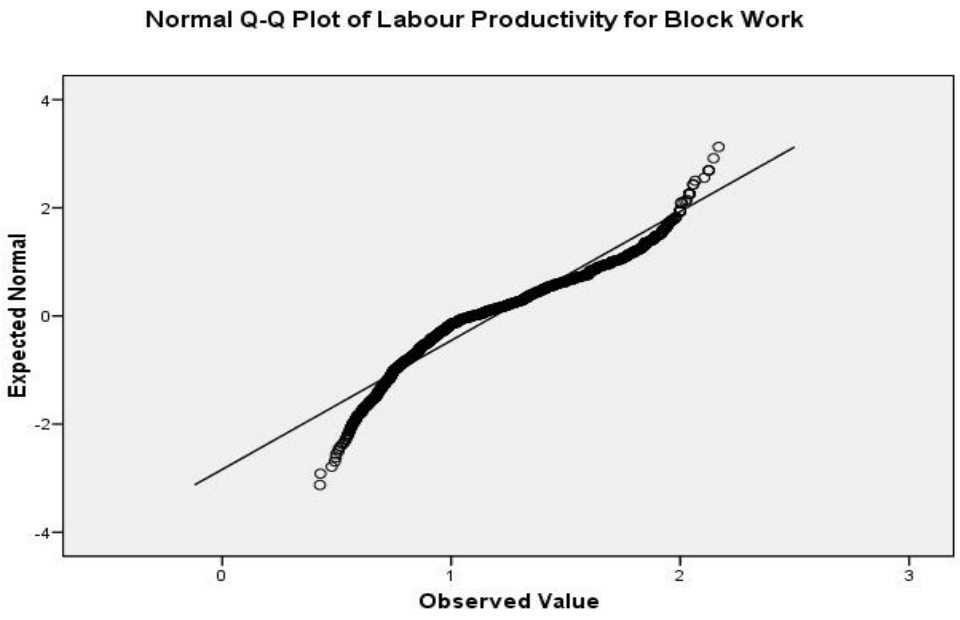

Fig 4.2 Line of Fit Probability Plot of Labour Productivity Data for Block laying

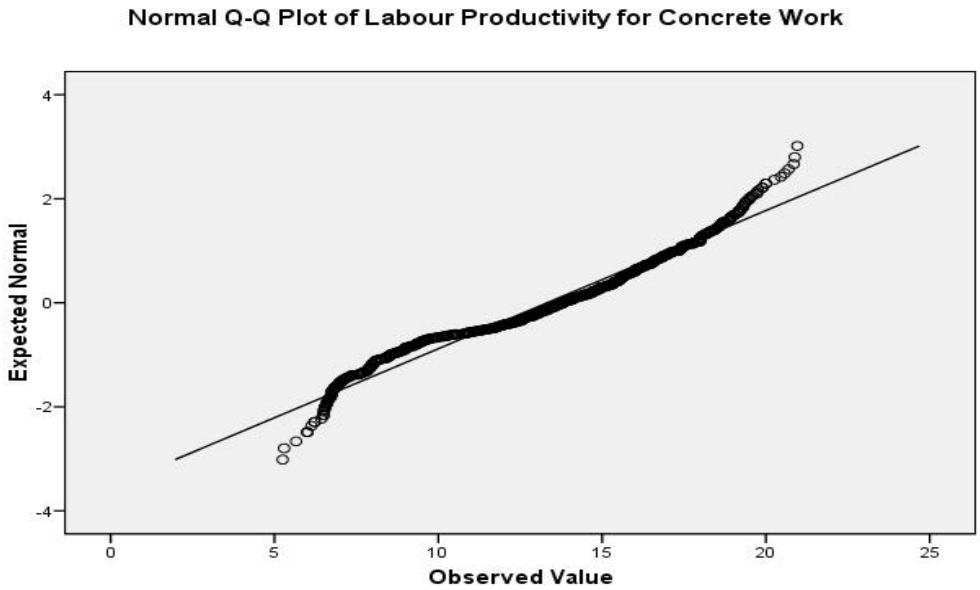

Fig 4.3Line of Fit Probability Plot of Labour Productivity Data for Concreting

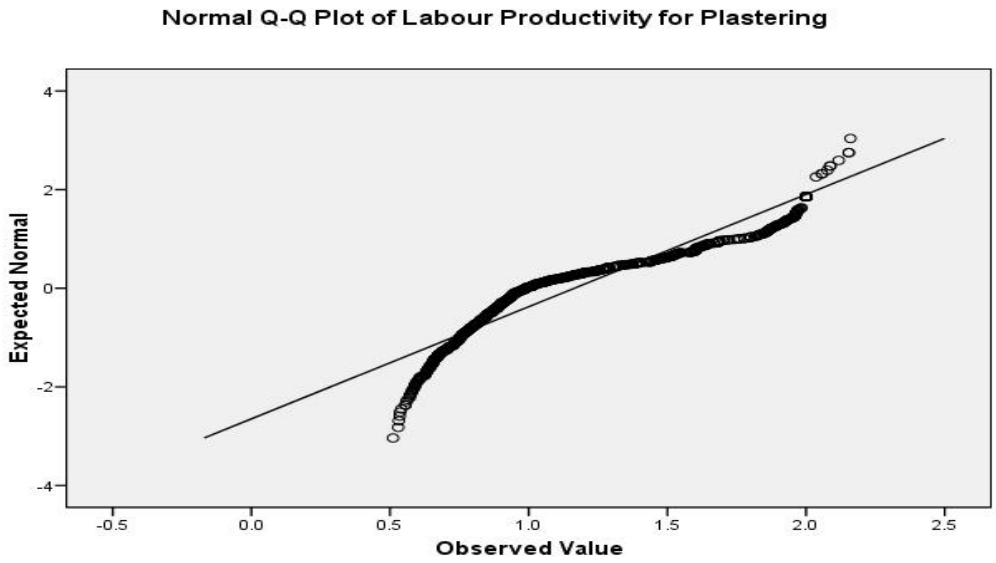

Figure 4.4Line of Fit Probability Plot of Labour Productivity Data for WallPlastering

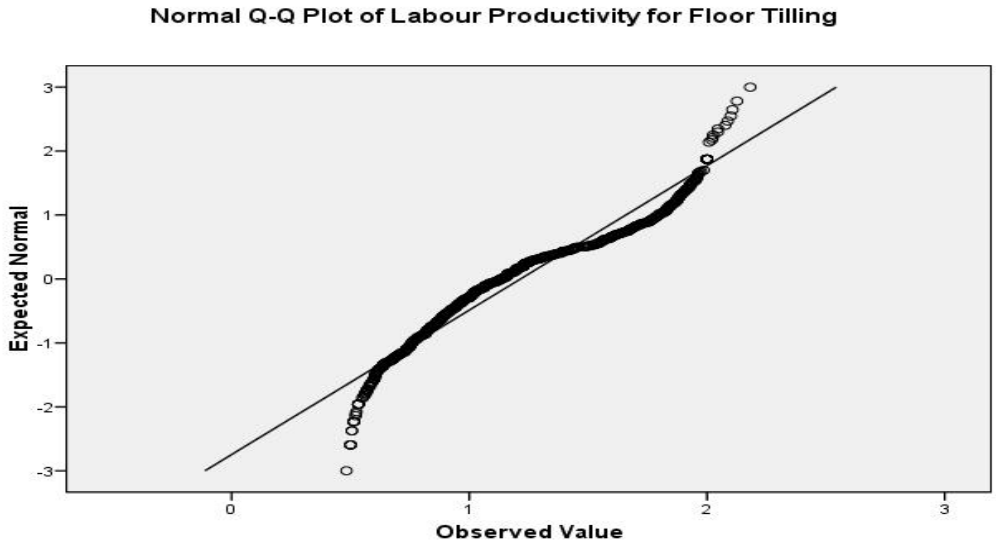

Figure 4. 5Line of Fit Probability Plot of Labour Productivity Data for Floor Tiling

4.3.1 Block Laying: The test for normality of labour productivity data was found to be slightly normally distributed. The normal probability plot of labour productivity data for block laying used for the study is shown in Figure 4.2. A sample size of 518 was earlier computed to be adequate but a data set of 1127 was used for the study. The purpose for large data set gathering was for accuracy. The mean of the sample was found to be 1.19 work hours /m^2 and the median was determined to be 1.09work hours /m^2. It was observed that the mean of the estimate was higher than the median. This indicates that the frequency distribution is not symmetrical. An observation of the line of fit in Figure 4.2 does not show any clear fit to the normal distribution. It is a skewed distribution. Also the analysis indicates that the distribution is positively skewed having a skewness value of 0.425 and standard deviation of 0.419.The distribution of the sample variable was insignificantly normal as demonstrated in Figure 4.3.The measure of variability was determined from the normal probability statistics computed. The range was found to be 2.214 which is the difference between the highest and the lowest scores in the distribution.The coefficient of variation for all the projects investigated for block work, which is the measure of the standard deviation and the mean, was calculated as 35.21%.

The labour productivity values gotten were used to compute the cumulative productivity.The cumulative productivity is a measure of the overall effort required to accomplish a task. It is a major component in assessing crew performance from project management index perspective. Statistical analysis of data showed that the mean andstandard deviation of cumulative productivity were found to be1.10 whr / m^2 and of 0.207 respectively.

4.3.2 Concreting: The concrete worklabour productivity data test for normality was found to be slightly normally distributed. The normal probability plot for the labour productivity data for concrete activity is shown in Figure 4.3, with slight deviation from the straight line of fit. A sample size of 353 was computed to be adequate but a data set of 778 was used for the study. The purpose for large data setgathering, as earlier mentioned, was for improvement of results. The mean of the sample was found to be 13.326 whr /m^2 and the median was determined to be 13.807 whr /m^2. It was observed that the mean of the estimate was less than the median. This indicates that the frequency distribution is not symmetrical.Also observation of the line of fit for concrete work in Figure 4.3 does not show any clear fit to normal distribution. It is a skewed distribution as shown in Figure 4.7. Also the distribution is negatively skewed having a skewness value of - 0.247 and standard deviation of 3.776.

The distribution of the sample variable was assumed to be slightlynormally distributed. The measure of variability was determined from the normal probability statistics computed. The range was found to be 15.71 which is the difference between the highest and the lowest scores in the distribution.The average coefficient of variation for all the projects which is a function of the standard deviation and the mean was calculated as 28.26%.

The labour productivity values calculated or synthesized from the raw data were used to compute the cumulative productivity. Which is the overall attempt required toaccomplish a concrete task. It is a key element in assessing crew performance from project management index perspective.

Statistical analysis of data showed that the mean andstandard deviation of cumulative productivity were found to be13.326whr / m^2 and of 3.776respectively.

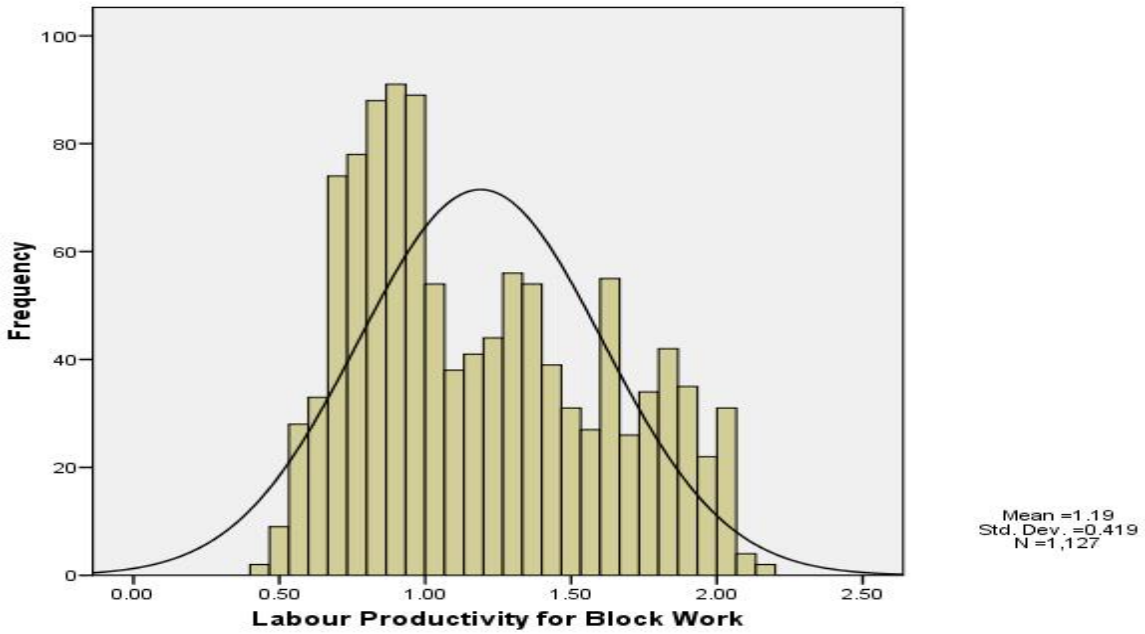

Figure 4.6 Normal Distribution Curve of Labour Productivity Data for Block work Activity

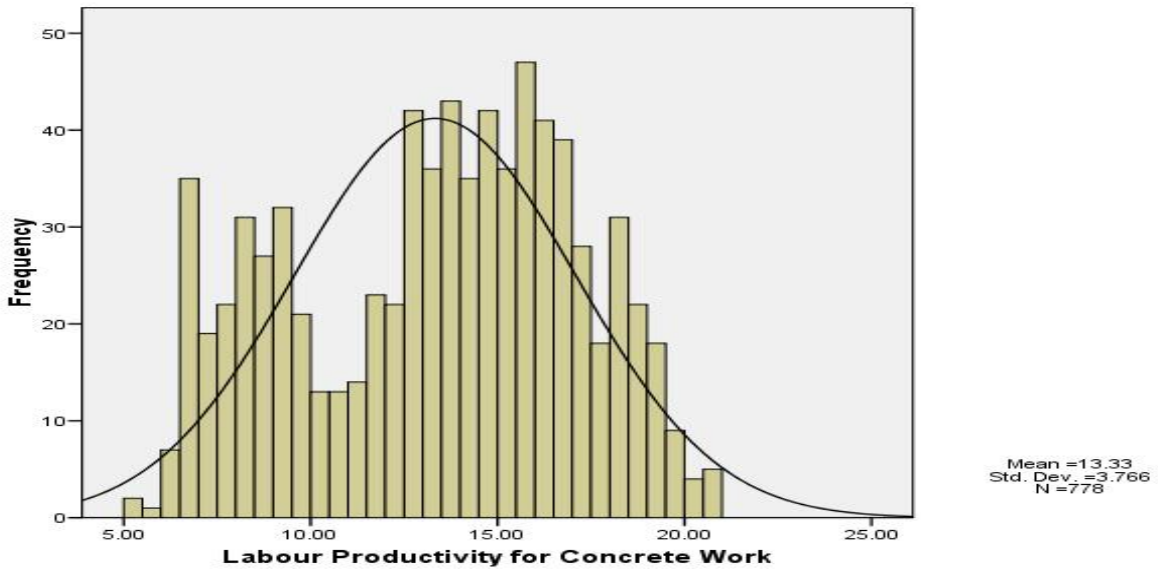

Figure 4.7 Normal Distribution Curve of Labour Productivity Data for Concreting Trade

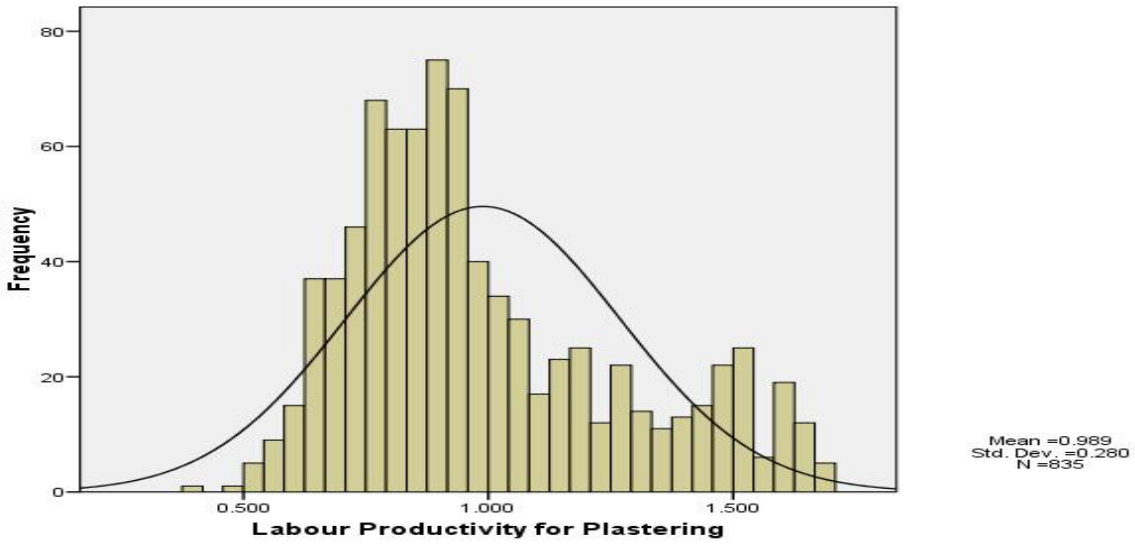

Figure 4. 8 Normal Distribution Curve of Labour Productivity Data for Wall Plastering Trade

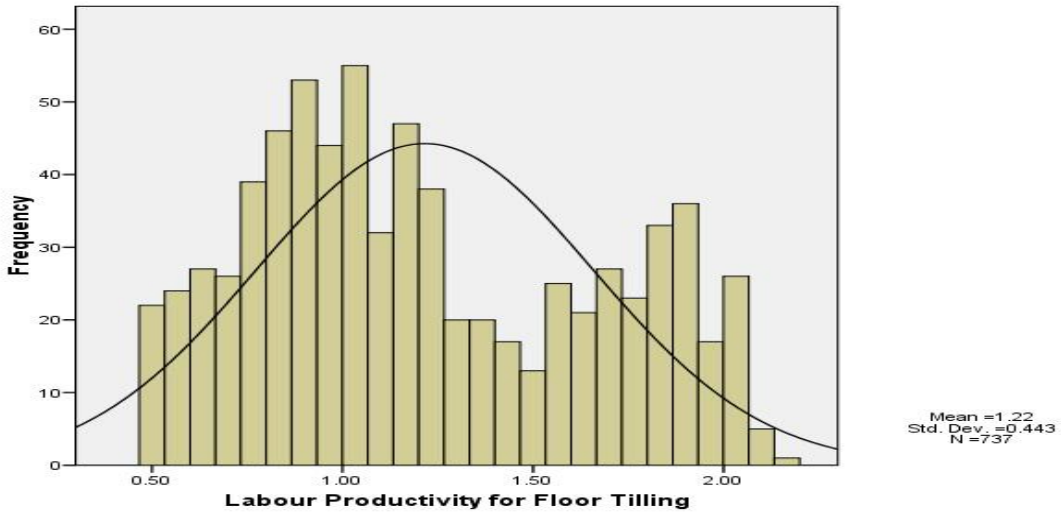

Figure 4.9. Normal Distribution Curve of Labour Productivity Data for Floor Tiling Trade

4.3.3 Wall Plastering: Similarly the test for normality of productivity data was found to be slightly normally distributed. The normal probability plot of labour productivity data for plastering trade used for the study is shown in Figure 4.4. A sample size of 377 was computed to be adequate, but a data set of 835 was obtained for the study, this could enhance the accuracy level. The mean of the sample was found to be 1.164 whr /m^2 and the median was determined to be 0.990 whr /m^2. It was observed that the mean of the estimate was higher than the median. This indicates that the frequency distribution is not symmetrical. It is a skewed distribution as shown in Figure 4.8. Also the distribution is positively skewed having a skewness value of 0.645 and standard deviation of 0.440.

The distribution of the sample variable wasfairlydistributed looking at the histogram plot in Figure 4.8. The measure of variability was determined from the normal probability statistics computed. The range was found to be 1.650 which is the difference between the highest and the lowest data in the distribution.The average coefficient of variation for all the projects which is theproduct of the standard deviation and the mean was calculated as 37.76%.The labour productivity values obtained were used to compute the cumulative productivity.The cumulative productivity is a measure of the overall effort required to accomplish a task. It is animportantaspect in assessing wall plastering crew performance from project management index perspective. Statistical analysis of data showed that the mean andstandard deviation of cumulative productivity were found to be1.06whr/m^2 and of 0.175respectively.

4.3.4 Floor Tiling: The normal probability plot of labour productivity data for floortiling trade used for the study is shown in Figure 4.5. A sample size of 737 was used for the investigation as against 357sample size determined. The mean of the sample was found to be 1.216whr /m^2 and the median was determined to be 1.134whr /m^2. It was observed that the mean of the estimate was higher than the median. This indicates that the frequency distribution is not symmetrical; it is a skewed distribution as shown in Figure 4.9. Also the distribution is positively skewed having a skewness value of 0.336 and standard deviation of 0.443.The distribution of the sample variable was slightly normally distributed. The measure of variability was determined from the normal probability statistics computed. The range was found to be 1.70 which is the difference between the highest and the lowest scores in the distribution.

The average coefficient of variation for all the projects which is a measure of the standard deviation and the mean was calculated as 36.43%.

4.3.5 Box and Whisker's Test

The productivity data were tested for any extreme outliers. The box and whiskers technique was adopted to examine the level of possible extreme outliers present in the data. Although extreme outliers were dealt with at pilot study stage, it was observed that the data for all four selected site activities were free from extreme outliers as shown in Figure 4.10. A graphical observation of the box and whiskers plots for the four activities points out that the line of symmetry in each of the boxes was either tilted towards the upper or lower arm. This points to the fact that the data were not symmetrical.This showed thatthe data were either skewed to the right or left. The plots showed that the block laying, wall plastering and floor tiling were positively skewed to the right while that of concrete activity was skewed to the left.

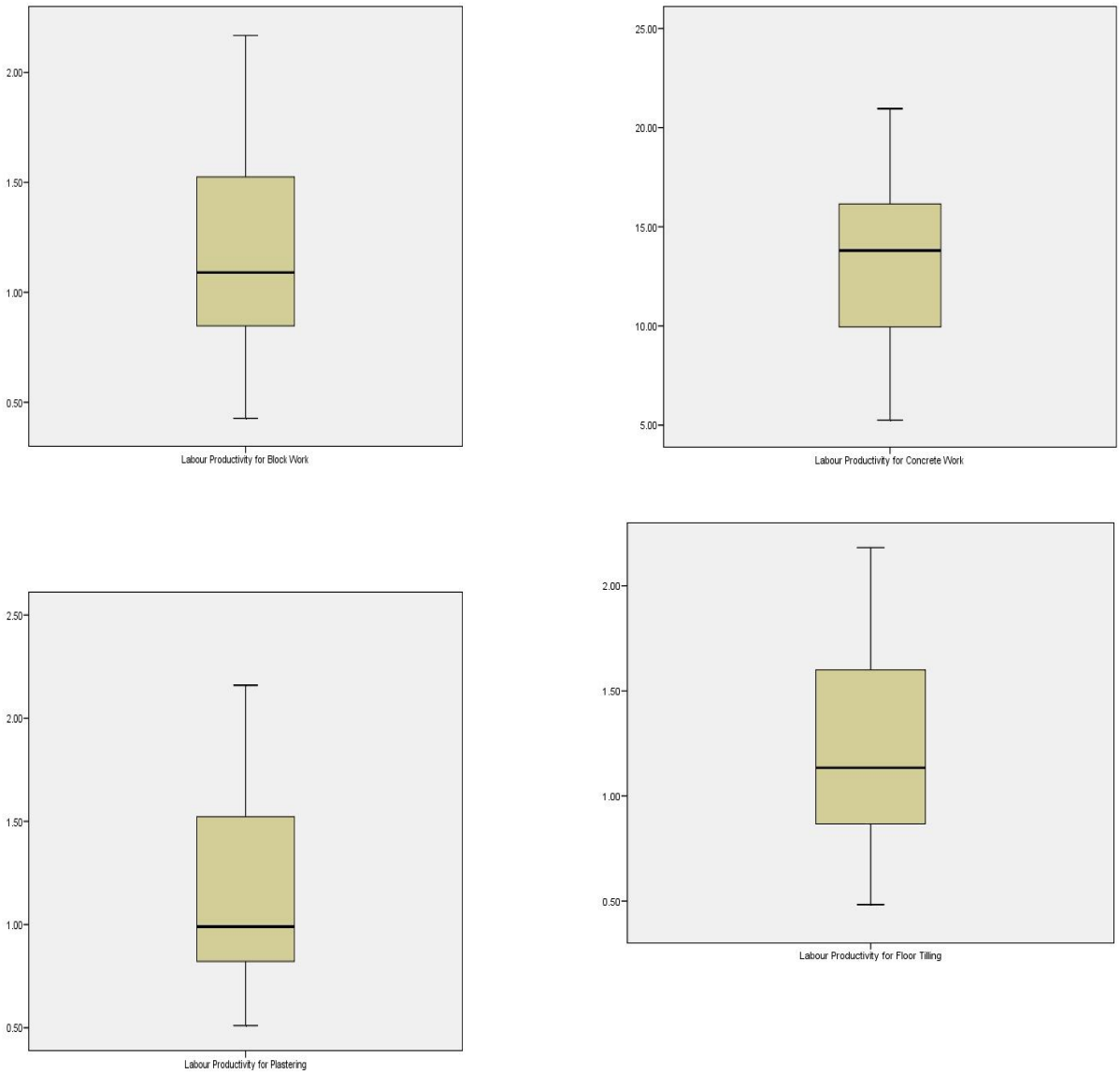

Figure 4.10 Box and Whisker's Plot for 4 Labour Productivities of Selected Activities

These findings confirm the conclusions from other researchers discussed in section 3.5.6 that positive skewness is common to construction activities with occasional negative skewness.

Table 4.2Kolmogorov-Smirnov and Shapiro-WilkTestsfor Normality

Labour Productivity Data	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Block laying Work	0.118	1127	0.000	0.946	1127	0.000
Concreting Work	0.077	778	0.000	0.963	778	0.000
Wall plastering Work	0.158	835	0.000	0.901	835	0.000
Floor Tiling Work	0.091	737	0.000	0.945	737	0.000

Source: Researcher's data analysis 2012

To further establish the normality test, kolmgorov-Smirov and Shapiro-Wilk tests were conducted. The purpose was to determine if the samples come from a population with a specific distribution.The kolmogorov -Smirnov test statistics for block laying, concreting work, wall plastering work and tiling work were calculated to be 0.118, 0.077, 0.158 and 0.091 respectively while that of Shapiro-wilk was computed as 0.946, 0.963, 0.901 and 0.945 for the same activities stated above respectively in Table 4.2. The p-values for all analysis were significant at 0.000 which are lower than 0.05 significant level. Since the p-valuesare lower than the significant level of 0.05, it all means that the sample is not drawn from a normal distribution. The data experienced some degrees of skewness in the distribution for all site activities. This confirms the earlier normality test conducted. The skewness values calculated for all data used for the activities investigated were less than unity therefore the distribution is considered to be fairly normally distributed.

4.3 VARIABILITY IN DAILY LABOUR PRODUCTIVITY FOR THE SELECTED SITE ACTIVITIES

4.4.1 Block Laying Activity: Figure 4.11 shows the variability in daily labour productivity of block laying activity for project 33 which provides a measure of levels of capacity flexibility. It was computed for other projects examined. It was determined from input (the number of man hours) to output (the quantities produced) relationship.

The coefficients of variability in labour productivity for all studied projects are shown in Appendix IV. The computed values of coefficient of variation for block work trade range from 0.108 its 0.443. This is the product of the standard deviation divided by the mean of the estimate.

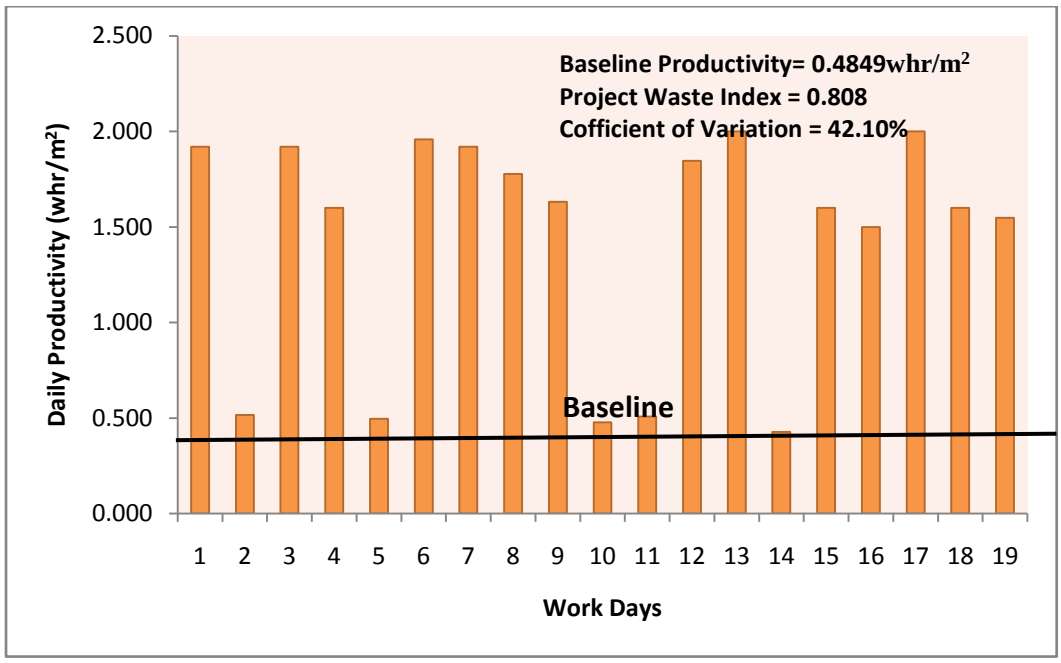

Figure 4.11 Relationship of daily labour productivity, baseline productivity and performance for block work activity (Project 33**)**

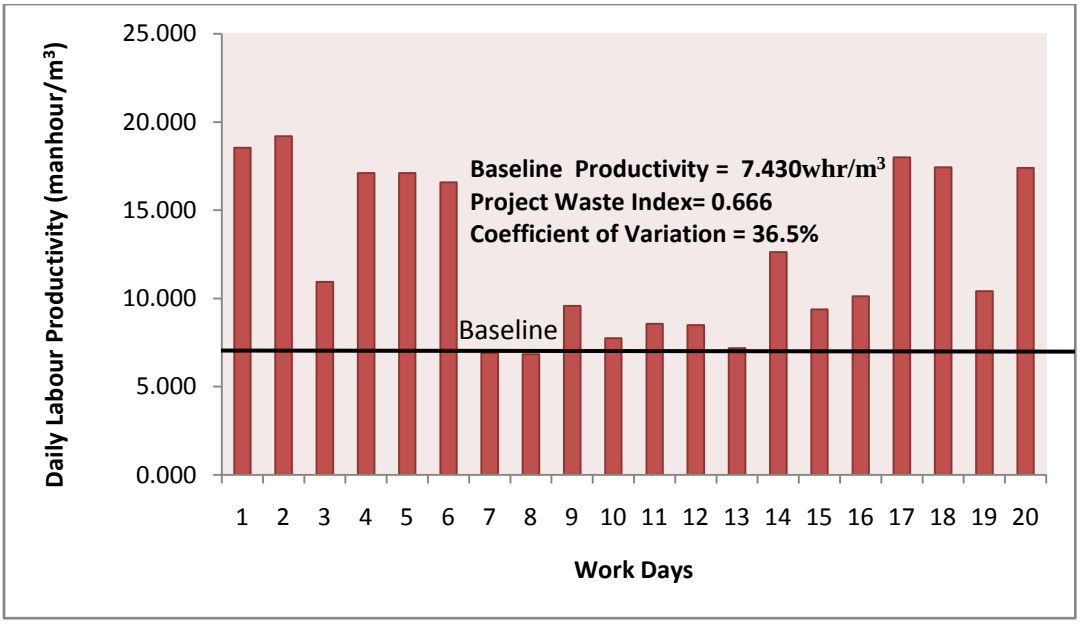

Figure 4.12 Relationship of daily labour productivity, baseline productivity and performance for concrete activity (Project 28)

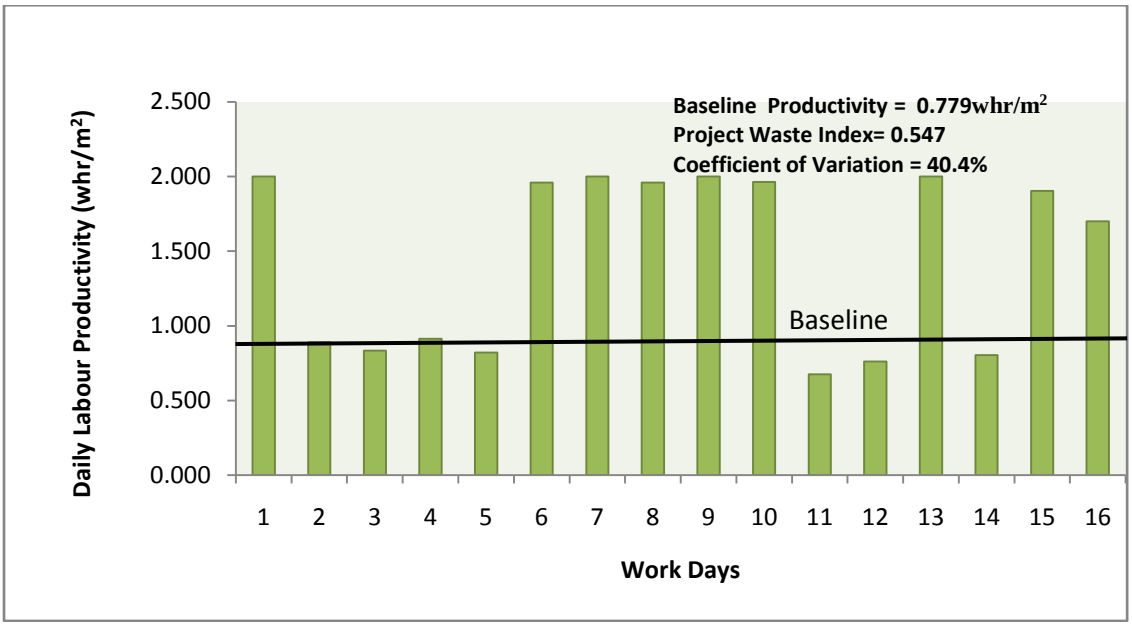

Figure 4.13 Relationship of daily labour productivity, baseline productivity and performance for wall plastering activity (Project 2)

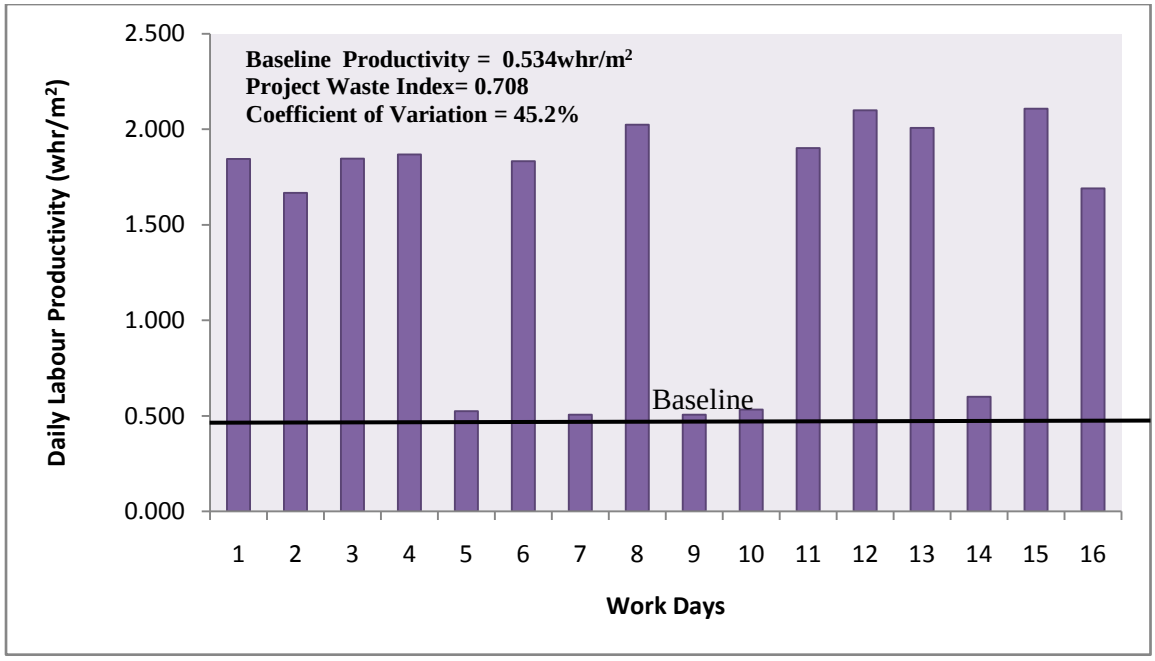

Figure 4.14 Relationship of daily labour productivity, baseline productivity and performance for floor tiling activity (Project 5)

The table in Appendix V illustrates the days for observing masonry work activities, the gang size, work hours, daily quantity, daily labour productivity, baseline days and abnormal days. These attributes were calculated using the benchmarking procedures as described in section 3.4.2.3.The block laying task monitored for project 33 was done for nineteen days. The total team size employed to construct 881 square metres of block work was 126 work men with a total work hours of 1008hours. This indicates that the construction firm used one site worker to achieve approximately 6.992m^2 of block work. The daily productivities ranged from 0.427to 2.00whr/m^2. The block laying work has a cumulative productivity of 1.144whr/m^2.This indicates that labour input was low since the cumulative productivity is greater than unity. Days' 2,5, 10, 11 and 14 were identified as baseline days (See section 3.4.3.3). These were the highestproductivity scores that were considered to define the baseline subset and the average of these five figures (0.516, 0.496, 0.478, 0.508 and 0.427whr/m^2) represents the baseline productivity or benchmark for the project which is

calculated to be 0.485whr/m^2. The block laying task for this project witnessed two abnormal days.

The project waste index which provides a measure of labour performance was found to be 0.808 which is the worst PWI of all projects investigated. This index facilitates the comparison of labour performance to a baseline criterion. The higher the PWI figure the poorer the labour performance. An examination of Figure 4.11 showed the existence of gap between daily labour productivities and the baseline productivity which was found to have 42.10% coefficient of variation. This level of variation shows ample room for improvement. The closer the values of daily labour productivity to the baseline productivity the better the labour performance;project 49 demonstrated this fact and it is shown inFigure 4.15. The baseline productivity for the project was computed to be 0.688whr/m^2.

Also it was observed that the gap between the daily productivities and the baseline productivity provided a coefficient of variation of 10.8% which produced a better labour performance (pwi) of 0.117. This supports the lean theory of improving performance by reducing variability in labour productivity.

4.4.2 Concreting activity: Figure 4.12 shows the variability in daily labour productivity of concretetask for project 28.The variability computation was done for each of the projects examinedshown in Appendix IV. It was determined from input to output relationship.The computed values of coefficient of variation for concreting activity range from 0.09to 0.48.

Appendix V, illustrates the days observed forconcreting activity, the gang size, work hours, daily quantity, daily labour productivity, baseline days and abnormal days. The concreting task observed in the project was done for twenty days. The total team size employed to lay203 metre cube of concrete work was 327 work men with a total work hours of 2818hrs.

This indicates that the construction firm used one site worker to achieve approximately 0.621m^3 of concrete. The daily productivities ranged from 6.838to 19.200whr/m^3. The concrete work has a cumulative productivity of 10.33whr/m^3.This indicates that labour input was fairly normal since this cumulative productivity is less than unity. The following days7, 8, 10, 12, and 13 were identified as baseline days for concreting task. These are the highest productivity scores that were considered to define the baseline subset and the average of these five figures (6.897, 6.838, 7.742, 8.496 and 7.176whr/m^3) represents the baseline productivity or benchmarkfor the project which is calculated to be 7.430whr/m^3. The concrete task recorded no abnormal days.

The project waste index which provides a measure of labour performance was found to be 0.666 which is the worst pwi of all projects investigated. This index facilitates the comparison of labour performance to a baseline criterion. The higher the pwi figure the poorer the labour performance. An examination of Figure 4.12 showed some level of gap between daily labour productivities and the baseline productivity which was found to be 36.50% coefficient of variation. This level of variation shows some level of opportunity for improving labour performance. The wider the values of daily labour productivity from the baseline productivity the poorer the labour performance. Project 60 in Figure 4.16 for concreting activity shows a better performance with daily productivity close to the baseline productivity value. The baseline productivity for the project was computed to be 13.113whr/m^3.

Also it was observed that the gap between the daily productivities and the baseline productivity provided a coefficient of variation of 9.2% which produced a better labour performance (pwi) of 0.160 compared to 0.666 obtained for project 28.

4.4.3 Wall Plastering Activity: Figure 4.13 shows the variability in daily labour productivity of wall plasteringtask for project 2.The variability computation was done for each of theother 60 projects examined (Appendix IV). It was determined from input to output relationship.The computed values of coefficient of variation for wall plastering activity range from 0.082to0.565. This is similar to the computation which is the product of the standard deviation divided by the mean of the estimate.

Appendix V, illustrates the days observed forwall plastering activity, the gang size, work hours, daily quantity, daily labour productivity, baseline days and abnormal days. The wall plastering task observed in the project was done for sixteen days. The total gang size employed to construct 1127 square metreof plaster work was 168 men with a total work hours of 1395hrs. This indicates that the construction firm used one site worker to achieve approximately 6.708m^2 of plaster. The daily productivities ranged from 0.675to2.00whr/m^2. The wall plastering work has a cumulative productivity of 1.238whr/m^2.This indicates that labour input was low since this cumulative productivity is greater than unity. The following days3, 5, 11, 12, and 14 were identified as baseline days for concreting task. These are the highest productivity scores that were considered to define the baseline subset and the average of these five figures (0.835, 0.821, 0.675, 0.761 and 0.804whr/m^2) represents the baseline productivity or benchmarkfor the project which is calculated to be 0.779whr/m^2. The wall plastering task recorded no abnormal days.

The project waste index which provides a measure of labour performance was found to be 0.547 which is the worst pwi of all 60 projects investigated. This index as earlier mentioned facilitates the comparison of labour performance to a baseline criterion. The higher the pwi figure the poorer the labour performance. Figure 4.13 illustrates level of gap between daily

labour productivities and the baseline productivity.Thecoefficient of variation was found to be 40.40%. This level of variation shows that there is ample space for improving labour performance. The wider the values of daily labour productivity from the baseline productivity the poorer the labour performance. Project 56 in Figure 4.17 for wall plastering activity shows a better performance with daily productivity close to the baseline productivity value. The baseline productivity for the project was computed to be 0.830whr/m^2.Also it was observed that the gap between the daily productivities and the baseline productivity provided a coefficient of variation of 8.2% which produced a better labour performance (pwi) of 0.115 compared to 0.547 obtained for project 2.

4.4.4 Floor Tiling Activity:the variability in daily labour productivity of floor tilingtask for project 5 is shown inFigure 4.14.The variability computation was performed for each of the projects examined (Appendix IV). It was determined from input to output relationship.The computed values of coefficient of variation for concreting activity range from 0.108to 0.576. This is similar to the earlier computation which is the product of the standard deviation divided by the mean of the estimate.

The days observed forfloor tiling activity is illustrated inAppendix V showing, the gang size, work hours, daily quantity, daily labour productivity, baseline days and abnormal days. The concreting task observed in the project was done for sixteen days. The total crew size utilized to piece together 547.55 square metreof floor tiling work was 94work men with a total work hours of 679hrs. This indicates that the construction firm used one site worker to achieve approximately 5.825m^2 of floor tiling. The daily productivities ranged from 0.506to 2.10whr/m^2. The floor tiling work has a cumulative productivity of 1.156whr/m^2.This indicates that labour input was fairly low since this cumulative productivity is greater than

unity. The following days5, 7, 9, 10, and 14 were selected as baseline days for floor tiling task. These are the highest productivity scores that were considered to define the baseline subset forfloor tiling activity. The average of these five figures (0.525, 0.506, 0.506, 0.533, and 0.600whr/m^2) represents the expected benchmarkfor the project which is calculated to be 0.534whr/m^2.

The project waste index which provides a measure of labour performance was found to be 0.708 which is the worst pwi of all projects investigated. The pwi figure is high therefore showing a poor labour performance for project 5. A close look at Figure 4.14 also showed some level of gap between daily labour productivities and the baseline productivity which was found to be 45.20% coefficient of variation. This level of variation shows some level of improvement on labour performance. There is disparity in the values of daily labour productivity and the baseline productivity resulting in poor labour performance. Project 54 in Figure 4.18 for floor tiling activity shows a better performance with daily productivity close to the baseline productivity value. The baseline productivity for the project was calculated to be 1.011whr/m^2.

Also it was observed that the gap between the daily productivities and the baseline productivity provided a coefficient of variation of 10.80% which produced a better labour performance (pwi) of 0.122 compared to 0.708 found for project 5.

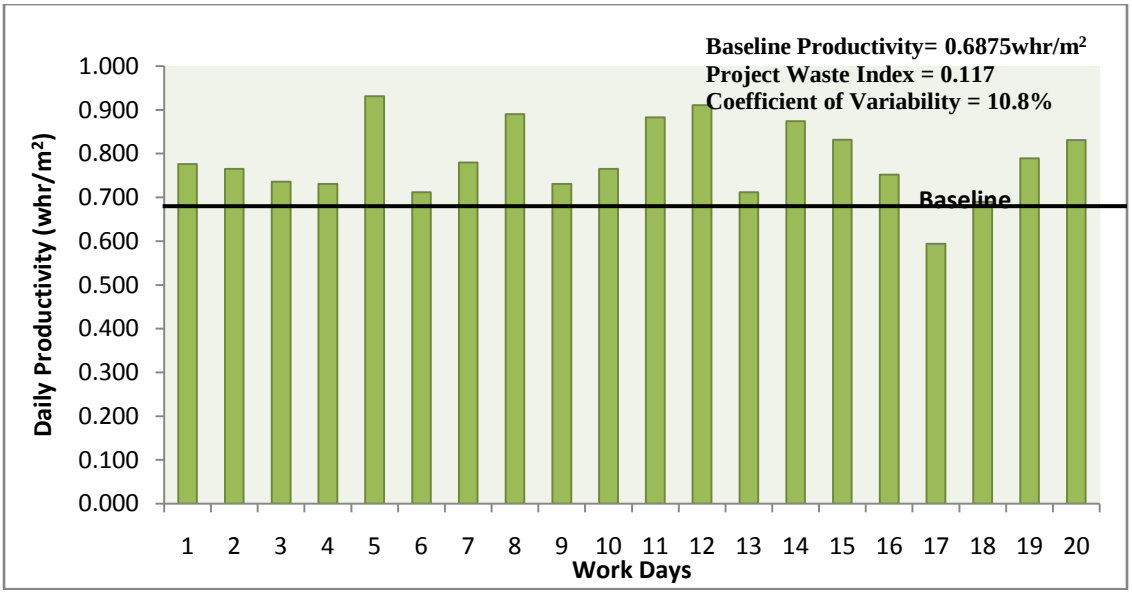

Figure 4.15 Best relationships of daily labour productivity, baseline productivity and performance for block work activity (Project 49)

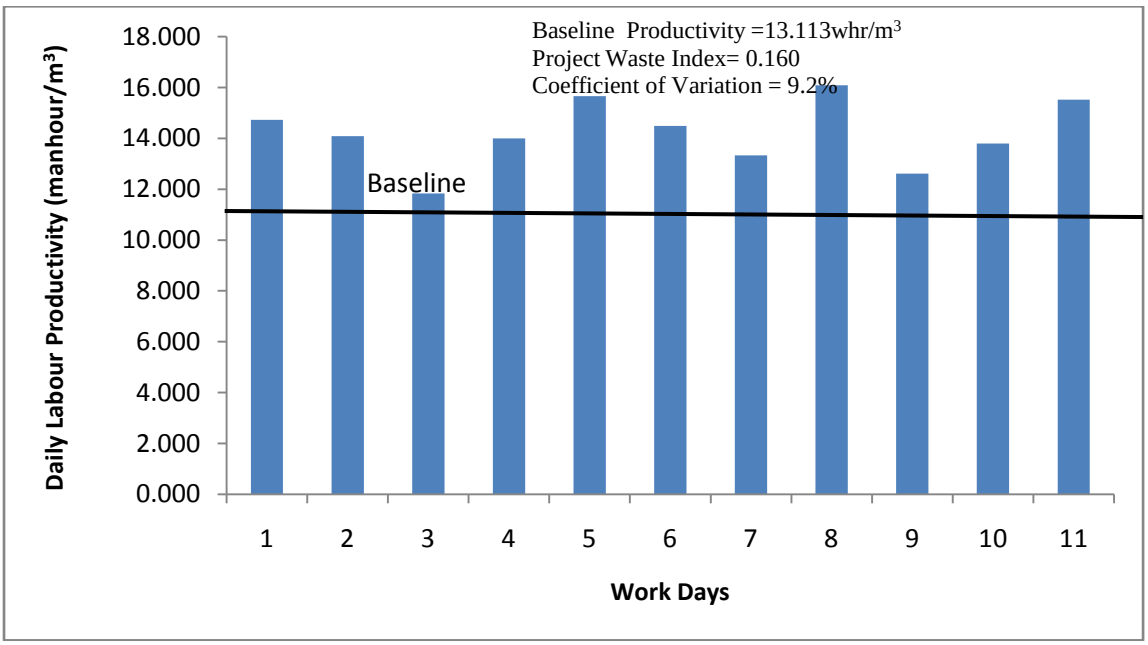

Figure 4.16 Best relationships of daily labour productivity, baseline productivity and performance for concrete work activity (Project 60)

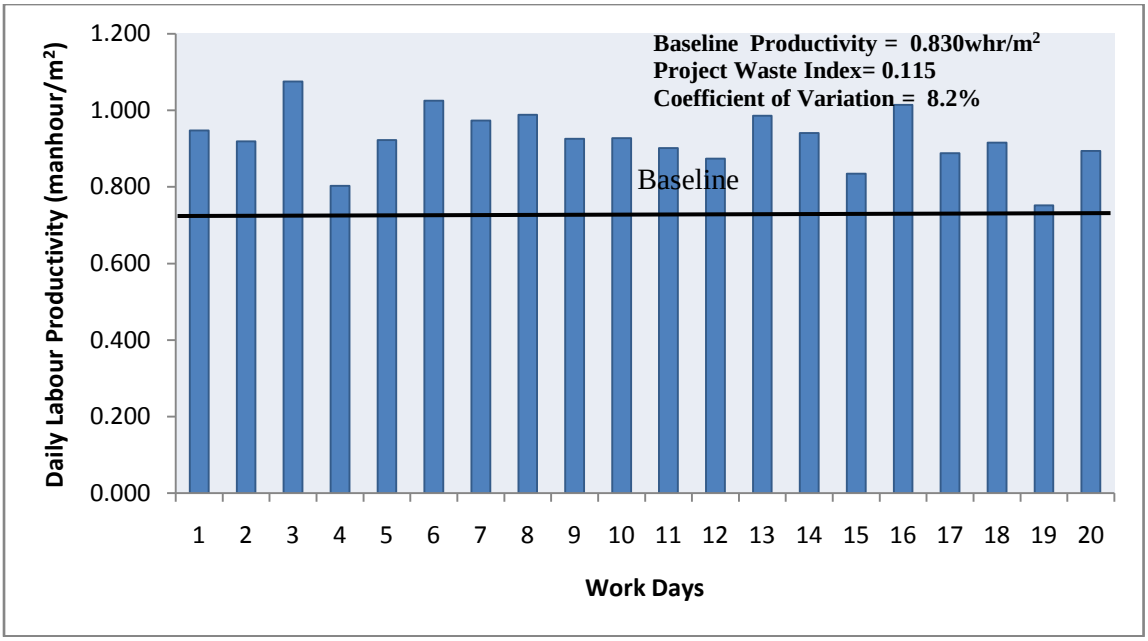

Figure 4.17 Best relationships of daily labour productivity, baseline productivity and performance for wall plastering activity (Project 56)

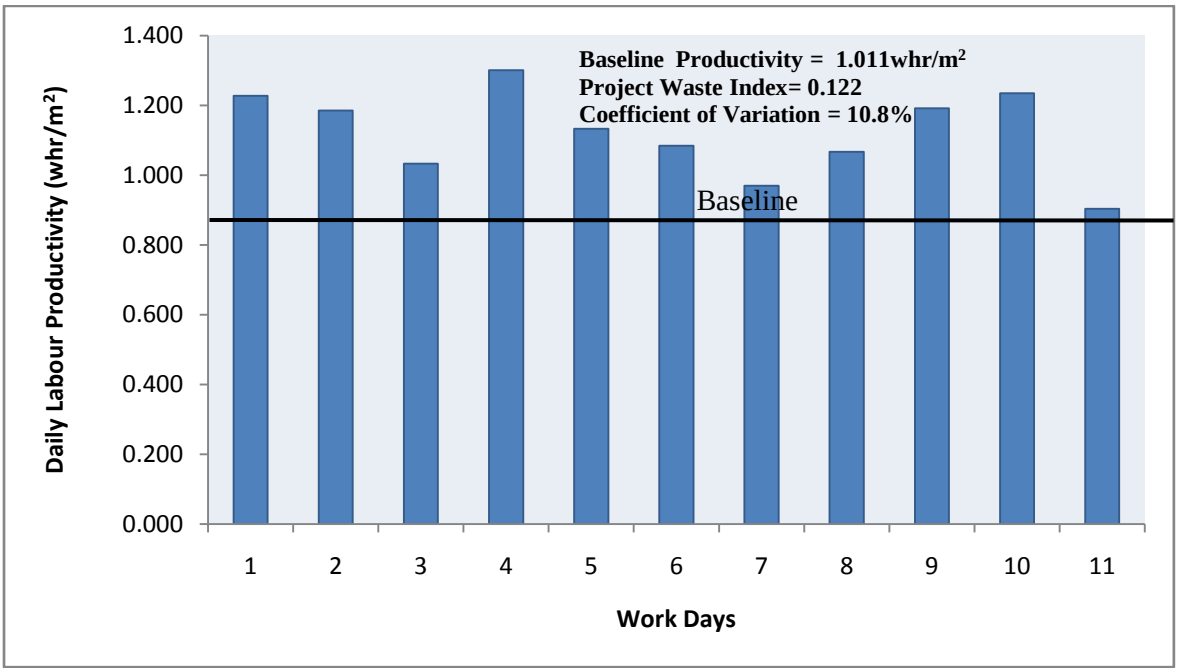

Figure 4.18 Best relationships of daily labour productivity, baseline productivity and performance for floor tiling activity (Project 54)

4.4.5 Summary: The assessment of variability is achieved by measuring the variations in daily labour productivity rates over the period of the projects. This assessment has been

carried out in this section. Considering the results of individual projects for all 244 sites (Appendix v) for all the selected site activities investigated, it was observed that the analysis demonstrated various degrees of variability in daily labour productivity.The mean variability for each of the site activities namely block laying, concreting, wall plastering and floor tiling were found to be 35.21%, 28.26%, 37.76% and 36.43% respectively. These results compete favourably with those of previous studies which were found to be 34%, 105%, 28% and 20% for block laying, concreting, wall plastering and floor tiling respectively. Although the result for concrete exhibited large disparity from the present research, it was judged that the data range used was too wide. That is the difference between the minimum and maximum values of data. This to a large extent affected the level of variability.

The level of variations indaily productivities of all site activities examined showed ample rooms for labour performance improvement. This means that the extent of gaps between the daily productivities and the baseline productivity were dependent on the level of the coefficient of variability. It was also found out that the closer the values of daily labour productivity to the baseline productivity the better the labour performance.This is evidenced with some of the projects that performed well which have low pwi values. Which means reducing variability improves labour performance. Therefore, this supports the lean theory of improving performance by reducing variability in labour productivity.

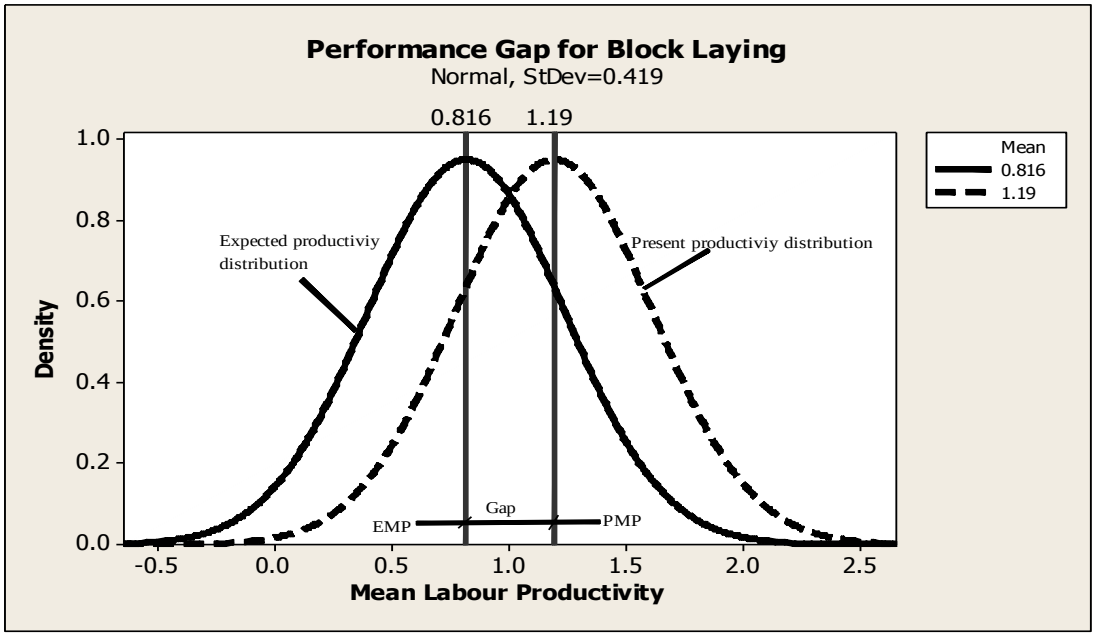

Figure 4.19 Normal Distribution Plot of Performance Gap for Block Laying

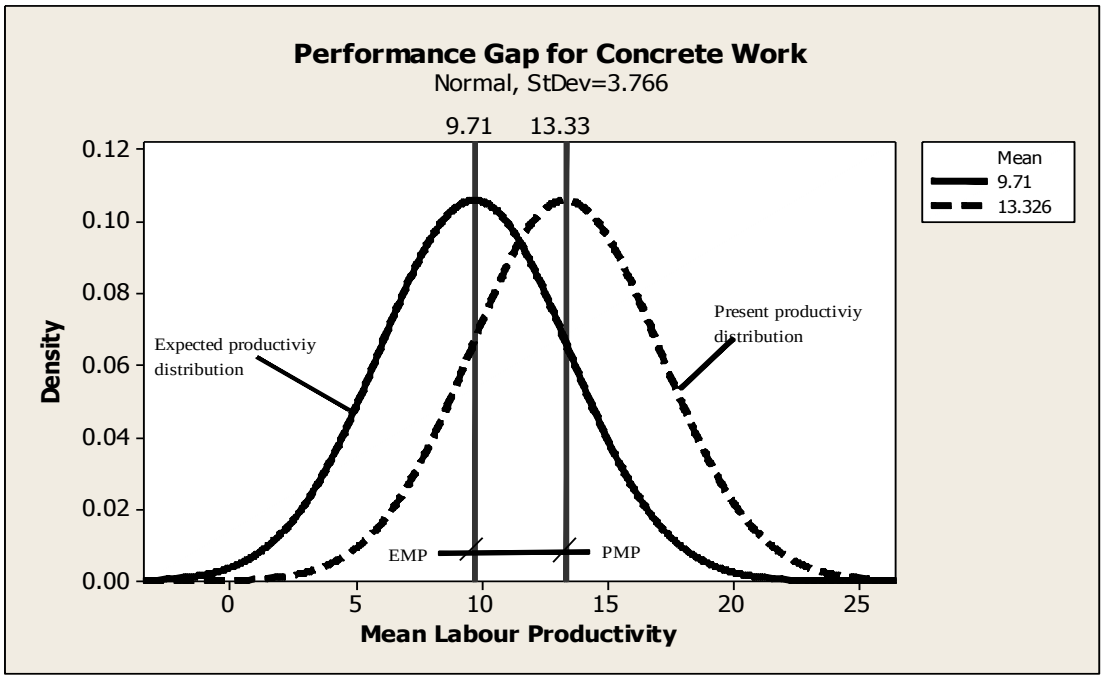

Figure 4.20 Normal Distribution Plot of Performance Gap for Concrete Work

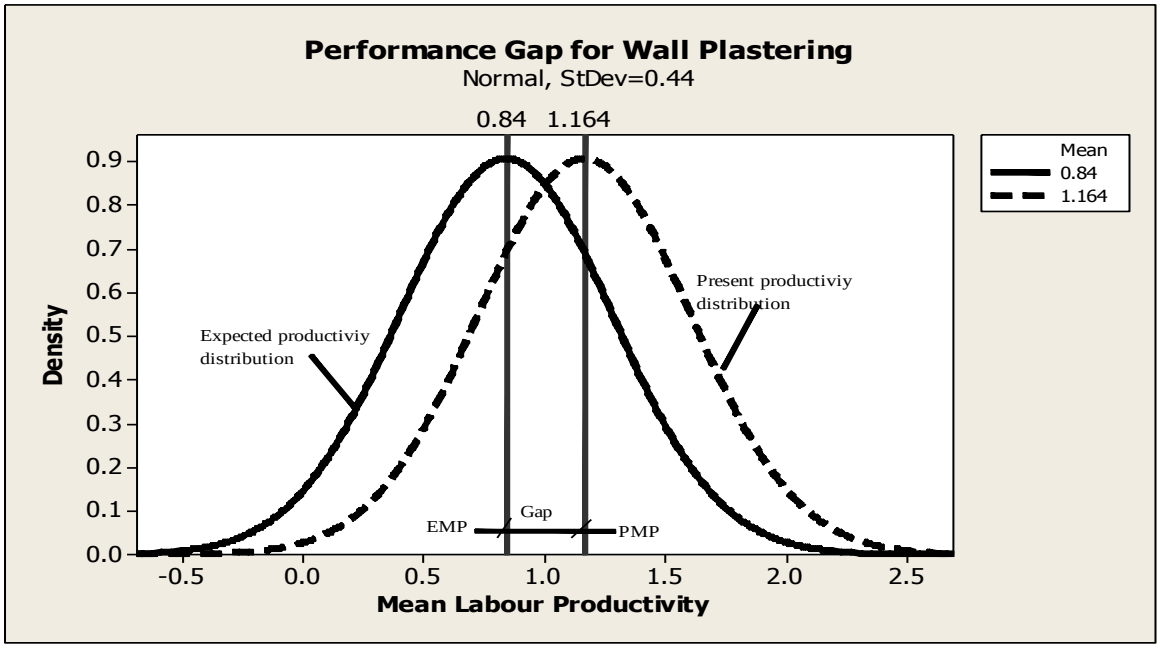

Figure 4.21 Normal Distribution Plot of Performance Gap for Wall Plastering

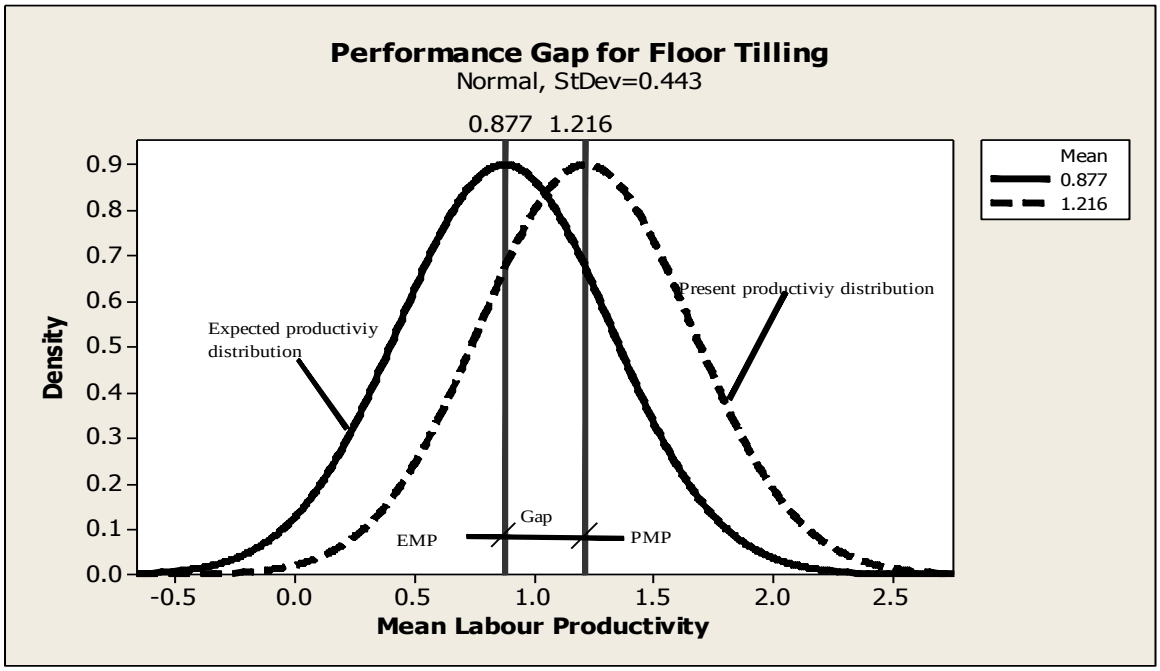

Figure 4.22 Normal Distribution Plot of Performance Gap for Floor Tiling Activity

4.5. PERFORMANCE IMPROVEMENT GAP MEASUREMENT

The target performance improvement gaps of all the site activities examined in this study are shown in Figures 4.19, 4.20, 4.21 and 4.22 for block laying, concrete work, wall plastering

and floor tiling activities respectively. The distributions define the productivity variability which provides opportunity for improvement. The target performance improvement gap, which is as a result of variability is assessed or quantified by determining the difference between expected mean productivity (EMP) (which is the mean baseline productivity) and present mean productivity (PMP). The wider the gap between PMP and EMP the bigger the value of thetarget performance improvement gap.

The performance improvement gap values for block laying, concrete work, wall plastering and floor tiling were found to be 0.374 man hrs/m^2, 3.62 man hrs/m^3, 0.324 man hrs / m^2 and 0.339 man hrs / m^2 respectively. The process performance improvement can be achieved by adjusting the group of variables that mainly influence the performance indicator. Thereforereducing these performance gap values could mean a significant improvement in performance, profit and productivity for builders and contractors.

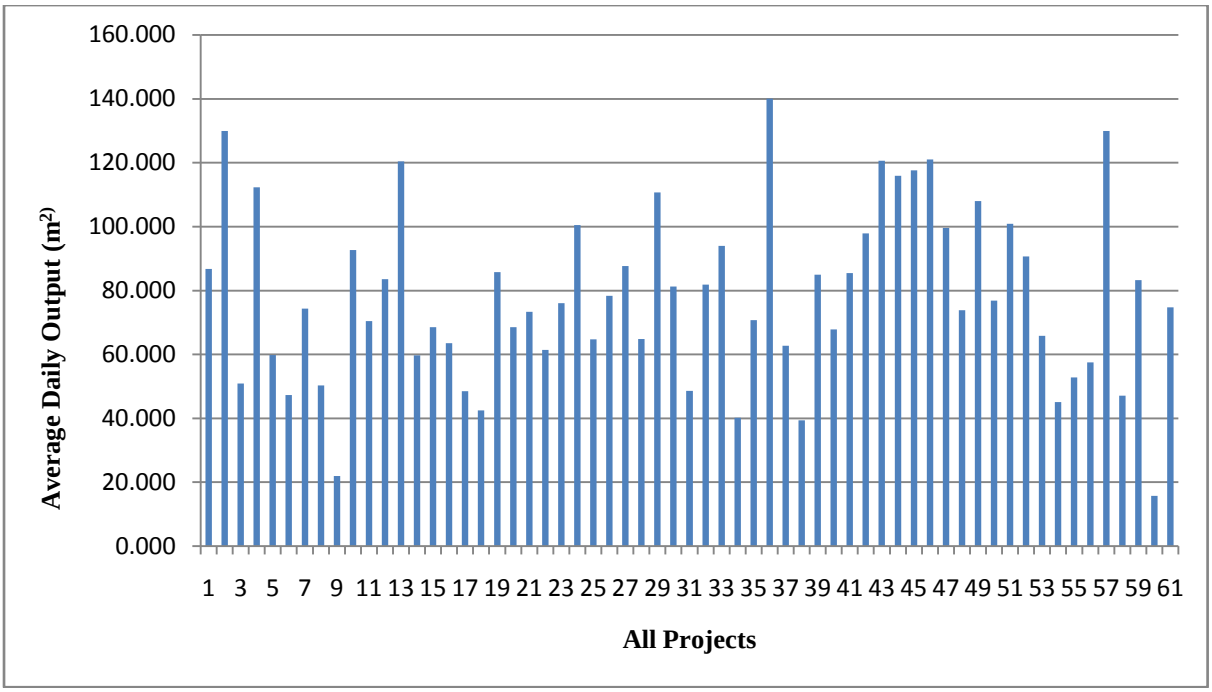

Figure 4.23 Variation in Average Daily Quantities for all Projects for Block work Activity

4.6 VARIATION IN AVERAGE DAILY QUANTITIES FOR ALL PROJECTS

Figures 4.23, 4.24, 4.25 and 4.26 show the average daily output for each project investigated for the four activities which are blockwork, concrete work, wall plastering and floor tiling activity. The graphs further showed that variability existed at various degrees in the daily construction output due to principally fluctuating labour input. Apart from labour productivity variability, construction output forms another source of variability in construction management. Considering the descriptive analysis in the figures mentioned above, block work had the lowest and highest average daily quantities of 18m2 and 140m2 from project sites 60 and 36 respectively, while in concreting work, projects 16 and 6 had lowest and highest average daily quantities to be 5.31m3 and 25.91m3 respectively. Wall plastering activity had thelowest and highest average daily quantities to be 18.15m2 and 161.65m2 for project numbers 26 and 32 respectively. Floor tiling work also had lowest and highest average daily output which are 10.80m2 and 81.03m2 for project sites 25 and 18 respectively (Table 4.3).

Table 4.3 Summary of Lowest and Highest Average Daily Quantities

S/N	Activity	Lowest Daily Quantity	Project Sites	Highest Daily Quantity	Project Sites
1	**Block laying**	**18m2**	**60**	**140m2**	**36**
2	**Concreting**	**5.31m3**	**16**	**25.91m3**	**6**
3	**Wall Plastering**	**18.15m2**	**26**	**161.65m2**	**32**
4	**Floor Tiling**	**10.80**	**25**	**81.03m2**	**18**

Source: Researcher's data analysis 2012

The level of variability shown in each of the graphs is a measure or demonstration of work flow variability which is measured or presented in this study as daily construction output. Variations in construction output provide a measure of level of work flow variability.

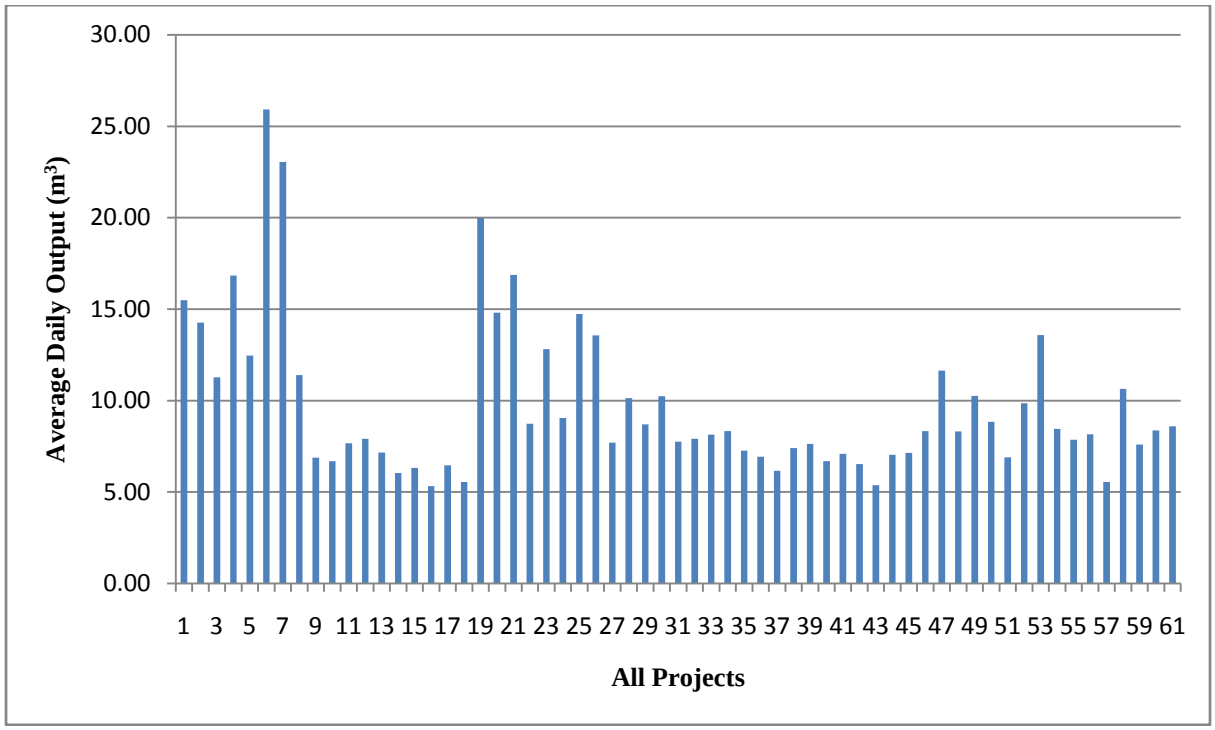

Figure 4.24Variation in Average Daily Quantities for all Projects forConcrete work Trade

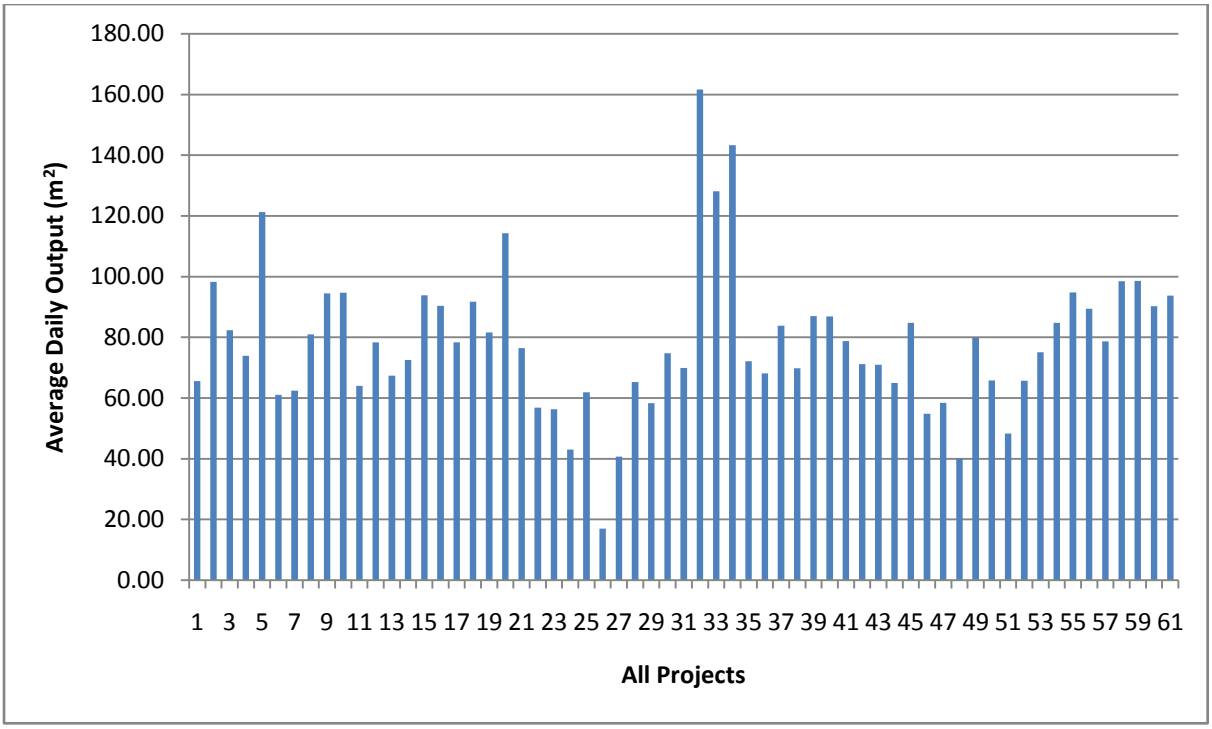

Figure 4.25Variation in Average Daily Quantities for all Projects forPlastering work

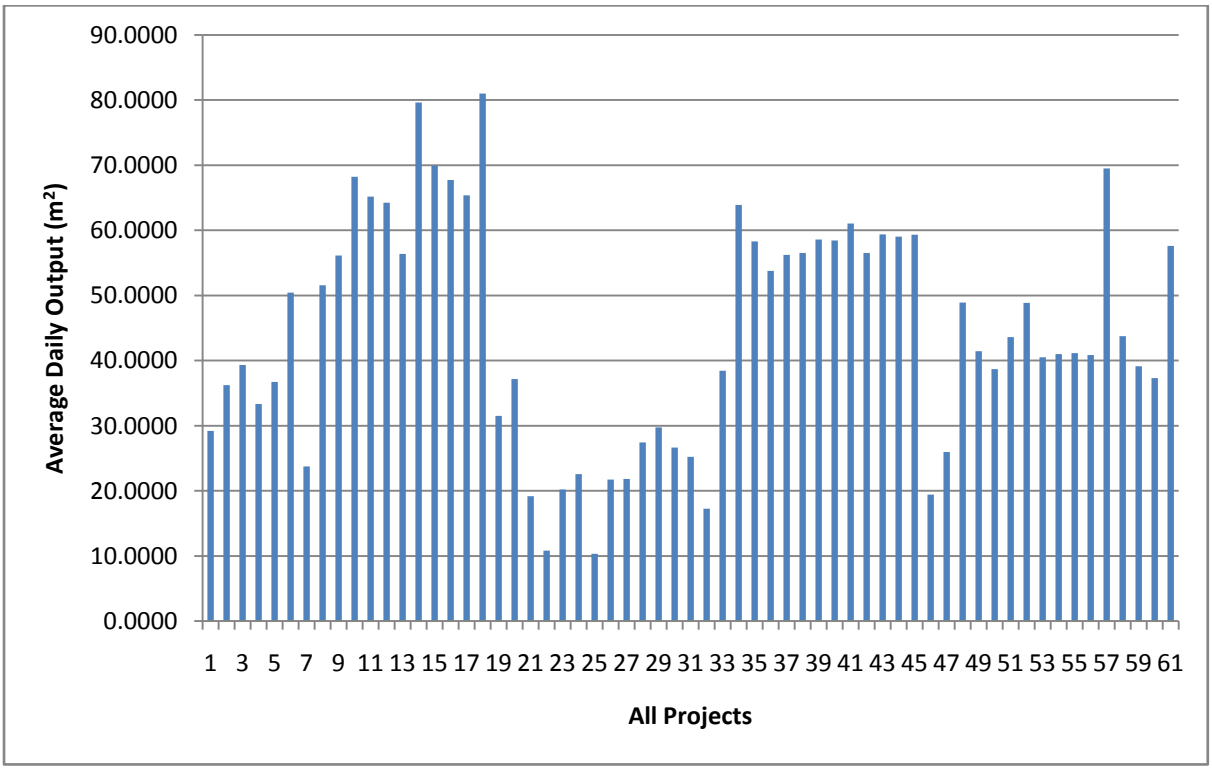

Figure 4.26Variation in Average Daily Quantities for all Projects forFloor Tiling work

4.7. THE RELATIONSHIP BETWEEN COEFFICIENT OF VARIABILITY AND PERFORMANCE (PWI)

4.7.1 Block Laying

Statistical tests were conducted to ascertain or measure the effect of productivity variability on performance forblock laying.

4.7.1.1 Construction Output

The values of coefficient of variation for construction output are shown in Appendix iv. These values and that of performance (PWI) were tested for any significant relationship. The correlation between the two variables was computed as 0.278 which was highly significant at 0.01 confidence level. The implication of this analysis with a coefficient of variation of 0.278 is that the variability in daily construction output has a weak or low correlation relationship with the project performance. Therefore the correlation coefficient obtained from this analysis confirms the earlier study that daily construction output and performance have minimal relationship. Furthermore, it appears from the test result that reducing variability in production output in order to improve performance has an insignificant or no effect on performance.

4.7.1.2 Labour Productivity

The figures calculated for coefficient of variation for labour productivity are shown in Appendix vi. The values for coefficient of variation in labour productivity range from 0.109 to 0.757. These values and the performance indexes calculated for all projects were tested for correlation analysis. The coefficient of correlation for the two variables was found to be 0.630, which is significant at 0.01 confidence level. The implication of this test result is that the variability in daily labour productivity is more highly correlated to project performance than construction output earlier determined. Furthermore, the result of the analysis shows that reducing variability in labour productivity appears to have a critical effect on performance.

Linear analysis of the two variables showed a coefficient of determination of 0.40, which means that 40% variation in crew performance is accounted for by variability in labour productivity. The linear equation is

Pwi=0.08424 + 0.9732x (4.1)

The equation has a model probability value (P-value) = **0.001**

From the linear model shown in Figure 4.27 it has an intercept of 0.08424 and for every increase of one unit of variability in labour productivity there is an increase of about **0.9732** in performance.Further analysis was carried out to ascertain the best predictive curve fit for

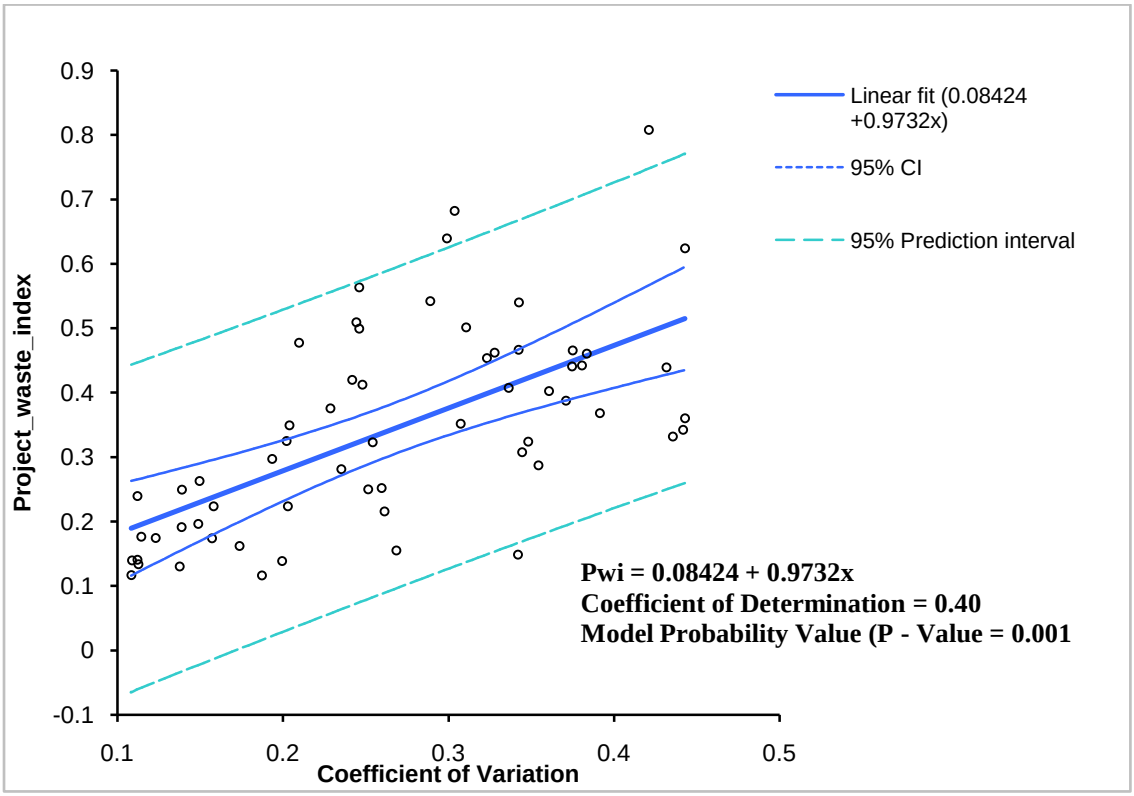

Figure 4.27 Linear Regression Model for Block Laying

the model, it was found out that the second order polynomial gave an improved coefficient of determination $\mathbf{R^2}$ of **0.44** with an equation model

Pwi = -0.1267 + 2.803x - 3.404x^2 (4.2)

The equation has a model probability value (P-value) = **0.001**

From the equation model in Figure 4.28, the intercept on Y axis is **-0.1267** and for every increase of one unit of variability in labour productivity there is an increase of about **2.803** in performance. But it was observed that for every unit increase in variability in labour productivity raised to the power of two, there is a decrease of about **-3.404** in performance. The model revealed that most of the data points fell within the 95% prediction interval point.

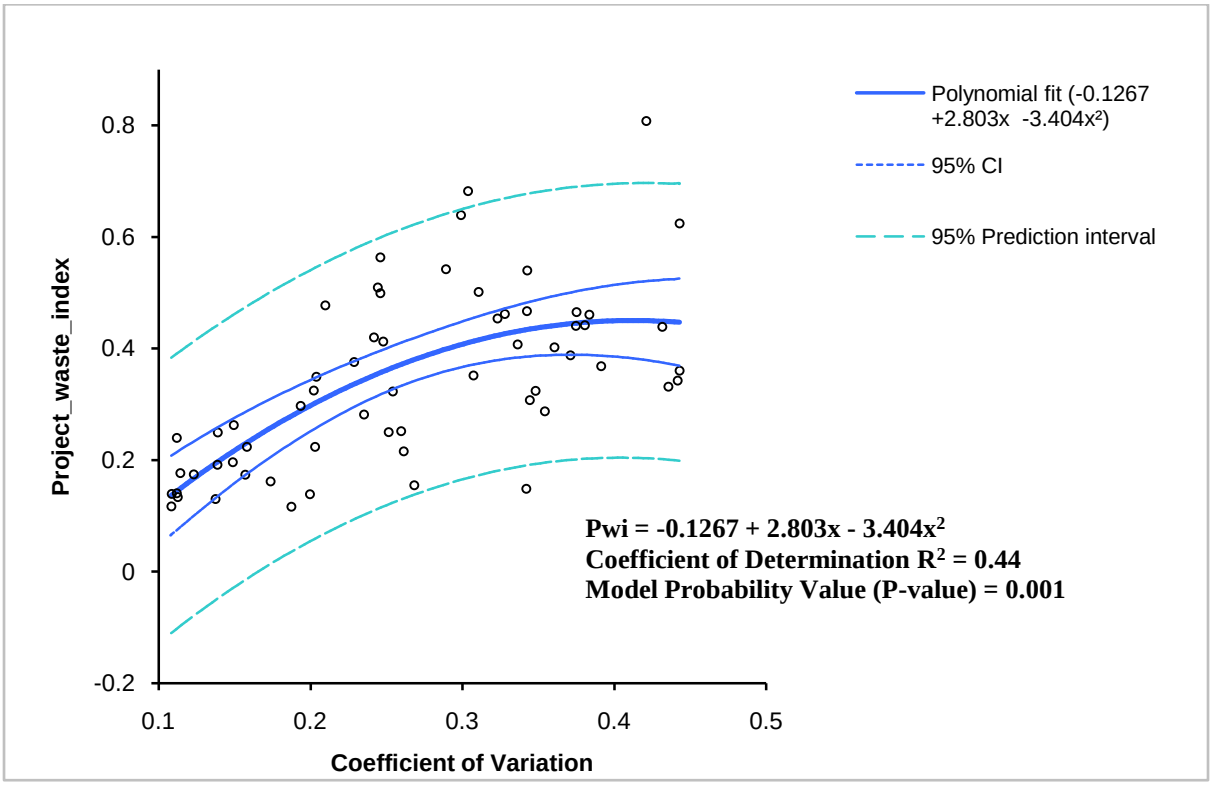

Figure 4.28 Best Curve Fit PolynomialRegression Model for Block Work Trade

The independent variables (work flow and labour productivity) were entered against the dependent variable to determine the effect of the two variables on performance. The coefficient of determination (**R^2**) was calculated to be **0.401,** which was significant at 0.001 with an equation model of,

Pwi = 0.99 – 0.64covquant + 1.034covlp (4.3)

Where: covquant = Coefficient of Variability for construction output

Covlp = Coefficient of Variability for labour productivity

The observation here is that the value of the coefficient of determination obtained from the multiple regression is the same with that of linear regression analysis conducted earlier for the two variables. The implication of this is that either of the two equation models could be used to predict the behaviour of crew performance. But a polynomial best curve fit analysis conducted showed a higher relationship with a coefficient of determination of **0.44.** The multiple regression analysis was found to have a lower significant effect on performance compared to the single variable, polynomial best curve fit analysis, of labour productivity variability thus single polynomial variable effect is proposed for the assessment of variability effect on performance.

4.7.2. Concrete Activity

4.7.2.1 Construction Output

The values of coefficient of variation for construction output are shown in Appendix iv. These values and that of performance (PWI) were tested for any significant relationship. The correlation between the two variables was computed as -0.229 which was not significant. The implication of this analysis with a coefficient of variation of -0.229 is that the variability in daily construction output has no correlation relationship with the project performance. Therefore the correlation coefficient obtained from this analysis confirms the earlier study that daily construction output and performance have minimal or no relationship. Furthermore, it appears from the test result that reducing variability in production output in order to improve performance has an insignificant or no effect on performance.

4.7.2.2 Labour Productivity

The figures calculated for coefficient of variation for labour productivity are shown in Appendix vi. The values for coefficient of variation in labour productivity range from

0.09to0.48. These values and the performance indexes calculated for all projects were tested for correlation analysis. The coefficient of correlation for the two variables was found to be 0.601, which is significant at 0.01 confidence level. The inference from this result is that the variability in daily labour productivity is more highly correlated to performance

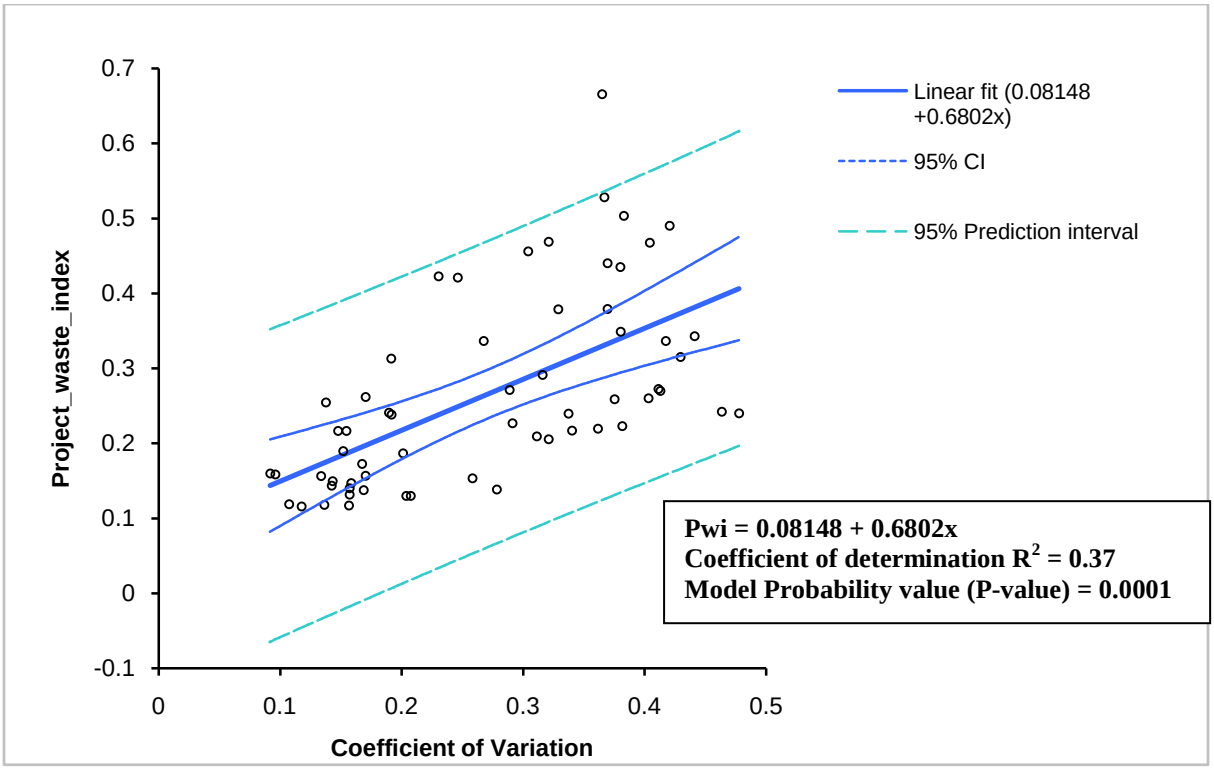

Figure 4.29 LinearRegression Model for Concreting

than construction output earlier determined.In addition, the result of the analysis shows that reducing variability in labour productivity appears to have a significant effect on performance.Linear regression analysis of the two variables showed a coefficient of determination for a linear relationship of about **0.37** which means that **37%** variation in crew performance is accounted for by variability in labour productivity.

The linear equation is

Pwi=0.08148+ 0.6802x (4.4)

The equation has a model probability value (P-value) = **0.02**

From the linear model shown in Figure 4.29 it has an intercept of **0.08148** and for every increase of one unit of variability in labour productivity there is an increase of about **0.6802** in performance.

Polynomial regression analysis was carried out to ascertain the best predictive curve fit for the model.It was found out that the second order polynomial gave an improved coefficient of determination $\mathbf{R^2}$ of **0.40** with an equation model

$$\mathbf{Pwi = -0.081 + 2.096x - 2.578x^2} \qquad (4.5)$$

The equation has a model probability value (P-value) = **0.001**

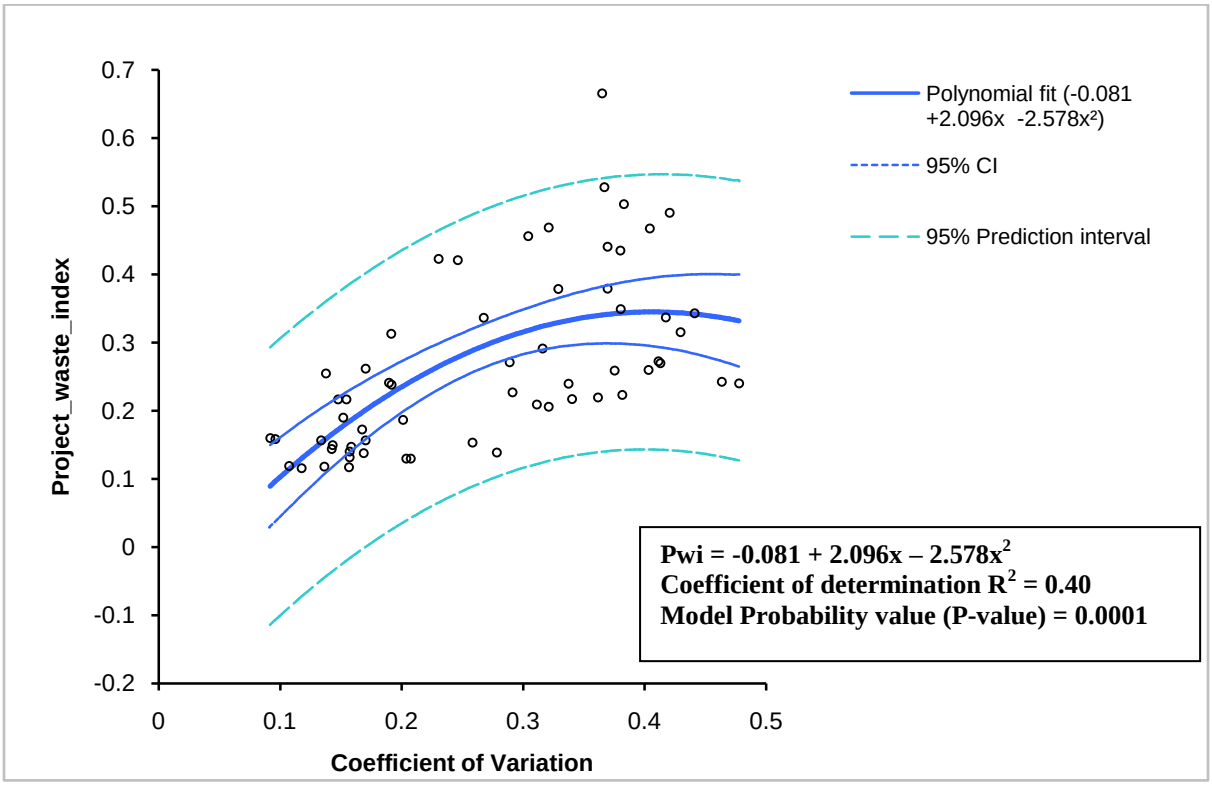

Figure 4.30 Best Curve Fit PolynomialRegression Model for Concreting

From the equation model in Figure 4.30, the intercept on Y axis is **-0.081** and for every increase of one unit of variability in labour productivity there is an increase of about **2.096** in Performance. But it was observed that for every unit increase in variability in labour

productivity raised to the power of two, there is a decrease of about **– 2.578** in Performance. The model revealed that most of the data points fell within the 95% prediction interval point.

The independent variables (work flow and labour productivity) were entered against the dependent variable to determine the effect of the two variables on performance. The coefficient of determination (**R^2)** was calculated to be **0.476,** which was significant at 0.001 with an equation model of,

Pwi = 0.213 – 0.216covquant + 0.747covlp (4.6)

The observation here is that the value of the coefficient of determination obtained from the multiple regression which is**0.476** ishigher than that of linear regression and thepolynomial best curve fit analysis conducted earlier on for the variableshaving a coefficients of determination of**0.37** and**0.40** respectively. The implication of this is that the multiple regressionequation model could be used to predict the behaviour of crew performance thus for concrete activity for single storey buildings, the combination of work flow variability and labour productivity variability could be used for the assessment of variability effect on performance.

4.7.3 Wall Plastering Activity

4.7.3.1 Construction Output

The values of coefficient of variation for construction output are shown in Appendixiv. These values and that of performance (PWI) were tested for any significant relationship. The correlation between the two variables was computed as 0.521 which was highly significant at 0.01 confidence level. The implication of this analysis with a coefficient of variation of 0.521 is that the variability in daily construction output has a strong correlation relationship with the project performance. Therefore the correlation coefficient obtained from this analysis confirms the fact that daily construction output and performance have significant relationship.

Furthermore, it appears from the test result that reducing variability in production output in order to improve performance has a significant effect on performance. The effect of construction output variability is measured by computing the coefficient of determination which was found to be 0.271.This means that 27% variation in crew performance is accounted for by variability in construction output.

4.7.3.2 Labour Productivity

The figures calculated for coefficient of variation for labour productivity are shown in Appendix vi. The values for coefficient of variation in labour productivity range from 0.115 to 0.547. These values and the performance indexes calculated for all projects were tested for correlation analysis. The coefficient of correlation for the two variables was found to be **0.764**, which is significant at 0.01 confidence level. The implication of this test result is that the variability in daily labour productivity is more highly correlated to project performance than construction output earlier determined. Furthermore, the result of the analysis shows that regulating variability in labour productivity appears to have a critical effect on performance. Thecoefficient of determination from a linear regression was found to be **0.58**, which means that **58%** variation in crew performance is accounted for by variability in labour productivity.The linear model is found in Figure 4.31. The linear equation is

Pwi= 0.07478 + 0.6192x **(4.7**)

The equation has a model probability value (P-value) = **0.0002**

Polynomial regression analysis conducted to determine the best curve fit for the relationship of the two variables showed a coefficient of determination of **0.67**. This means that **67%** variation in crew performance is accounted for by variability in labour productivity.

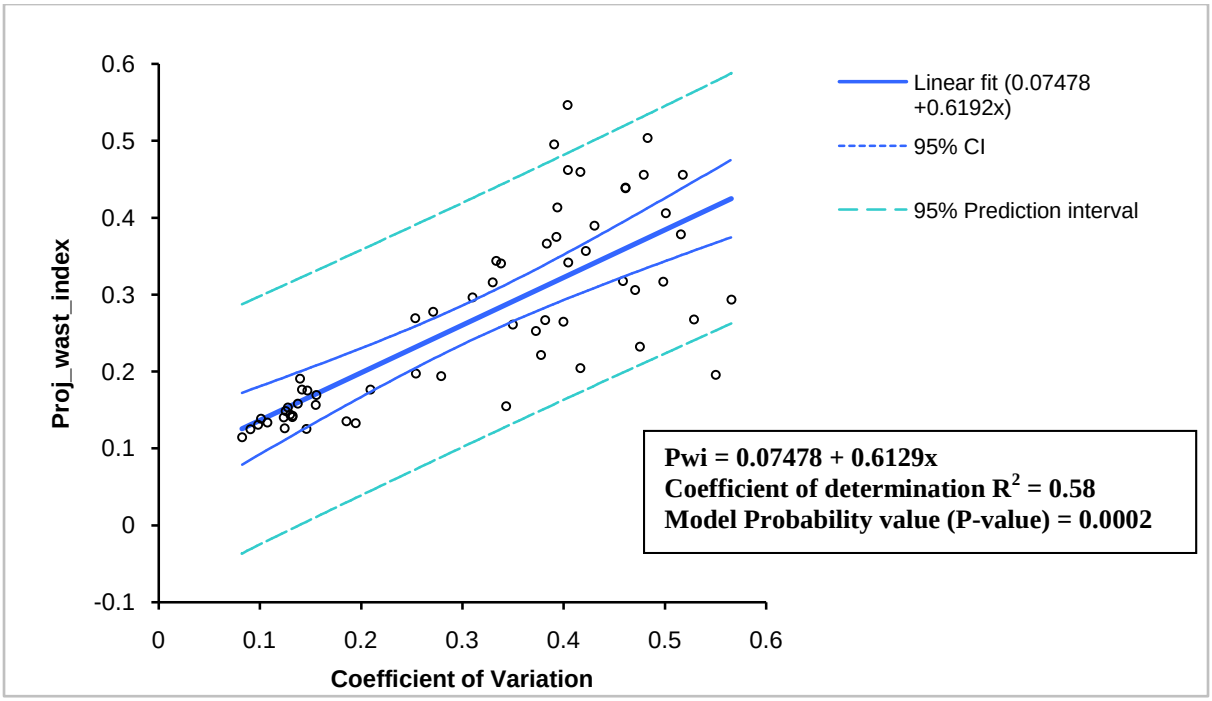

Figure 4. 31 Linear RegressionModel for Wall Plastering

Additional analysis was carried out to ascertain the best predictive curve fit for the model, it was found that the second order polynomial gave an improved coefficient of determination $\mathbf{R^2}$ of **0.67** with an equation model

$$\mathbf{Pwi = 0.2792 - 2.407x + 12.05x^2 + 13.81x^3} \quad (4.8)$$

The equation has a model probability value (P-value) = **0.001.**

From the equation model in Figure 4.32the intercept on Y axis is **0.2792** which means that for every increase of one unit of variability in labour productivity there is a decrease of about **2.407**in Performance. But it was observed that for every unit increase in variability in labour productivity raised to the power of two, there is anincrease of about **12.05** in Performance.

It wasfurther noticed that for everyunit change in variability in labour productivity raised to the third power, there is anincrease of about **13.81** in performance. The model revealed that most of the data points fell within the 95% prediction interval point.

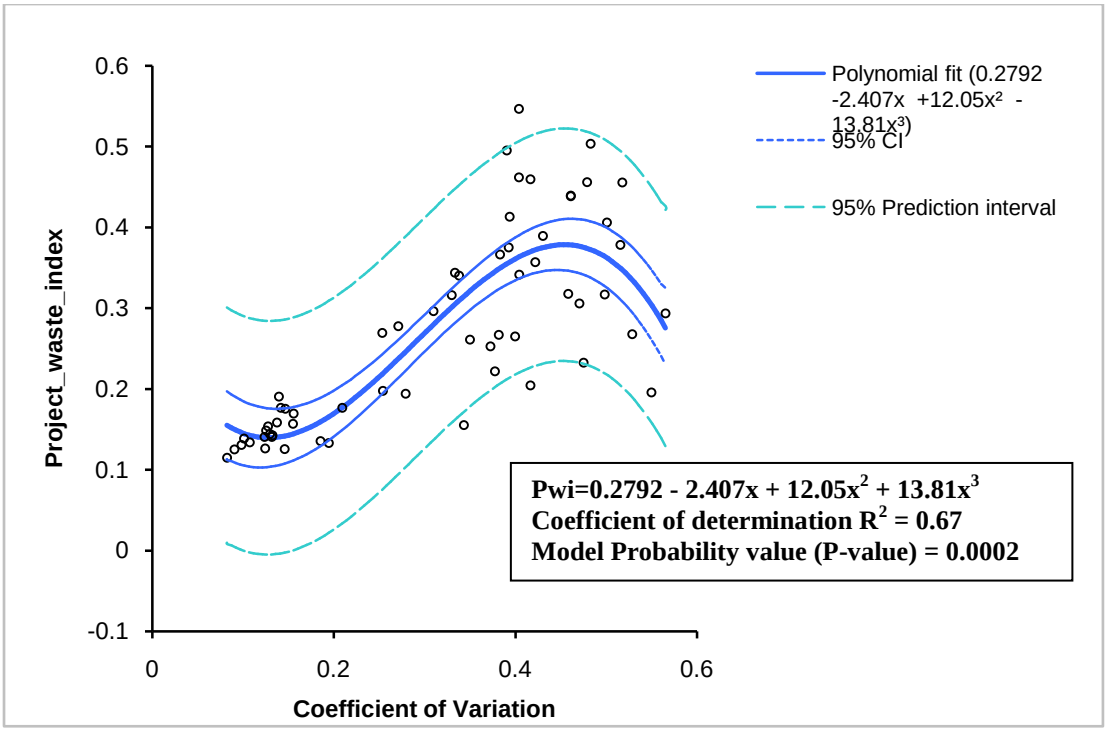

Figure 4.32Best Curve Fit Polynomial Regression Model for Wall Plastering

Further exploration using multiple regression for the above analysis revealed that entering the two variables, in order to test the combined effect of construction output andlabour productivity, into the equation gives a coefficient of determination of **0.58** which was significant at 0.001 with an equation model of

Pwi = 0.07736 – 0.01567covquant + 0.6299covlp (4.9)

The observation here is that the value of the coefficient of determination obtained from multiple regression is the same as that of linear regression analysis conducted earlier for the two variables. The implication of this is that either of the two models could be used to predict the behaviour of crew performance. But a polynomial best curve fit analysis conducted showed a higher effect orrelationship with a coefficient of determination of **0.67**as shownin Figure 4.32**.**

4.7.4 Floor Tiling Activity.

4.7.4.1 Construction Output

The values of coefficient of variation for construction output are shown in Appendix iv. These values and those of performance (PWI) were tested for any significant relationship. The correlation between the two variables was computed as 0.530 which was highly significant at 0.01 confidence level. The implication of this analysis with this level of correlationcoefficient is that the variability in daily construction output has a strong correlation relationship with the project performance. Therefore the correlation coefficient obtained from this analysis is contrary to the earlier study that daily construction output and performance have minimal relationship. Furthermore, it appears from the test result that reducing variability in production output in order to improve performance has a significant effect on performance.

4.7.4.2 Labour Productivity

The figures calculated for coefficient of variation for labour productivity are shown in Appendix VI. These values of coefficient of variation and the performance indexes calculated for all projects were tested for correlation analysis. The coefficient of correlation for the two variables was found to be 0.588, which is significant at 0.01 confidence level. The implication of this test result is that the variability in daily labour productivity is more highly correlated to project performance than construction output as earlier determined. Furthermore, the result of the analysis shows that reducing variability in labour productivity appears to have a critical effect on performance.

Further linear regression analysis of the two variables showed a coefficient of determination of about **35%**, which means that **35%** variation in crew performance is accounted for by variability in labour productivity. The linear model is presented in Figure 4.33. The linear equation is

Pwi= 0.092 + 0.5584x **(4.10)**

The equation has a model probability value (P-value) = **0.008**

From the equation model in Figure 4.33, the intercept on Y axis is **0.092**and for every increase of one unit of variability in labour productivity there is an increase of about **0.5584** in performance. Polynomial regression analysis conducted to determine the best curve fit for the relationship of the two variables showed a coefficient of determination of **0.44**. This means that **44%** variation in crew performance is accounted for by variability in labour productivity.

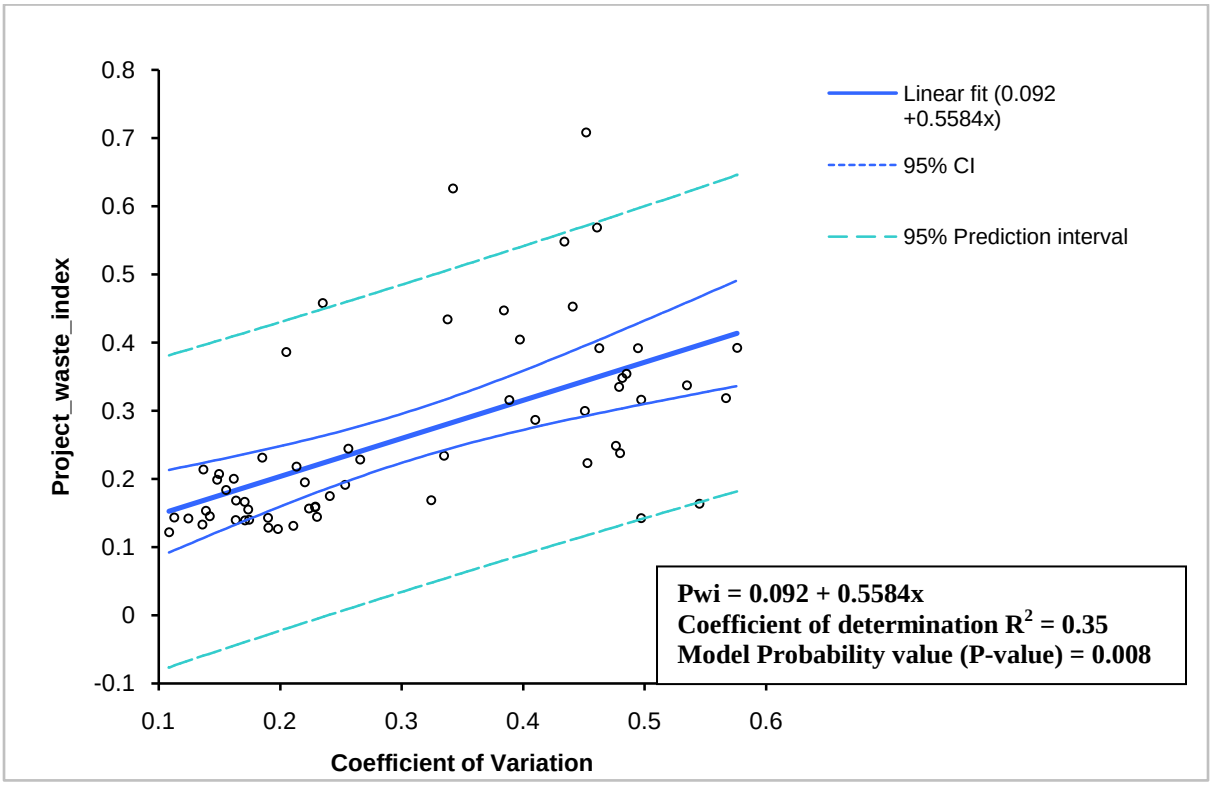

Figure 4. 33 LinearRegression Model for Floor Tiling

Additional analysis was carried out to ascertain the best predictive curve fit for the model, it was found out that the second order polynomial gave an improved coefficient of determination $\mathbf{R^2}$ of **0.44** with an equation model

Pwi = 0.1983 - 1.40x + 9.232x^2 – 11.57x^3 **(**4.11)

The equation has a model probability value (P-value) = **0.001.**

From the equation model in Figure 4.34, the intercept on Y axis is **0.1983**and for every changein one unit of variability in labour productivity there is adecrease of about **1.40** in performance. But it was observed that for every unit increase in variability in labour productivity raised to the power of two, there is anincrease of about **9.232** in performance.

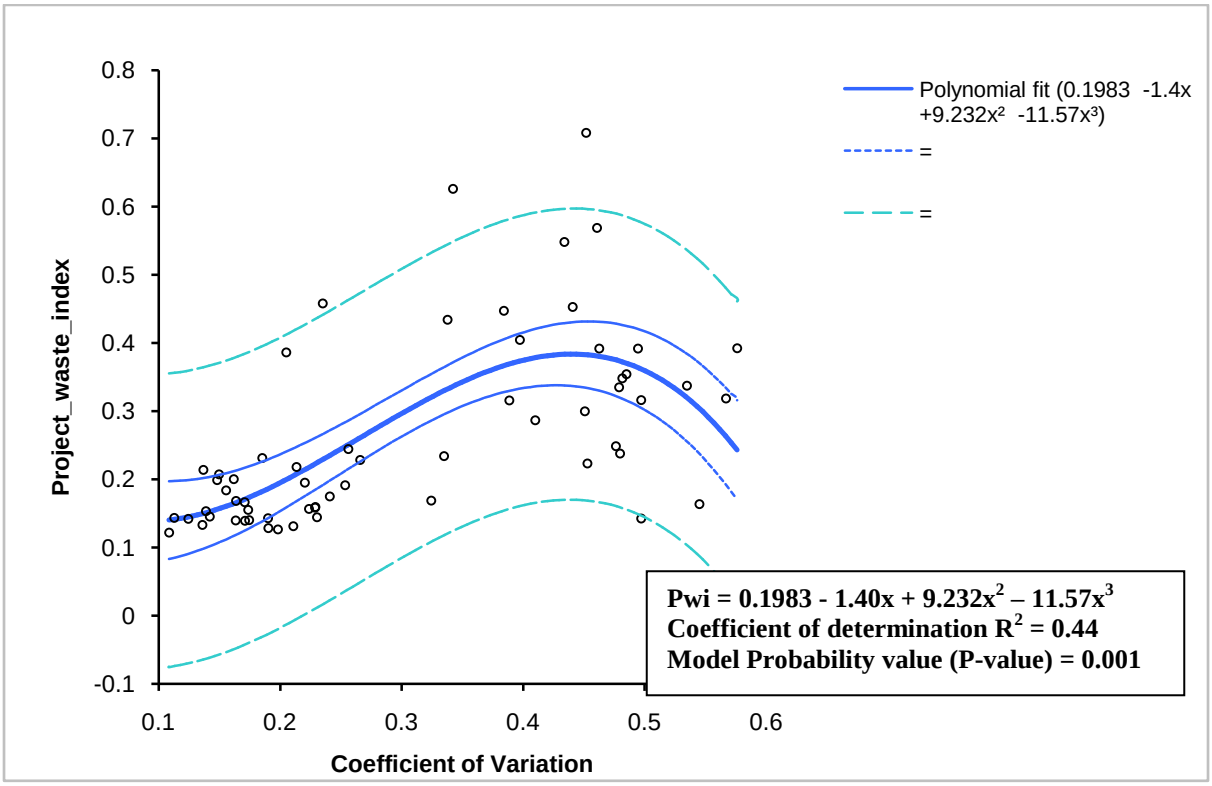

Figure 4. 34 Best Curve Fit Polynomial RegressionModel for Floor Tiling

It wasfurther noticed that for everyunit change in variability in labour productivity raised to the power of three, there is a decrease of about **11.57** in performance. The model revealed that most of the data points fell within the 95% prediction interval point.

A multiple regression test carried out revealed that inputting the two variablesinto the equation for the purpose of testing the combined effect of construction output andlabour

productivity, gives a coefficient of determination**(R^2)** of **0.372**which was significant 0.001 with an equation model of

Pwi = 0.047 - 0.221covquant + 0.405covlp (4.12)

It was note that the value of the coefficient of determination obtained from the multiple regression is slightly higher than that of linear regression analysis conducted (Figure 4.33) earlier on for the single variable. It also observed that the P-value was 0.123 which is higher than the significant level of 0.05, therefore the result cannot be used to predict the behaviour of crew performance. But a polynomial best curve fit analysis conducted showed a higher effect orrelationship with a coefficient of determination of **0.44** as shownin Figure 4.34**.**

Table 4.4 Summary of Analysis of all Building Trades Investigated

Statistics	Block work Trade	Concrete Trade	Wall Plastering Trade	Floor Tiling
N (Data Points)	1127	778	835	737
Mean (daily productivity)	1.19	13.326	1.164	1.162
Median	1.09	13.807	0.990	1.134
Std Deviation	0.419	3.766	0.440	0.443
Skewness	0.425	- 0.247	0.645	0.336
Range	2.17	15.71	1.650	1.70
Coefficient of Variation (COV)	35.21%	28.26%	37.76%	36.43%
Correlation between cov and project waste index (r)	0.630	0.601	0.764	0.588

Source; Researcher's analysis of Data 2012

Table 4.5 Comparing Results with Previous Studies

Activity Description	Sample Size	Mean Output whr/m^2	Standard Deviation	Skewness	Correlation Coeff. (r)	Coefficient of Variation	Cov for Previous Studies
Blocklaying	**1127**	**1.19**	**0.419**	**0.425**	**0.630**	**35.21%**	**34% Noor(1992)**
Concreting	**778**	**13.33**	**3.766**	**- 0.247**	**0.601**	**28.26%**	**105% Lema(1996)**
Wall Plastering	**835**	**1.164**	**0.440**	**0.645**	**0.764**	**37.76%**	**28% Noor(1992)**
Floor Tiling	**737**	**1.162**	**0.443**	**0.336**	**0.588**	**36.43%**	**20% Noor(1992)**

Source; Researcher's analysis of Data 2012

CHAPTER FIVE

SUMMARY,CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARYOF FINDINGS

(i) It was found out that among the critical factors affecting productivity negatively lack of experience, materials shortage and lack of working tools have high relative important indices of 67.94, 66.52 and 64.00 respectively.

(i) Other causes of variation in labour productivity include interruptions (>15 minutes) competence, overtime working (fatigue) and planned/unplanned increase in size of labourforce.

(iii) Correlation between project waste index (performance) and coefficient of variability for construction output for all tested building trades had the following results; block work = 0.278 ; concrete work = 0.229; plastering work = 0.521 and Tiling work = 0.530.

(iv) Correlation results show that there are strong associations between dependent variables projectwaste index (performance) and coefficient of variability for labour productivity which is the independent variable. The analysis yielded R values as follows,blockwork = 0.630; concrete work = 0.601; plastering work = 0.764 and Tiling work = 0.588. Therefore, the independent variables are thus found to be significant predictors of performance of site labour crew for all activities investigated.

(v) It was found that 44% variation in crew performance in block laying is accounted for by variability in labour productivity.

(vi) The coefficient of determination computed for concrete work activity showed that the effect of variability in labour productivity on performance is 37%.Which is the level of variation in crew performance for concrete work accounted for by variability in labour productivity.

(vii) The analysis on plastering work demonstrated that the coefficient of variability in labour productivity which is the independent variable as well as the predictor set, could account for 67% of the variability in crew performance in terms of labour productivity.

(viii) Tiling work as a predictor set, accounted for 44% of the variability in crew performance.

(ix) The effect of labour productivity variability on performance was observed to be greater than the combined effects of construction outputs and labour productivity variability on performance for all trades.

(x) Labour productivity gaps of 0.374 man hrs/m^2, 3.62 man hrs/m^3, 0.324 man hrs / m^2 and 0.339 man hrs / m^2 were observed for block, concreting, wall plastering and floor tiling respectively.

5.2 CONCLUSION

It has been discovered in this research that variability exist in daily labour productivity of cement based works on site in Nigeria to such a magnitude that is consistent with those of other developing countries such as Egypt and Kenya.

The correlation between work flow variability and performance was low for block laying and concrete activities while it was moderate for wall plastering and floor tiling activities. Similarly, the correlation between labour productivity and performance was highly significant for all selected site activities and therefore it is suggested that in measuring the impacts of variability on performance, emphasis should be placed on labour productivity variability instead of work flow or construction output variability. The values of variability in labour productivity were compared with the project performance (PWI) it was found out that the higher the values of labour productivity variability the poorer the performance. Also the

baseline productivities computed for all selected activities were compared with the mean labour productivities.

Performance gaps existed for all activities. This is an indication of opportunity for performance improvement in labour utilization for all site activities investigated. Thereforesite management of labour should close up performance gaps in managing cement based activities on site. Variability affects jobsite performance as established in this study. It varies across and within projects and also depends on management skill of site operatives. To improve the performance of jobsite labour therefore, labour variability should be reduced by the application of flexible capacity management.This suggests that reducing variability will bring Ifabout improvement in labour performance.

5.3 RECOMMENDATIONS ON PERFORMANCE IMPROVEMENT

(i) The effects of the critical factors identified in the study should be eliminated by engaging competent hands, maintaining steady flow of construction materials and ensuring that essential working tools are available, adequate and maintained.

(ii) The correlation between work flow variability and performance was found to be low for block laying and concrete activities while moderate for wall plastering and floor tiling activities.Therefore it is recommended that in measuring the impacts of variability on performance, emphasis should be placed on labour productivity variability instead of work flow or construction output variability.

(iii)The correlation between labour productivity and performance was discovered to be highly significant for all selected site activities therefore it is suggested that labour productivity variability be used to measure the impacts of variability on performance.

(iv) Thevariations in crew performance in all activities investigated were found to be as a result of variations in labour productivity.Therefore the following are suggested;

(a) Where there is growth and the output increases faster than input; the increase in input should be fairly proportionately less than the increase in output throughout the period of operation.

(b) labour input must be kept stable to increase output incentives plan must be in place.

(c) Determine to get more output with a reduction in input.

(d) For greater efficiency maintain same output with fewer inputs to reduce output variability.

(e) Where Output decreases, the decrease in input should be proportionately greater than the decrease in output.

(v) Multiple variables effect ofwork flow and labour productivity variability on labour performance was found to be lower than the single variable effect oflabour productivityvariability thus single variable effect is proposed in the assessment of variability effect on performance.

(vi) It is proposed that site managers should close up performance gaps in project execution by reducing the disparity in values between baseline productivity and the mean labour productivity for the project.

5.4 AREAS FOR FUTURE RESEARCH

(i) Investigate Variability from lean construction technique perspective using productivity data from productive time.

(ii) Developing distribution model for cement based materials employing the lean concept.

(iii) The research should be further investigated with the inclusion of other performance indices such as performance ratio and disruptive index.

(iv) Cement based materials should be further investigated with the inclusion of non cement based materials for the purpose of comparing the variability effects.

(v) The effects of labour productivity variability on jobsite labour performance were established as 44%, 40%, 67% and 44% for block laying, concreting, wall plastering and floor tiling respectively. These mean that these levels of variations in crew performance were accounted for by variability in labour productivity. The remaining percentages which are caused by other factors not considered in this study should be further investigated.

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APPENDIX I

Department of Building, Faculty of Environmental Design,
Ahmadu Bello University Zaria
(Research Survey)

SECTION A

Preliminary Information for Construction Managers/Supervisors

A1. Response Date…….....

A2. State the name of your establishment……

A3. Respondent Title (Please Indicate)…….

SECTION B

Factors affecting Labour Productivity

To what degree will the following factors affect labour productivity negatively in your firm during project execution?

ASTL01 Absenteeism among the site labourers

- ☐ 1 AFFECTS WITH LITTLE EXTENT
- ☐ 2 AFFECTS TO SOME EXTENT
- ☐ 3 AFFECTS WITH AVERAGE EXTENT
- ☐ 4 AFFECTS WITH LARGE EXTENT
- ☐ 5 AFFECTS WITH VERY LARGE EXENT

ACCD02 Accidents on site

- ☐ 1 AFFECTS WITH LITTLE EXTENT
- ☐ 2 AFFECTS TO SOMEEXTENT
- ☐ 3 AFFECTS WITH AVERAGE EXTENT
- ☐ 4 AFFECTS WITH LARGE EXTENT
- ☐ 5 AFFECTS WITH VERY LARGE EXTENT

CHSL04 Characteristics of site location.

- ☐ 1. AFFECTS WITH LITTLE EXTENT
- ☐ 2. AFFECTS TO SOMEEXTENT
- ☐ 3. AFFECTS WITH AVERAGE EXTENT

☐ 4. AFFECTS WITH LARGE EXTENT

☐ 5. AFFECTS WITH VERY LARGE EXTENT

INTER04 Confined working space.

☐ 1. AFFECTS WITH LITTLE EXTENT

☐ 2. AFFECTS TO SOMEEXTENT

☐ 3. AFFECTS WITH AVERAGE EXTENT

☐ 4. AFFECTS WITH LARGE EXTENT

☐ 5. AFFECTS WITH VERY LARGE EXTENT

INTER05 Distance of materials to work location

☐ 1 AFFECTS WITH LITTLE EXTENT

☐ 2 AFFECTS TO SOMEEXTENT

☐ 3 AFFECTS WITH AVERAGE EXTENT

☐ 4 AFFECTS WITH LARGE EXTENT

☐ 5 AFFECTS WITH VERY LARGE EXTENT

HEWD07 Height at which work is done

☐ 1. AFFECTS WITH LITTLE EXTENT

☐ 2. AFFECTS TO SOMEEXTENT

☐ 3. AFFECTS WITH AVERAGE EXTENT

☐ 4. AFFECTS WITH LARGE EXTENT

☐ 5. AFFECTS WITH VERY LARGE EXTENT

INTER08 Interference from other workers

☐ 1 AFFECTS WITH LITTLE EXTENT

☐ 2 AFFECTS TO SOMEEXTENT

☐ 3 AFFECTS WITH AVERAGE EXTENT

☐ 4 AFFECTS WITH LARGE EXTENT

☐ 5 AFFECTS WITH VERY LARGE EXTENT

LKLE09 Lack of Labour Experience

- ☐ 1. AFFECTS WITH LITTLE EXTENT
- ☐ 2. AFFECTS TO SOMEEXTENT
- ☐ 3. AFFECTS WITH AVERAGE EXTENT
- ☐ 4. AFFECTS WITH LARGE EXTENT
- ☐ 5. AFFECTS WITH VERY LARGE EXTENT

.

LKTE10 Lack of tools/equipment

- ☐ 1. AFFECTS WITH LITTLE EXTENT
- ☐ 2. AFFECTS TO SOMEEXTENT
- ☐ 3. AFFECTS WITH AVERAGE EXTENT
- ☐ 4. AFFECTS WITH LARGE EXTENT
- ☐ 5. AFFECTS WITH VERY LARGE EXTENT

MASG11 Material Shortages

- ☐ 1. AFFECTS WITH LITTLE EXTENT
- ☐ 2. AFFECTS TO SOMEEXTENT
- ☐ 3. AFFECTS WITH AVERAGE EXTENT
- ☐ 4. AFFECTS WITH LARGE EXTENT
- ☐ 5. AFFECTS WITH VERY LARGE EXTENT

DELAY06 Occurrence of delays and interruptions (Inspection, supervision,drawings and specifications variation delays)

- ☐ 1. AFFECTS WITH LITTLE EXTENT
- ☐ 2. AFFECTS TO SOMEEXTENT
- ☐ 3. AFFECTS WITH AVERAGE EXTENT
- ☐ 4. AFFECTS WITH LARGE EXTENT
- ☐ 5. AFFECTS WITH VERY LARGE EXTENT

PASY12 Payment system (daily, output or subcontracting)

- ☐ 1. AFFECTS WITH LITTLE EXTENT
- ☐ 2. AFFECTS TO SOMEEXTENT
- ☐ 3. AFFECTS WITH AVERAGE EXTENT
- ☐ 4. AFFECTS WITH LARGE EXTENT
- ☐ 5. AFFECTS WITH VERY LARGE EXTENT

INTER15 Rework

- ☐ 1. AFFECTS WITH LITTLE EXTENT
- ☐ 2. AFFECTS TO SOMEEXTENT
- ☐ 3. AFFECTS WITH AVERAGE EXTENT
- ☐ 4. AFFECTS WITH LARGE EXTENT
- ☐ 5. AFFECTS WITH VERY LARGE EXTENT

SZCG13 Size and composition of the gangs

- ☐ 1. AFFECTS WITH LITTLE EXTENT
- ☐ 2. AFFECTS TO SOMEEXTENT
- ☐ 3. AFFECTS WITH AVERAGE EXTENT
- ☐ 4. AFFECTS WITH LARGE EXTENT
- ☐ 5. AFFECTS WITH VERY LARGE EXTENT

INNUL14 Supervision (poor or good) marked by excessive waiting

- ☐ 1. AFFECTS WITH LITTLE EXTENT
- ☐ 2. AFFECTS TO SOMEEXTENT
- ☐ 3. AFFECTS WITH AVERAGE EXTENT
- ☐ 4. AFFECTS WITH LARGE EXTENT
- ☐ 5. AFFECTS WITH VERY LARGE EXTENT

WTCD15 Weather changes/conditions

- ☐ 1. AFFECTS WITH LITTLE EXTENT
- ☐ 2. AFFECTS TO SOMEEXTENT
- ☐ 3. AFFECTS WITH AVERAGE EXTENT

☐ 4. AFFECTS WITH LARGE EXTENT

☐ 5. AFFECTS WITH VERY LARGE EXTENT

STFAC16 State, apart from the above, any other critical factor likely to affect productivity on your site……..

☐ 1. AFFECTS WITH LITTLE EXTENT

☐ 2. AFFECTS TO SOMEEXTENT

☐ 3. AFFECTS WITH AVERAGE EXTENT

☐ 4. AFFECTS WITH LARGE EXTENT

☐ 5. AFFECTS WITH VERY LARGE EXTENT

APPENDX II

Department of Building, Faculty of Environmental Design,
Ahmadu Bello University Zaria
(Research Survey Form)
Daily on-site Data Gathering Sheet.

Project name_____

Location_____

Floor Area of building_____

Type of Building_____

Date Collected_____

Work Activity_____

QUANTITIES				WORK HOURS		
S/N	Length	Height	Thickness	Starting Time	Break Time	Closing Time
Sum						

NUMBER OF CREW	
Skilled No	Unskilled No

CRITICAL FACTORS

- The size and make-up of the gangs.
- Lack of Labour Experience
- Supervision (poor or good)
- Payment system(daily, output or subcontractor)
- Occurrence of delays such as;
  Material Shortages, Lack of tools/equipment, Absenteeism among the site labourers, Accidents, Weather changes etc
- Alteration in drawing /specification
- The height at which work is done.
- The characteristics of site location.
- Learning outcomes because of repetition.
- The nature of contract agreement.
- Long periods of work (fatigue)

	○ Distance of materials to work stations

APPENDIX III

4.2 SITE PRODUCTIVITY MEASURMENT

Table 4.1 Data Presentation and Analysis of site masonry work Collected from Project 1

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	13	110.5	120.80	0.915	*
2	22	187	109.00	1.715	
3	20	170	118.00	1.440	
4	21	178.5	174.60	1.022	
5	4	28	15.30	1.830	
6	2	17	9.60	1.77	
7	2	12	6.80	1.765	
8	4	36	22.10	1.629	
9	16	136	143.10	0.950	*
10	20	170	165.30	1.028	
11	6	51	26.50	1.925	
12	5	42.5	18.20	2.335	
13	6	51	36.60	1.393	
14	16	136	186.40	0.729	*
15	12	78	137.20	0.568	*
16	10	85	98.90	0.859	*
17	2	17	6.40	2.656	
SUM	**181**	**1505.5**	**1394.80**	**1.079**	**0.804**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.02 Data Presentation and Analysis of site masonry work Collected from Project 2

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	7	52.50	35.20	1.490	
2	7	52.50	89.40	0.587	*
3	11	82.50	133.30	0.619	
4	16	120.00	198.10	0.606	
5	16	120.00	175.20	0.685	
6	13	97.50	167.00	0.584	*
7	13	97.50	175.40	0.556	*
8	13	97.50	168.00	0.580	*
9	11	82.50	102.20	0.807	
10	12	90.00	94.40	0.953	
11	13	97.50	124.80	0.781	
12	12	90.00	131.00	6.687	
13	11	82.50	105.30	0.783	
14	20	150.00	235.40	0.637	
15	5	37.50	68.40	0.548	*
16	6	45.00	35.30	1.275	
17	12	90.00	129.20	0.697	
18	18	135.00	172.70	0.781	
SUM	**203**	**1620.00**	**2340.30**	**0.692**	**0.571**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.03 Data Presentation and Analysis of site masonry work Collected from Project 3

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	14	112	84.00	1.330	
2	10	95	72.00	1.319	
3	4	32	38.00	0.842	
4	6	48	62.70	0.765	*
5	6	48	59.10	0.812	
6	4	32	16.00	2.000	
7	3	24	32.60	0.736	*****
8	2	16	9.40	1.702	
9	2	16	7.21	2.219	
10	5	40	32.00	1.250	
11	5	40	42.00	0.952	
12	4	32	36.70	0.872	
13	7	56	78.00	0.718	*
14	3	24	18.10	1.326	
15	5	40	38.00	1.053	
16	18	144	165.30	0.871	
17	3	24	34.80	0.689	*
18	7	56	75.90	0.738	*
19	7	56	65.20	0.859	
SUM	**115**	**935**	**967.01**	**0.967**	**0.729**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.04 Data Presentation and Analysis of site masonry work Collected from Project 4

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	4	34	28.46	1.195	
2	16	136	171.60	0.793	
3	12	102	76.90	1.326	
4	16	102	129.64	0.787	*
5	16	136	123.70	1.099	
6	10	85	96.34	0.882	
7	30	255	360.22	0.708	*
8	6	51	81.22	0.628	
9	6	51	70.75	0.721	*
10	6	51	59.74	0.854	
11	16	136	157.5	0.863	
12	6	51	41.12	1.240	
13	12	102	127.99	0.797	
14	2	17	8.75	1.943	
15	10	85	121.26	0.700	*
16	10	85	142.29	0.597	*
SUM	**174**	**1499**	**1797.48**	**0.823**	**0.703**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.05 Data Presentation and Analysis of site masonry work Collected fromProject 5

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	9	81	17.88	4.530	
2	7	63	51.58	1.221	
3	9	81	80.00	1.010	
4	9	81	53.17	1.523	
5	9	81	86.29	0.939	*
6	6	54	38.20	1.414	
7	6	48	50.13	0.958	*
8	9	81	61.51	1.316	
9	8	72	42.41	1.698	
10	7	63	63.21	0.996	*
11	7	63	64.96	0.969	*
12	7	63	58.85	1.071	
13	6	54	52.64	1.026	
14	7	63	74.39	0.847	*
SUM	**109**	**948**	**795.22**	**1.192**	**0.942**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.06 Data Presentation and Analysis of site masonry work Collected fromProject 6

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	8	68	31.00	2.194	
2	6	51	31.00	1.645	*
3	11	93.5	49.00	1.908	
4	7	59.5	30.00	1.983	
5	8	68	43.00	1.581	*
6	16	136	118.40	1.148	*
7	14	119	80.90	1.470	*
8	16	136	90.90	1.496	*
9	10	85	41.90	2.029	
10	12	102	42.00	2.429	
11	12	102	41.10	2.482	
12	9	76.5	38.20	2.003	
13	10	85	39.20	2.168	
14	12	102	40.90	2.494	
15	12	102	40.90	2.494	
16	8	68	30.50	2.230	
17	8	68	30.00	2.267	
18	8	68	32.00	2.125	
SUM	**187**	**1589.50**	**850.50**	**1.869**	**1.468**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.07 Data Presentation and Analysis of site masonry work Collected fromProject 7

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	12	102.00	48.00	2.125	
2	12	103.00	48.00	2.125	
3	6	51.00	38.00	1.342	
4	10	85.00	52.00	1.634	
5	17	144.50	96.00	1.505	
6	17	144.50	189.70	0.762	*
7	12	102.00	72.00	1.417	
8	17	144.50	76.00	1.901	
9	12	102.00	62.00	1.645	
10	6	51.00	48.30	1.056	*
11	10	85.00	48.00	1.771	
12	10	85.00	48.00	1.771	
13	18	153.00	118.60	1.290	*
14	14	119.00	78.00	1.525	
15	14	119.00	98.00	1.214	*
16	10	85.00	69.10	1.230	*
SUM	**197**	**1674.50**	**1141.40**	**1.467**	**1.110**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.08 Data Presentation and Analysis of site masonry work Collected fromProject 8

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	12	96	51.00	1.882	
2	10	86	46.00	1.739	
3	14	112	63.00	1.778	
4	14	112	51.70	2.166	
5	12	96	41.90	2.291	
6	10	80	51.10	1.565	*
7	14	112	61.00	1.836	
8	6	48	31.20	1.538	*
9	12	46	46.20	2.078	
10	14	112	69.50	1.612	*
11	8	64	35.20	1.818	
12	14	112	66.50	1.684	*
13	12	96	48.00	2.000	
14	14	112	60.70	1.845	
15	6	48	31.20	1.538	*
SUM	**172**	**1376**	**754.20**	**1.824**	**1.587**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.09 Data Presentation and Analysis of site masonry work Collected from Project 9

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	3	24	10.60	2.264	
2	3	24	11.00	2.181	
3	3	24	10.70	2.243	
4	2	16	10.00	1.600	
5	6	48	31.50	1.524	
6	6	48	3.200	1.500	
7	6	48	3.200	1.500	
8	4	32	40.10	0.798	*
9	3	24	30.50	0.787	*
10	3	24	16.50	1.455	*
11	4	32	40.30	0.794	*
12	4	32	37.00	0.865	*
13	6	48	30.00	1.600	
14	6	48	30.00	1.600	
15	2	16	10.40	1.538	
16	2	16	10.00	1.600	
17	6	48	30.00	1.600	
18	6	48	30.00	1.600	
19	6	48	31.20	1.538	
SUM	**81**	**600**	**474.80**	**1.264**	**0.940**

Source: ***Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.10 Data Presentation and Analysis of site masonry work Collected from Project 10

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	12	102	73.92	1.379	
2	16	136	127.31	1.068	*
3	16	136	60.48	2.248	
4	16	136	94.45	1.440	
5	16	136	74.49	1.826	
6	10	85	58.81	1.445	
7	14	119	67.35	1.766	
8	16	136	182.14	0.747	*
9	16	136	159.12	0.855	*
10	14	119	126.14	0.943	*
11	14	119	70.25	1.694	
12	10	85	46.38	1.833	
13	12	102	43.10	2.267	
14	16	136	105.95	1.284	*
15	16	136	99.68	1.364	
SUM	**214**	**1819**	**1389.58**	**1.309**	**0.978**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.11 Data Presentation and Analysis of site masonry work Collected from Project 11

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	6	45	46.10	0.978	*
2	12	90	48.00	1.875	
3	6	45	38.00	1.184	
4	6	45	31.090	1.452	
5	8	60	42.00	1.429	
6	17	127.5	96.00	1.328	
7	18	135	199.20	0.678	*****
8	12	90	81.00	1.111	
9	17	127.5	96.00	1.325	
10	12	90	61.00	1.475	
11	6	45	48.30	0.932	*
12	7	38.50	29.00	1.328	
13	18	135	187.50	0.720	*
14	10	75	48.00	1.563	
15	2	6	5.70	1.053	*
SUM	**157**	**1154.50**	**1056.50**	**1.093**	**0.872**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.12 Data Presentation and Analysis of site masonry work Collected fromProject 12

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	12	96	72.00	1.333	
2	14	112	84.00	1.333	
3	14	112	84.00	1.333	
4	12	96	72.00	1.333	
5	13	104	98.00	1.061	
6	6	48	40.00	1.200	
7	10	80	75.50	1.059	
8	16	128	125.00	1.024	*
9	12	96	78.00	1.230	
10	8	64	58.00	1.103	
11	16	128	108.00	1.185	
12	16	128	132.00	0.969	*
13	14	112	120.00	0.933	*
14	12	96	75.00	1.280	
15	8	64	60.00	1.067	
16	8	64	60.50	1.058	
17	6	48	44.50	1.079	
18	14	112	126.20	0.887	*
19	8	64	75.80	0.844	*
SUM	**219**	**1752**	**1588.50**	**1.103**	**0.931**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.13 Data Presentation and Analysis of site masonry work Collected from Project 13

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	16	136	170.40	0.798	
2	16	136	186.40	0.730	*
3	6	51	36.60	1.393	
4	12	102	137.20	0.743	*****
5	12	102	105.80	0.983	
6	10	85	98.90	0.859	
7	2	17	17.60	0.966	
8	18	153	174.60	0.876	
9	14	119	149.60	0.795	
10	16	136	193.60	0.702	*
11	15	127.50	147.70	0.863	
12	12	102	132.00	0.773	
13	6	51	71.50	0.713	*
14	18	153	202.10	0.757	
15	12	102	123.90	0.823	
16	4	34	40.80	0.833	
17	3	34	45.40	0.749	
18	8	68	73.30	0.928	
19	16	136	187.10	0.727	*
20	12	102	113.80	0.896	
SUM	**229**	**1946.5**	**2406.30**	**0.809**	**0.723**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.14 Data Presentation and Analysis of site masonry work Collected from Project 14

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	8	64	38.69	1.654	
2	12	96	93.46	1.027	
3	6	48	50.46	0.951	*
4	8	64	37.12	1.734	
5	6	48	47.50	1.010	*
6	8	64	57.36	1.116	
7	12	96	83.18	1.154	
8	8	64	104.39	0.613	*
9	10	80	58.90	1.358	
10	11	88	88.28	0.997	*
11	11	88	68.14	1.291	
12	10	80	48.68	1.643	
13	8	64	62.92	1.017	*
14	10	80	64.24	1.245	
15	10	80	47.90	1.670	
16	4	32	25.50	1.255	
17	8	64	39.01	1.641	
SUM	**150**	**1200**	**1015.74**	**1.181**	**0.918**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.15 Data Presentation and Analysis of site masonry work Collected from Project 15

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	8	68.00	70.00	0.971	
2	8	68.00	73.00	0.931	
3	8	68.00	75.00	0.907	*
4	8	68.00	71.00	0.918	
5	8	68.00	72.00	0.944	
6	8	68.00	72.00	0.944	
7	8	68.00	72.50	0.938	
8	9	76.50	71.00	1.078	
9	9	76.50	71.00	1.069	
10	9	76.50	71.20	1.074	
11	6	51.00	65.50	0.778	*
12	9	76.50	75.00	1.020	
13	8	68.00	73.00	0.930	
14	4	34.00	48.50	0.700	*
15	6	51.00	60.50	0.843	*
16	10	85.00	72.00	1.181	
17	10	85.00	71.00	1.197	
18	10	85.00	71.50	1.188	
19	4	34.00	45.50	0.747	*
SUM	**150**	**1275.00**	**1301.20**	**0.980**	**0.795**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.16 Data Presentation and Analysis of site masonry work Collected fromProject 16

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	8	68	42.60	1.590	
2	8	68	46.30	1.469	
3	10	85	51.20	1.660	
4	10	85	60.40	1.407	
5	4	34	17.30	1.965	
6	12	102	143.60	0.710	*
7	14	119	152.10	0.782	*
8	14	119	139.60	0.852	*
9	12	102	119.70	0.852	*
10	6	51	28.90	1.765	
11	6	51	31.40	1.624	
12	4	34	24.60	1.382	*
13	4	34	20.40	1.667	
14	2	17	11.60	1.465	
SUM	**114**	**969**	**889.70**	**1.089**	**0.916**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.17 Data Presentation and Analysis of site masonry work Collected from Project 17

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	4	32	35.00	0.914	
2	4	32	35.90	0.891	
3	4	32	35.50	0.901	
4	8	64	70.80	0.904	
5	8	64	72.20	0.886	*
6	6	48	52.20	0.920	
7	8	64	25.50	0.848	*****
8	4	32	36.00	0.888	*
9	8	64	71.80	0.891	
10	8	64	70.00	0.914	
11	8	64	71.60	0.894	
12	4	32	35.70	0.896	
13	4	32	34.90	0.917	
14	4	32	35.50	0.901	
15	8	64	74.20	0.863	*
16	8	64	70.80	0.904	
17	4	32	34.00	0.941	
18	4	32	38.00	0.842	*
19	4	32	35.00	0.914	
20	4	32	35.10	0.912	
SUM	**108**	**912**	**983.80**	**0.927**	**0.865**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.18 Data Presentation and Analysis of site masonry work Collected from Project 18

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	8	64	85.56	0.746	*
2	8	64	80.50	0.795	*
3	8	64	36.66	1.746	
4	8	64	41.16	1.555	
5	2	8	3.44	2.326	
6	4	32	45.90	0.697	*
7	4	32	33.74	0.948	*****
8	6	48	38.40	1.250	
9	6	48	90.00	0.533	*
10	3	24	20.70	1.159	
11	4	32	24.75	1.293	
12	2	16	8.46	1.890	
13	2	16	2.76	5.797	
14	4	32	10.86	2.948	
SUM	**69**	**544**	**522.89**	**1.040**	**0.744**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.19 Data Presentation and Analysis of site masonry work Collected from Project 19

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	6	51	38.70	1.318	
2	16	136	186.40	0.730	*
3	12	102	158.20	0.645	*
4	12	102	103.80	0.983	
5	6	51	36.60	1.393	
6	16	136	186.90	0.730	*
7	12	102	137.20	0.743	
8	12	102	103.80	0.983	
9	10	85	98.90	0.860	
10	2	17	20.00	0.850	
11	6	51	27.70	1.882	
12	4	34	21.90	1.553	
13	12	102	147.20	0.693	*
14	10	85	129.10	0.658	*
15	6	51	69.50	0.734	
16	2	17	23.00	0.739	
17	2	17	14.00	1.214	
18	6	51	41.10	1.241	
SUM	**152**	**129**	**1542.90**	**0.834**	**0.691**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.20 Data Presentation and Analysis of site masonry work Collected fromProject 20

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	8	68.00	44.10	1.540	
2	4	34.00	19.40	1.750	
3	8	68.00	24.00	0.919	*
4	8	68.00	59.00	1.153	*****
5	7	59.50	59.00	1.008	*
6	9	76.50	52.40	1.460	
7	6	51.00	49.90	1.022	*****
8	2	17.00	13.90	1.220	
9	20	170.00	190.00	0.895	*
10	34	289.00	216.00	1.338	
11	12	102.00	76.40	1.335	
12	4	34.00	17.30	1.965	
13	4	34.00	19.40	1.753	
14	4	34.00	22.00	1.545	
15	14	119.00	68.10	1.747	
16	4	34.00	17.30	1.965	
17	32	272.00	216.00	1.259	
SUM	**180**	**1530.00**	**1214.20**	**1.260**	**0.999**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.21 Data Presentation and Analysis of site masonry work Collected fromProject 21

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	8	68.00	75.00	0.906	
2	8	68.00	78.00	0.871	
3	8	68.00	79.00	0.861	*
4	8	68.00	77.00	0.883	
5	8	68.00	79.00	0.861	*
6	8	68.00	79.00	0.861	*
7	8	68.00	79.00	0.861	*
8	7	598.50	76.00	0.783	*
9	9	76.50	77.00	0.994	
10	9	76.50	76.50	1.000	
11	9	76.50	7.000	1.093	
12	9	76.50	71.20	1.074	
13	9	76.50	70.20	1.089	
14	9	76.50	79.00	0.968	
15	10	85.00	75.00	1.183	
16	10	85.00	76.00	1.120	
17	10	85.00	77.00	1.104	
18	10	85.00	78.00	1.089	
19	10	85.00	79.00	1.076	
20	10	85.00	79.00	1.076	
SUM	**177**	**1504.50**	**1528.90**	**0.984**	**0.847**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.22 Data Presentation and Analysis of site masonry work Collected fromProject 22

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	12	102.00	38.10	2.677	
2	16	136.00	108.10	1.258	*
3	12	102.00	40.10	2.544	
4	12	102.00	40.20	2.537	
5	12	102.00	40.30	2.531	
6	16	136.00	102.00	1.333	*
7	11	93.50	96.80	0.966	*
8	11	93.50	40.10	2.332	
9	11	93.50	50.20	1.863	
10	15	127.50	60.20	2.118	
11	13	110.50	60.70	1.826	*
12	17	144.50	90.40	1.598	*
13	6	51.00	23.00	2.217	
14	10	85.00	46.00	1.848	
SUM	**174**	**1479.00**	**836.20**	**1.769**	**1.145**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.23 Data Presentation and Analysis of site masonry work Collected fromProject 23

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	12	96	38.20	2.513	
2	12	96	38.00	2.526	
3	16	128	118.20	1.083	*
4	12	96	40.20	2.388	
5	12	96	40.00	2.400	
6	16	128	102.00	1.255	
7	11	88	97.80	0.899	*****
8	11	88	97.20	0.905	*
9	7	56	40.90	1.369	
10	9	72	50.90	1.415	
11	17	136	102.60	1.326	
12	15	120	97.90	1.226	*
13	15	120	97.20	1.235	*
14	20	40	103.90	1.540	
SUM	**185**	**1480**	**1065.00**	**1.390**	**1.070**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.24 Data Presentation and Analysis of site masonry work Collected fromProject 24

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	10	80	125.70	0.636	
2	8	64	96.50	0.663	
3	12	96	134.20	0.715	
4	8	64	104.10	0.615	
5	6	48	83.20	0.577	*
6	8	64	94.50	0.677	
7	6	48	73.90	0.650	
8	8	64	107.30	0.596	
9	6	48	87.20	0.550	*
10	12	96	156.00	0.615	
11	10	80	95.30	0.839	
12	6	48	82.40	0.583	*
13	8	64	97.90	0.654	
14	6	48	75.30	0.637	
15	8	64	93.40	0.685	
16	10	80	142.3	0.562	*
17	6	48	87.30	0.550	*
18	8	64	93.70	0.683	
19	10	80	104.30	0.767	
20	6	48	75.60	0.635	
SUM	**162**	**1296**	**2010.10**	**0.645**	**0.564**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.25 Data Presentation and Analysis of site masonry work Collected fromProject 25

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	14	112	70.00	1.600	
2	14	112	71.20	1.573	
3	12	96	62.30	1.541	*
4	10	80	51.70	1.547	*****
5	16	128	78.90	1.622	
6	12	96	63.20	1.519	*
7	14	112	69.70	1.607	
8	12	96	59.70	1.608	
9	10	80	50.70	1.578	
10	16	128	80.10	1.598	
11	14	112	71.70	1.562	*
12	14	112	68.90	1.626	
13	12	96	59.30	1.619	
14	10	80	51.10	1.566	*
15	12	96	60.60	1.584	
16	14	112	71.20	1.573	
17	10	80	49.70	1.609	
18	14	112	70.70	1.584	
19	14	112	68.90	1.626	
SUM	**244**	**1952**	**1229.60**	**1.588**	**1.547**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.26 Data Presentation and Analysis of site masonry work Collected fromProject 26

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	14	126	134.80	0.935	
2	14	126	154.60	0.815	*
3	12	108	98.20	1.099	
4	12	108	91.40	1.182	
5	4	36	46.90	0.768	*
6	8	68	61.20	1.111	
7	10	85	67.80	1.253	
8	4	32	16.90	1.893	
9	8	72	61.80	1.165	
10	8	72	69.80	1.032	
11	6	51	43.60	1.170	
12	2	16	6.10	2.622	
13	8	72	72.00	1.000	
14	6	51	57.70	0.884	*
15	12	108	150.00	0.720	*
16	8	68	80.50	0.845	*
17	21	189	180.60	1.047	
18	6	45	41.00	1.098	
19	10	90	83.10	1.083	
20	8	64	49.00	1.306	
SUM	**181**	**1587**	**1566.50**	**1.013**	**0.806**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.27 Data Presentation and Analysis of site masonry work Collected fromProject 27

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	10	80	87.40	0.915	
2	10	80	72.20	1.018	
3	12	96	94.60	1.015	
4	6	48	41.10	1.168	
5	14	112	124.60	0.899	
6	16	128	147.20	0.870	*
7	16	128	123.0	1.041	
8	18	1444	164.80	0.872	*
9	8	64	63.00	1.016	
10	6	48	49.10	0.978	
11	16	128	155.90	0.821	*
12	16	128	147.60	0.867	*
13	10	80	98.00	0.816	*
14	14	112	121.10	0.925	
15	6	48	51.80	0.927	
16	4	32	20.40	1.569	
17	2	16	6.20	2.581	
18	2	16	9.80	1.632	
SUM	**186**	**1488**	**1577.80**	**0.943**	**0.850**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.28 Data Presentation and Analysis of site masonry work Collected fromProject 28

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	16	128	97.60	1.311	*
2	16	128	87.20	1.468	
3	10	80	41.30	1.937	
4	16	128	85.00	1.506	
5	15	120	89.60	1.348	*
6	12	96	70.60	1.360	*
7	14	112	82.10	1.364	*****
8	14	112	80.90	1.384	*
9	8	64	36.80	1.739	
10	4	32	17.90	1.787	
11	4	32	21.40	1.495	
12	4	32	16.40	1.951	
13	15	120	59.80	2.007	
14	19	152	91.20	1.667	
15	19	152	92.90	1.636	
16	18	144	73.80	1.951	
17	13	104	49.60	2.096	
18	10	80	46.10	1.735	
19	20	160	91.90	1.741	
SUM	**247**	**1976**	**1232.1**	**1.604**	**1.353**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.29 Data Presentation and Analysis of site masonry work Collected fromProject 29

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	7	56	72.00	0.777	
2	11	88	121.50	0.724	
3	11	88	106.6	0.826	
4	10	80	108.8	0.735	
5	14	112	126.00	0.888	
6	10	80	118.10	0.677	*
7	8	64	98.00	0.653	*****
8	5	40	54.70	0.731	
9	5	40	59.20	0.676	*
10	7	56	67.10	0.835	
11	15	12.0	161.70	0.667	*
12	15	120	161.70	0.742	
13	11	88	149.60	0.588	*
14	5	40	58.90	0.679	
15	4	32	38.90	0.823	
16	15	120	174.60	0.687	
17	13	104	101.60	1.024	
18	12	96	119.70	0.802	
19	13	104	151.80	0.685	
20	14	112	164.30	0.682	
SUM	**197**	**1576**	**2137.00**	**0.737**	**0.652**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

Table 4.30 Data Presentation and Analysis of site masonry work Collected fromProject 30

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and Productivity
1	4	36	63.40	0.568	
2	6	54	84.50	0.643	
3	4	36	62.90	0.572	
4	4	36	73.10	0.492	*****
5	12	108	142.20	0.759	
6	6	54	75.80	0.712	
7	2	18	35.38	0.508	*****
8	6	54	97.20	0.556	
9	10	80	132.50	0.604	
10	6	54	93.60	0.577	
11	12	96	143.50	0.669	
12	4	32	74.60	0.429	*
13	6	48	91.20	0.526	*
14	2	16	29.70	0.539	
15	2	16	39.20	0.408	*
16	4	36	64.50	0.558	
17	4	36	72.50	0.497	
18	10	80	132.50	0.604	
19	4	36	52.70	0.683	
20	4	36	63.90	0.563	
SUM	**112**	**962**	**1624.88**	**0.592**	**0.473**

*Source:**Researcher's data analysis 2011, * Used in the computation of baseline productivity.***

APPENDIX IV

BLOCK WORK

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
1	1.056	0.805	0.308	88.188	64.309	0.729	1.288	0.443	0.344
2	0.693	0.571	0.149	129.765	56.278	0.434	0.763	0.261	0.342
3	0.964	0.729	0.288	51.053	36.208	0.709	1.076	0.381	0.354
4	1.031	0.671	0.441	89.625	80.956	0.903	1.241	0.465	0.375
5	1.125	0.764	0.442	59.292	27.315	0.461	1.304	0.496	0.381
6	1.458	0.936	0.640	60.572	37.299	0.616	1.688	0.505	0.299
7	1.243	0.802	0.540	84.250	45.872	0.544	1.425	0.488	0.342
8	1.452	0.896	0.683	61.200	16.332	0.267	1.505	0.457	0.304
9	1.347	0.940	0.500	25.316	10.755	0.425	1.443	0.355	0.246
10	1.217	0.840	0.462	99.600	47.493	0.477	1.414	0.464	0.328
11	1.165	0.794	0.454	66.067	55.626	0.842	1.324	0.428	0.323
12	1.084	0.799	0.349	85.053	40.135	0.472	1.171	0.239	0.204
13	1.066	0.723	0.420	91.300	52.616	0.576	1.170	0.283	0.242
14	1.181	0.918	0.323	59.706	21.667	0.363	1.257	0.319	0.254
15	1.205	0.795	0.502	55.842	12.429	0.223	1.255	0.390	0.311
16	1.067	0.750	0.388	64.857	54.797	0.845	1.402	0.520	0.371
17	1.063	0.727	0.413	42.900	19.366	0.451	1.133	0.281	0.248
18	0.999	0.728	0.332	41.417	31.257	0.755	1.339	0.583	0.436
19	1.023	0.691	0.408	70.167	61.501	0.876	1.344	0.452	0.336
20	1.276	1.046	0.282	70.412	68.507	0.973	1.419	0.334	0.235
21	1.005	0.863	0.174	76.850	2.560	0.033	1.007	0.124	0.123
22	1.588	1.323	0.325	66.692	24.834	0.372	1.674	0.338	0.202
23	1.335	1.129	0.252	79.214	28.028	0.354	1.424	0.369	0.259
24	1.055	0.775	0.343	61.350	29.560	0.482	1.271	0.561	0.442

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
25	1.314	0.854	0.564	78.263	24.626	0.315	1.404	0.345	0.246
26	1.010	0.806	0.250	78.650	45.528	0.579	1.100	0.277	0.251
27	1.142	0.855	0.352	75.167	54.608	0.726	1.363	0.419	0.307
28	1.566	1.352	0.263	66.421	27.788	0.418	1.616	0.241	0.149
29	1.011	0.652	0.439	80.550	46.379	0.576	1.206	0.520	0.431
30	0.597	0.491	0.130	81.400	34.246	0.421	0.583	0.080	0.137
31	1.049	0.892	0.192	48.579	18.295	0.377	1.058	0.147	0.139
32	0.999	0.884	0.141	81.895	24.839	0.303	1.011	0.113	0.112
33	1.144	0.485	0.808	46.421	31.772	0.684	1.434	0.604	0.421
34	1.152	0.846	0.376	42.350	16.806	0.397	1.245	0.284	0.229
35	1.108	0.925	0.224	70.737	21.242	0.300	1.137	0.180	0.158
36	1.220	0.839	0.467	130.905	44.651	0.341	1.330	0.455	0.342
37	1.421	1.179	0.298	61.950	37.478	0.605	1.513	0.293	0.193
38	1.355	0.940	0.510	49.789	24.645	0.495	1.402	0.342	0.244
39	1.283	0.841	0.542	89.100	37.134	0.417	1.384	0.400	0.289
40	1.098	0.915	0.224	69.571	27.883	0.401	1.136	0.230	0.203
41	1.142	0.966	0.216	79.765	40.026	0.502	1.214	0.317	0.261
42	1.095	0.891	0.250	98.000	30.778	0.314	1.080	0.150	0.139
43	0.774	0.632	0.174	120.650	45.204	0.375	0.803	0.126	0.157
44	0.844	0.735	0.134	115.952	46.884	0.404	0.862	0.097	0.112
45	0.860	0.716	0.177	117.750	29.272	0.249	0.856	0.098	0.114
46	1.131	0.802	0.403	96.550	48.572	0.503	1.281	0.462	0.361
47	1.024	0.723	0.369	79.750	37.356	0.468	1.163	0.455	0.391
48	0.972	0.678	0.361	58.350	27.630	0.474	1.104	0.489	0.443
49	0.783	0.688	0.117	108.100	27.369	0.253	0.784	0.085	0.108
50	1.146	0.770	0.461	55.900	26.326	0.471	1.274	0.488	0.383

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
51	0.816	0.702	0.140	100.952	26.899	0.266	0.820	0.089	0.109
52	1.122	0.742	0.466	66.895	37.055	0.554	1.330	0.499	0.375
53	0.931	0.771	0.196	65.905	31.820	0.483	0.948	0.141	0.149
54	1.268	1.073	0.240	45.143	13.305	0.295	1.280	0.143	0.112
55	1.025	0.930	0.117	52.727	24.484	0.464	1.086	0.203	0.187
56	1.298	0.908	0.478	66.400	32.391	0.488	1.315	0.275	0.210
57	1.145	0.635	0.625	106.286	49.135	0.462	1.312	0.581	0.443
58	0.762	0.629	0.162	98.381	35.373	0.360	0.787	0.137	0.174
59	0.736	0.622	0.139	136.550	56.245	0.412	0.781	0.156	0.199
60	0.958	0.694	0.324	26.389	14.246	0.540	1.037	0.361	0.348
61	0.812	0.686	0.155	96.600	42.717	0.442	0.852	0.228	0.268

Source:*Researcher's data analysis 2012.*

PLASTERING WORK

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
1	1.1110	0.8113	0.357	64.30	29.16	0.45	1.291	0.5447	0.422
2	1.2378	0.7789	0.547	70.44	30.98	0.44	1.449	0.5849	0.404
3	1.0201	0.6374	0.456	54.18	27.49	0.51	1.288	0.6663	0.517
4	1.0277	0.6049	0.504	48.93	24.79	0.51	1.303	0.6288	0.483
5	0.9873	0.6694	0.379	91.58	48.34	0.53	1.230	0.6341	0.516
6	1.0284	0.6455	0.456	41.88	26.93	0.64	1.286	0.6160	0.479
7	0.9673	0.7104	0.306	52.50	21.15	0.40	1.118	0.5259	0.470
8	1.1531	0.8455	0.366	122.46	42.90	0.35	1.298	0.4970	0.383
9	1.1342	0.8455	0.344	126.79	37.60	0.30	1.231	0.4103	0.333
10	1.4566	1.3515	0.125	94.74	17.40	0.18	1.450	0.1312	0.090
11	1.3654	1.2599	0.126	70.60	16.79	0.24	1.390	0.2027	0.146
12	1.4340	1.3009	0.159	92.33	17.13	0.19	1.459	0.2002	0.137
13	1.3245	1.1760	0.177	83.87	23.49	0.28	1.360	0.1922	0.141
14	1.4728	1.3603	0.134	82.02	14.45	0.18	1.485	0.1594	0.107
15	1.1725	0.9463	0.269	117.87	31.78	0.27	1.242	0.3147	0.253
16	1.1063	0.8409	0.316	129.80	43.85	0.34	1.222	0.4028	0.330
17	1.0447	0.8222	0.265	122.61	41.70	0.34	1.169	0.4672	0.400
18	1.1155	0.8296	0.341	135.73	39.73	0.29	1.216	0.4109	0.338
19	0.8897	0.5488	0.406	56.00	28.82	0.51	1.164	0.5827	0.501
20	1.0056	0.7389	0.318	92.08	34.83	0.38	1.125	0.5156	0.458
21	0.7533	0.6470	0.127	76.43	15.67	0.21	0.755	0.0938	0.124
22	0.8211	0.6567	0.196	50.61	33.15	0.66	1.070	0.5883	0.550
23	1.0361	0.7871	0.297	61.00	41.34	0.68	1.050	0.3251	0.310
24	0.9586	0.7926	0.198	42.98	33.36	0.78	1.003	0.2548	0.254
25	0.9146	0.8008	0.136	62.62	38.89	0.62	0.950	0.1760	0.185

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
26	1.3499	1.2300	0.143	18.15	4.57	0.25	1.376	0.1820	0.132
27	0.8502	0.6254	0.268	35.17	21.86	0.62	1.090	0.5764	0.529
28	1.0010	0.6328	0.439	45.82	23.46	0.51	1.253	0.5777	0.461
29	1.0108	0.6419	0.439	42.14	21.34	0.51	1.271	0.5854	0.461
30	1.1096	0.7238	0.460	54.33	21.63	0.40	1.310	0.5453	0.416
31	1.0527	0.7658	0.342	55.05	17.90	0.33	1.182	0.4775	0.404
32	0.7720	0.6601	0.133	161.65	48.09	0.30	0.809	0.1573	0.194
33	0.8141	0.6510	0.194	128.10	61.02	0.48	0.853	0.2379	0.279
34	0.9405	0.6743	0.317	115.82	44.71	0.39	1.131	0.5634	0.498
35	0.9178	0.7459	0.205	73.73	39.47	0.54	1.050	0.4374	0.416
36	1.4152	1.2728	0.170	74.41	19.38	0.26	1.428	0.2223	0.156
37	0.9922	0.8060	0.222	102.60	54.21	0.53	1.167	0.4405	0.377
38	1.3204	1.1914	0.154	69.83	14.02	0.20	1.321	0.1682	0.127
39	1.0710	0.9226	0.177	96.17	32.00	0.33	1.099	0.2299	0.209
40	1.0846	0.8514	0.278	96.81	30.23	0.31	1.148	0.3112	0.271
41	0.9687	0.7494	0.261	116.55	51.44	0.44	1.118	0.3909	0.350
42	0.9354	0.7232	0.253	91.73	44.61	0.49	1.061	0.3950	0.372
43	1.1266	0.9950	0.157	70.92	12.66	0.18	1.112	0.1724	0.155
44	1.1986	1.0804	0.141	71.83	16.41	0.23	1.195	0.1575	0.132
45	1.4151	1.2939	0.144	88.83	27.06	0.30	1.424	0.1845	0.130
46	0.8851	0.7547	0.155	54.80	22.90	0.42	0.995	0.3415	0.343
47	0.8429	0.5964	0.294	49.83	27.12	0.54	1.131	0.6395	0.565
48	1.0921	0.7043	0.462	31.13	19.53	0.63	1.219	0.4922	0.404
49	1.1803	0.7645	0.495	57.57	35.95	0.62	1.422	0.5550	0.390
50	0.9134	0.7953	0.141	65.80	21.61	0.33	0.929	0.1146	0.123
51	1.1150	0.7999	0.375	38.00	16.81	0.44	1.243	0.4878	0.392

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
52	1.1086	0.7815	0.390	51.10	18.16	0.36	1.253	0.5393	0.430
53	1.1639	0.8170	0.413	57.16	27.90	0.49	1.315	0.5174	0.394
54	1.0486	0.9237	0.149	84.82	20.26	0.24	1.055	0.1321	0.125
55	0.9591	0.8427	0.139	94.77	24.07	0.25	0.958	0.0967	0.101
56	0.9267	0.8303	0.115	89.40	17.11	0.19	0.925	0.0761	0.082
57	0.9267	0.7313	0.233	79.53	33.32	0.42	1.069	0.5077	0.475
58	0.9415	0.8316	0.131	98.51	27.35	0.28	0.936	0.0919	0.098
59	1.0686	0.8442	0.267	85.55	31.16	0.36	1.207	0.4605	0.381
60	0.9195	0.7593	0.191	90.21	16.83	0.19	0.921	0.1285	0.140
61	0.9329	0.7855	0.176	93.79	20.32	0.22	0.933	0.1367	0.147

Source:*Researcher's data analysis 2012.*

FLOOR TILLING WORK

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
1	1.0573	0.6598	0.4531	29.1947	18.0211	0.6173	1.3333	0.5873	0.440
2	1.0237	0.7722	0.2867	36.2420	17.9850	0.4962	1.1307	0.4633	0.410
3	1.1074	0.6265	0.5482	39.3457	25.5070	0.6483	1.3845	0.6004	0.434
4	1.0373	0.5381	0.5691	33.3286	24.7204	0.7417	1.3197	0.6080	0.461
5	1.1556	0.5342	0.7084	36.7219	23.5945	0.6425	1.4726	0.6650	0.452
6	1.1129	0.7204	0.4474	50.4444	28.2202	0.5594	1.3197	0.5066	0.384
7	1.8630	1.6810	0.2075	23.7623	3.4667	0.1459	1.8659	0.2793	0.150
8	1.1517	0.9981	0.1751	51.5760	15.6032	0.3025	1.2029	0.2895	0.241
9	1.0798	0.9085	0.1953	56.1200	20.4402	0.3642	1.1148	0.2456	0.220
10	0.9028	0.5587	0.3923	68.2300	35.8081	0.5248	1.1515	0.6632	0.576
11	1.0679	0.9405	0.1453	65.1730	17.5756	0.2697	1.0622	0.1508	0.142
12	1.2915	1.1517	0.1594	64.2678	18.2583	0.2841	1.3309	0.3047	0.229
13	1.1704	1.0473	0.1403	56.3920	19.4274	0.3445	1.2062	0.2102	0.174
14	0.8590	0.6405	0.2490	79.6320	43.4640	0.5458	1.0689	0.5090	0.476
15	1.0511	0.8832	0.1914	69.9270	27.4067	0.3919	1.0831	0.2744	0.253
16	1.0050	0.8572	0.1684	67.7555	22.8525	0.3373	1.0114	0.1654	0.164
17	1.0267	0.9021	0.1420	65.3550	18.4836	0.2828	1.0099	0.1255	0.124
18	0.9059	0.7101	0.2232	81.0250	47.0358	0.5805	1.0847	0.4911	0.453
19	0.9079	0.6119	0.3374	31.5000	18.3258	0.5818	1.1276	0.6027	0.534
20	0.8769	0.5974	0.3186	37.1429	19.2748	0.5189	1.1163	0.6327	0.567
21	1.6529	1.4782	0.1992	19.1780	5.1274	0.2674	1.6832	0.2492	0.148
22	1.5841	1.4497	0.1532	10.7950	3.9524	0.3661	1.6277	0.2259	0.139
23	0.9266	0.6489	0.3165	20.1820	11.8864	0.5890	1.2049	0.5988	0.497
24	1.2609	1.0465	0.2444	22.5589	6.7721	0.3002	1.2677	0.3245	0.256
25	1.4815	1.2902	0.2181	10.3091	2.9133	0.2826	1.5622	0.3333	0.213

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
26	1.0167	0.8915	0.1427	21.7273	12.6340	0.5815	1.3647	0.6781	0.497
27	1.1632	1.0151	0.1689	21.8360	13.6338	0.6244	1.3786	0.4468	0.324
28	1.3097	1.1066	0.2315	27.4504	10.5061	0.3827	1.3790	0.2553	0.185
29	1.0336	0.8282	0.2342	29.7273	12.9916	0.4370	1.1609	0.3884	0.335
30	1.2847	0.8829	0.4580	26.6600	11.2064	0.4203	1.2846	0.3017	0.235
31	1.2982	0.9591	0.3866	25.2270	10.4981	0.4161	1.3771	0.2822	0.205
32	1.2392	0.8581	0.4344	17.2400	5.5123	0.3197	1.2675	0.4278	0.338
33	1.2745	1.0740	0.2286	38.4450	25.2996	0.6581	1.3650	0.3628	0.266
34	1.0510	0.7454	0.3484	63.9067	21.0030	0.3287	1.1909	0.5734	0.481
35	1.0257	0.6819	0.3920	58.3000	31.7597	0.5448	1.2703	0.6278	0.494
36	1.1005	0.9744	0.1438	53.7920	15.8167	0.2940	1.0797	0.1217	0.113
37	1.1240	0.9850	0.1585	56.2260	22.9649	0.4084	1.1360	0.2597	0.229
38	1.0814	0.9686	0.1285	56.5020	22.4169	0.3967	1.0929	0.2079	0.190
39	1.0959	0.7520	0.3920	58.5840	19.7034	0.3363	1.2207	0.5644	0.462
40	1.0366	0.7733	0.3002	58.4580	30.8922	0.5285	1.2720	0.5733	0.451
41	1.0272	0.9102	0.1334	61.0370	16.2416	0.2661	1.0246	0.1392	0.136
42	1.0187	0.7078	0.3543	56.5450	20.9340	0.3702	1.1471	0.5561	0.485
43	1.0304	0.9050	0.1429	59.3960	13.0724	0.2201	1.0250	0.1947	0.190
44	0.9997	0.7055	0.3354	59.0200	24.9037	0.4220	1.1564	0.5536	0.479
45	1.1955	1.0340	0.1842	59.3040	10.6838	0.1802	1.1908	0.1851	0.155
46	1.6273	1.4395	0.2141	19.4277	5.4658	0.2813	1.6262	0.2223	0.137
47	1.2526	0.7032	0.6262	25.9470	16.5655	0.6384	1.4361	0.4914	0.342
48	0.7931	0.6496	0.1636	48.8911	35.5935	0.7280	1.1692	0.6371	0.545
49	1.1144	0.7593	0.4048	41.4211	14.5881	0.3522	1.2284	0.4878	0.397
50	0.8243	0.6484	0.2005	38.7000	15.2215	0.3933	0.8181	0.1322	0.162
51	0.8738	0.7276	0.1667	43.5909	9.8400	0.2257	0.8846	0.1510	0.171

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
52	0.8670	0.7307	0.1554	48.8750	14.6555	0.2999	0.8723	0.1513	0.173
53	1.0970	0.8200	0.3158	40.5000	13.9380	0.3441	1.2445	0.4832	0.388
54	1.1183	1.0115	0.1218	40.9700	16.1868	0.3951	1.1210	0.1216	0.108
55	0.9963	0.8740	0.1394	41.1540	11.4504	0.2782	0.9960	0.1704	0.171
56	0.9651	0.8498	0.1315	40.8240	17.3914	0.4260	1.0054	0.2117	0.211
57	0.9196	0.7110	0.2379	69.4830	36.3661	0.5234	1.1100	0.5322	0.479
58	0.9825	0.8598	0.1399	43.7670	10.9761	0.2508	0.9925	0.1620	0.163
59	1.0406	0.9294	0.1267	39.1120	15.2041	0.3887	1.0883	0.2154	0.198
60	1.0727	0.9459	0.1446	37.2875	13.8688	0.3719	1.1030	0.2538	0.230
61	0.9765	0.8389	0.1568	57.6220	23.4716	0.4073	1.0505	0.2350	0.224

Source: ***Researcher's data analysis 2012.***

CONCRETE WORK

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
1	9.77	6.70	0.32	15.48	9.87	0.64	11.19	4.80	0.43
2	12.59	8.05	0.47	14.27	4.28	0.30	12.70	5.13	0.40
3	11.57	6.81	0.49	11.28	4.25	0.38	10.87	4.57	0.42
4	12.05	7.77	0.44	16.85	9.29	0.55	13.77	5.08	0.37
5	15.18	12.14	0.31	12.46	4.59	0.37	15.33	2.93	0.19
6	10.33	8.33	0.21	25.91	21.78	0.84	12.29	3.94	0.32
7	10.08	7.43	0.27	23.05	24.86	1.08	12.16	5.00	0.41
8	9.10	6.77	0.24	11.40	7.51	0.66	11.26	5.38	0.48
9	13.10	11.76	0.14	6.88	3.94	0.57	13.67	2.31	0.17
10	10.00	6.73	0.34	6.69	4.04	0.60	11.74	4.90	0.42
11	9.84	6.50	0.34	7.66	6.34	0.83	11.93	5.26	0.44
12	9.02	6.66	0.24	7.91	7.95	1.01	10.91	5.05	0.46
13	10.12	7.50	0.27	7.16	7.01	0.98	13.01	5.37	0.41
14	12.65	7.77	0.50	6.04	2.33	0.39	12.73	4.87	0.38
15	11.88	8.20	0.38	6.32	3.60	0.57	13.05	4.82	0.37
16	14.62	12.31	0.24	5.31	2.36	0.44	14.56	2.79	0.19
17	11.39	8.00	0.35	6.46	3.67	0.57	12.46	4.73	0.38
18	12.62	9.35	0.34	5.55	2.67	0.48	12.79	3.42	0.27
19	11.55	8.72	0.29	20.00	17.65	0.88	12.26	3.87	0.32
20	13.08	11.72	0.14	14.81	10.33	0.70	13.85	2.17	0.16
21	9.27	7.07	0.23	16.87	7.99	0.47	10.28	2.99	0.29
22	12.22	7.99	0.44	8.73	5.05	0.58	12.90	4.90	0.38
23	12.55	7.43	0.53	12.82	6.73	0.53	13.83	5.07	0.37
24	15.88	14.42	0.15	9.04	4.22	0.47	15.91	2.28	0.14
25	11.28	9.79	0.15	14.74	11.53	0.78	12.15	3.14	0.26

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
26	8.33	6.99	0.14	13.56	7.20	0.53	8.91	2.48	0.28
27	11.32	8.81	0.26	7.69	6.24	0.81	13.51	5.07	0.38
28	13.89	7.43	0.67	10.14	7.22	0.71	12.51	4.56	0.36
29	10.79	8.76	0.21	8.71	8.97	1.03	13.53	4.21	0.31
30	10.40	8.07	0.24	10.24	15.07	1.47	13.43	4.53	0.34
31	13.62	12.08	0.16	7.75	4.79	0.62	13.25	1.27	0.10
32	11.76	10.60	0.12	7.90	4.69	0.59	11.63	1.25	0.11
33	13.24	8.69	0.47	8.14	4.58	0.56	14.34	4.60	0.32
34	13.91	9.48	0.46	8.32	5.72	0.69	15.07	4.58	0.30
35	11.88	10.35	0.16	7.27	4.25	0.58	12.43	2.12	0.17
36	12.55	8.87	0.38	6.94	4.86	0.70	14.61	4.80	0.33
37	12.57	11.29	0.13	6.16	4.12	0.67	13.24	2.08	0.16
38	11.23	9.97	0.13	7.41	4.82	0.65	12.25	2.49	0.20
39	10.77	8.66	0.22	7.63	5.80	0.76	12.97	4.41	0.34
40	11.77	10.51	0.13	6.69	4.81	0.72	12.77	2.65	0.21
41	12.08	9.45	0.27	7.10	4.96	0.70	13.98	4.04	0.29
42	12.99	11.85	0.12	6.52	4.05	0.62	13.45	2.11	0.16
43	13.74	11.90	0.19	5.37	2.94	0.55	13.51	2.05	0.15
44	10.64	8.51	0.22	7.04	6.05	0.86	13.04	4.71	0.36
45	10.70	8.53	0.22	7.15	6.42	0.90	13.68	5.22	0.38
46	14.75	12.28	0.25	8.33	6.08	0.73	14.70	2.02	0.14
47	13.04	11.64	0.14	11.64	6.08	0.52	13.74	1.96	0.14
48	13.07	8.98	0.42	8.32	7.55	0.91	14.70	3.62	0.25
49	12.40	8.30	0.42	10.25	6.32	0.62	13.05	3.01	0.23
50	14.11	12.01	0.22	8.84	6.25	0.71	14.30	2.21	0.15
51	13.71	12.56	0.12	6.89	6.92	1.00	14.37	1.96	0.14

Project No	Cumulative Productivity	Baseline Productivity	Project Waste Index	Average Daily Productivity	Std Dev of Daily Quantities	CoV Daily Quantities	Mean of Daily Productivity	Std. Dev. of Daily Productivity	Coefficient of Variation
52	13.97	11.43	0.26	9.85	6.48	0.66	13.70	2.33	0.17
53	14.64	12.54	0.22	13.58	5.84	0.43	15.06	2.22	0.15
54	14.00	12.87	0.12	8.45	6.84	0.81	14.21	1.67	0.12
55	14.48	12.81	0.17	7.85	5.63	0.72	14.93	2.50	0.17
56	14.50	13.07	0.15	8.16	6.59	0.81	15.09	2.39	0.16
57	13.95	12.43	0.16	5.55	3.58	0.64	14.33	1.91	0.13
58	10.16	7.64	0.26	10.64	9.56	0.90	12.56	5.06	0.40
59	14.71	12.37	0.24	7.60	5.63	0.74	14.69	2.78	0.19
60	14.67	13.11	0.16	8.36	5.65	0.68	14.19	1.30	0.09
61	13.28	11.47	0.19	8.60	6.57	0.76	13.47	2.71	0.20

Source:*Researcher's data analysis 2012.*

APPENDIX V

BLOCK WORK (PROJECT 33)

1. SITE PRODUCTIVITY MEASURMENT

Data Presentation and Analysis of site work Collected from Project 33

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	6	48	25	1.920	
2	4	32	62	0.516	*
3	6	48	25	1.920	
4	10	80	50	1.600	
5	4	32	65	0.496	*
6	12	96	49	1.959	
7	6	48	25	1.920	
8	6	48	27	1.778	
9	10	80	49	1.633	
10	4	32	67	0.478	*
11	10	80	158	0.508	*
12	6	48	26	1.846	
13	6	48	24	2.000	
14	4	32	75	0.427	*
15	6	48	30	1.600	
16	6	48	32	1.500	
17	8	64	32	2.000	
18	6	48	30	1.600	
19	6	48	31	1.548	
SUM	**126**	**1008**	**881**	**27.249**	

Source: ***Researcher's data analysis 2012, * Used in the computation of baseline productivity.***

CONCRETE WORK (PROJECT 28)

2. SITE PRODUCTIVITY MEASURMENT

Data Presentation and Analysis of site work Collected from Project 28

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	12	102	5.5	18.545	
2	12	96	5	19.200	
3	13	104	9.5	10.947	
4	38	342	20	17.100	
5	38	342	20	17.100	
6	35	315	19	16.579	
7	5	40	5.8	6.897	*
8	5	40	5.85	6.838	*
9	7	56	5.85	9.573	
10	6	48	6.2	7.742	*
11	6	51	5.95	8.571	
12	6	48	5.65	8.496	*
13	6	42	5.85	7.179	*
14	6	24	1.9	12.632	
SUM	**327**	**2818**	**202.85**	**250.154**	

*Source:**Researcher's data analysis 2012, * Used in the computation of baseline productivity.***

PLASTERING (PROJECT 2)

3. SITE PRODUCTIVITY MEASURMENT

Data Presentation and Analysis of site work Collected from Project 2

Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	6	48	24	2.000	
2	12	96	108	0.889	
3	12	96	115	0.835	*
4	12	96	105	0.914	
5	12	96	117	0.821	*
6	12	96	49	1.959	
7	12	96	48	2.000	
8	12	96	49	1.959	
9	12	96	48	2.000	
10	12	108	55	1.964	
11	6	54	80	0.675	*
12	6	54	71	0.761	*
13	12	108	54	2.000	
14	10	90	112	0.804	*
15	10	80	42	1.905	
16	10	85	50	1.700	
SUM	**8**	**1395**	**1127**	**23.184**	

*Source:**Researcher's data analysis 2012, * Used in the computation of baseline productivity.***

FLOOR TILLING (PROJECT 2)

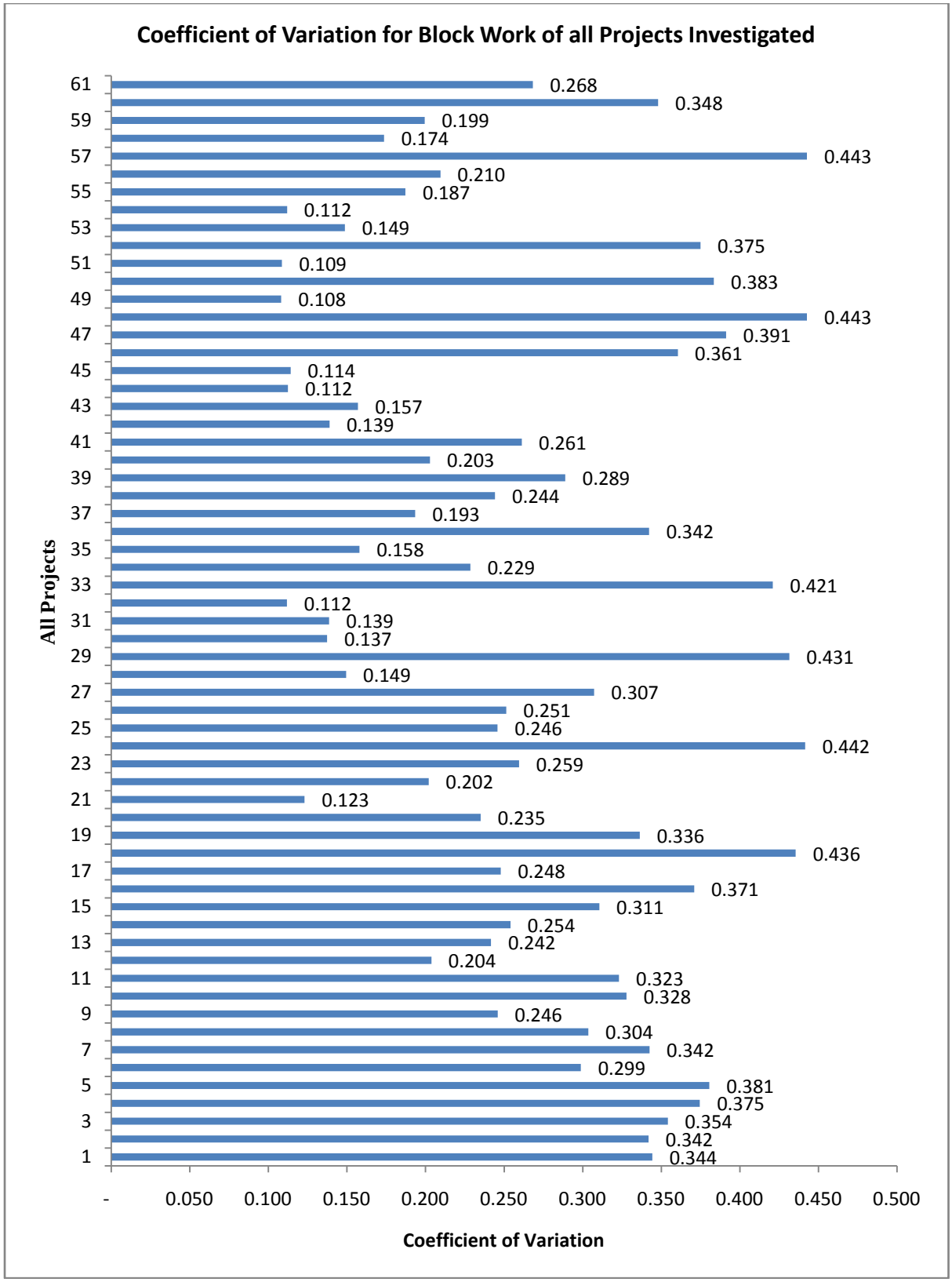
4. SITE PRODUCTIVITY MEASURMENT

Data Presentation and Analysis of site work Collected from Project 2

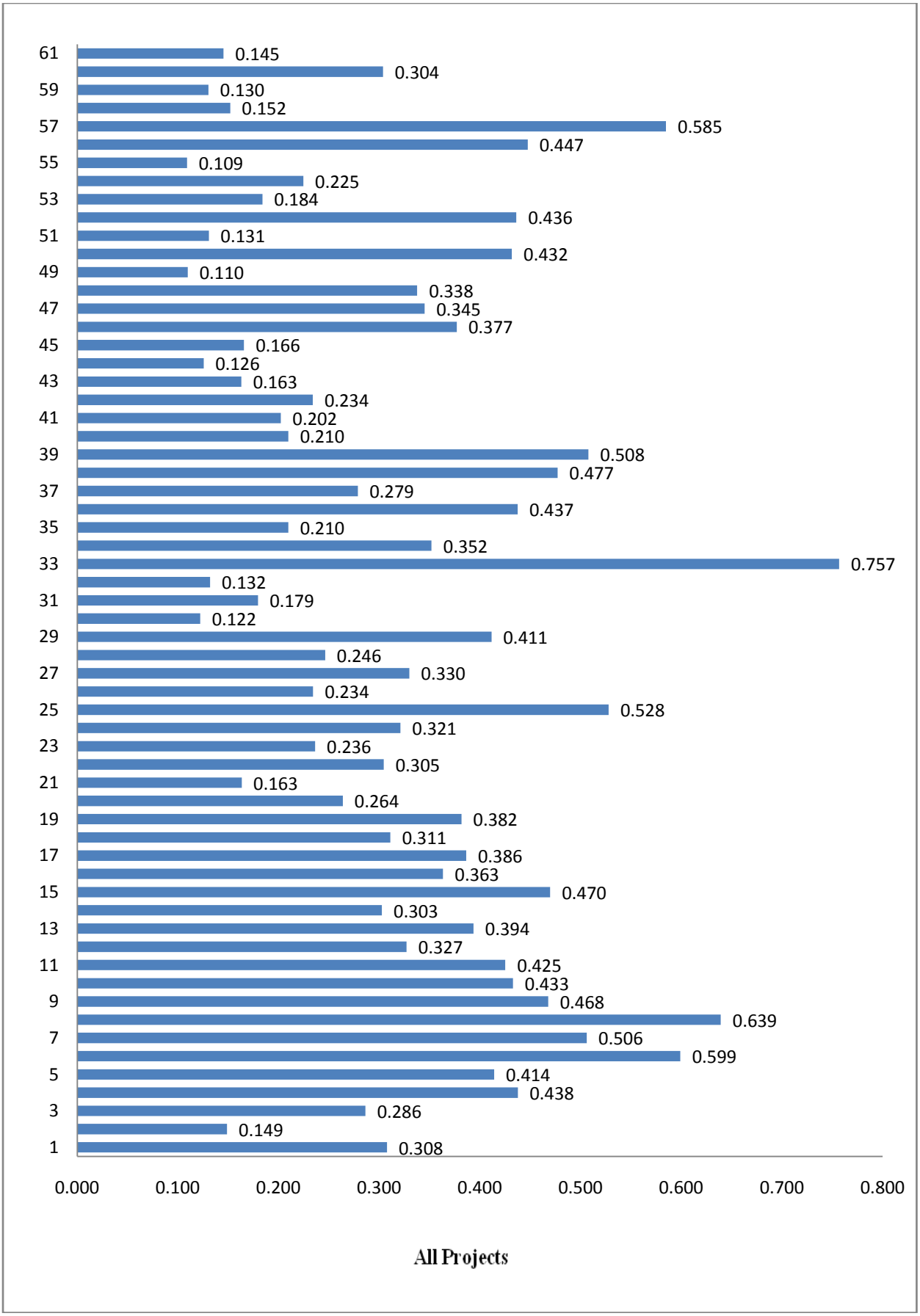
Day	Crew Size	Work hours (h)	Daily Quantities (m^2)	Labour Daily productivity (h/m^2)	Baseline days and productivity
1	4	32	17.34	1.845	
2	6	48	28.78	1.668	
3	7	40	21.67	1.846	
4	7	56	29.98	1.868	
5	3	21	40	0.525	*
6	4	32	17.45	1.834	
7	5	40	79	0.506	*
8	7	56	27.67	2.024	
9	5	40	79	0.506	*
10	6	48	90	0.533	*
11	7	56	29.45	1.902	
12	7	56	26.67	2.100	
13	7	56	27.89	2.008	
14	7	18	30	0.600	*
15	5	40	18.98	2.107	
16	7	40	23.67	1.690	
SUM	**94**	**679**	**587.55**	**23.562**	

Source: ***Researcher's data analysis 2012, * Used in the computation of baseline productivity.***

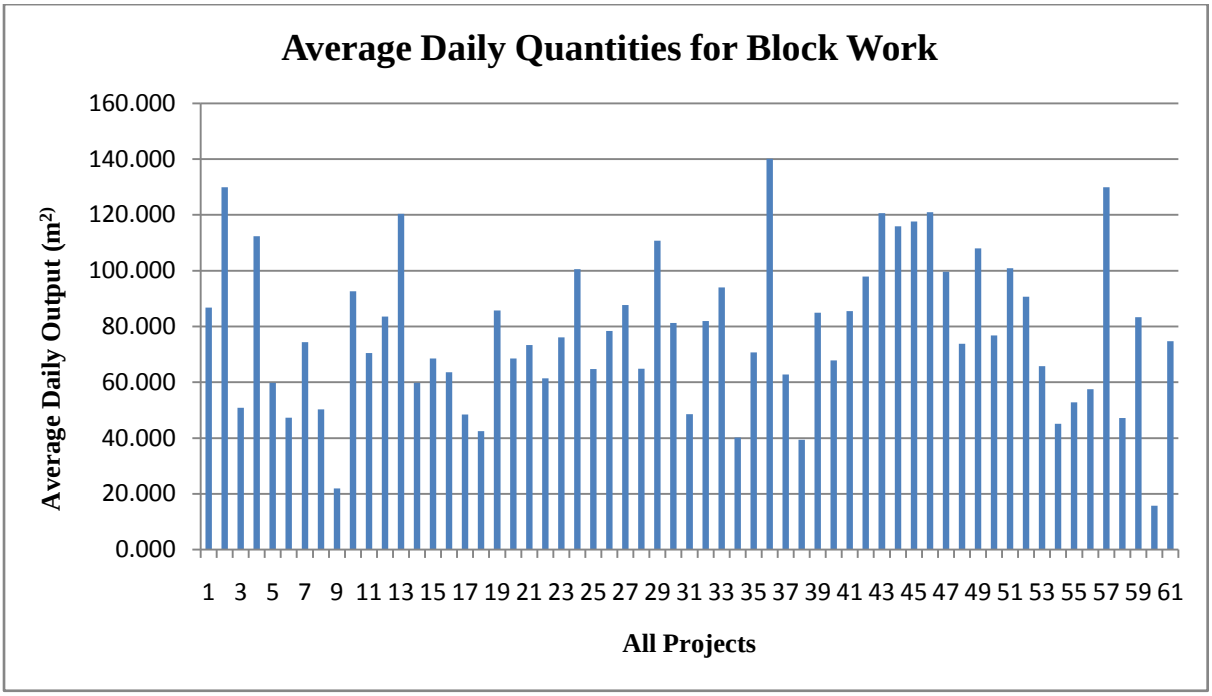
APPENDIX VI



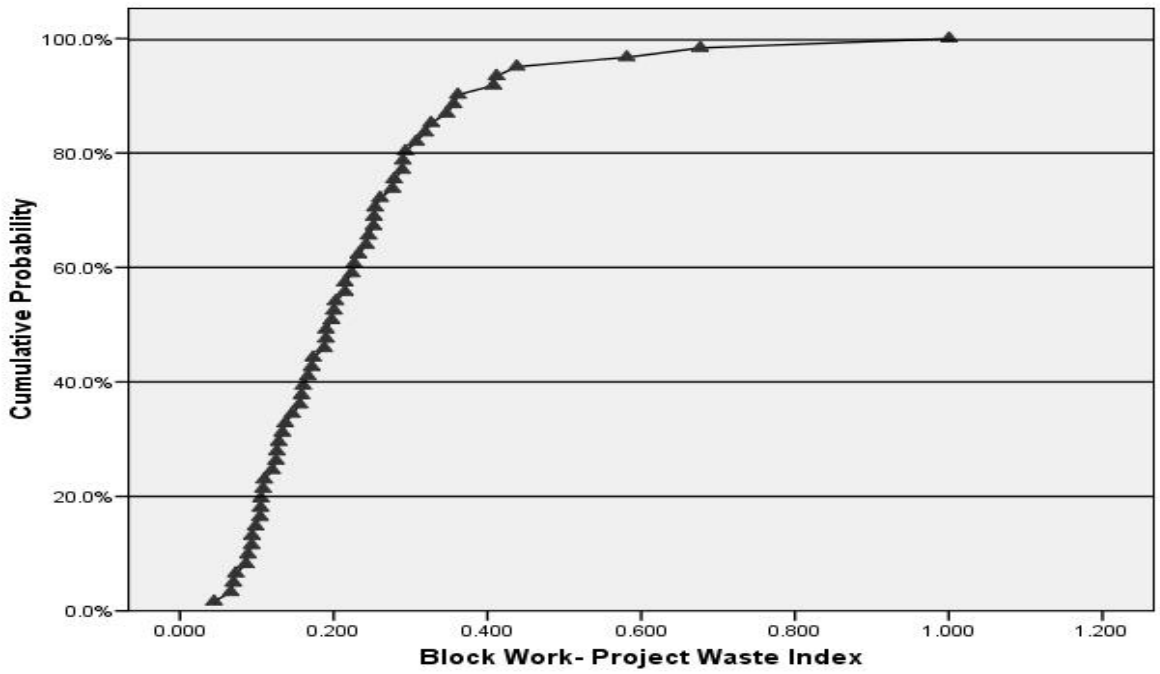
Values of Coefficient of Variability in Daily Labour Productivity for all block work Projects



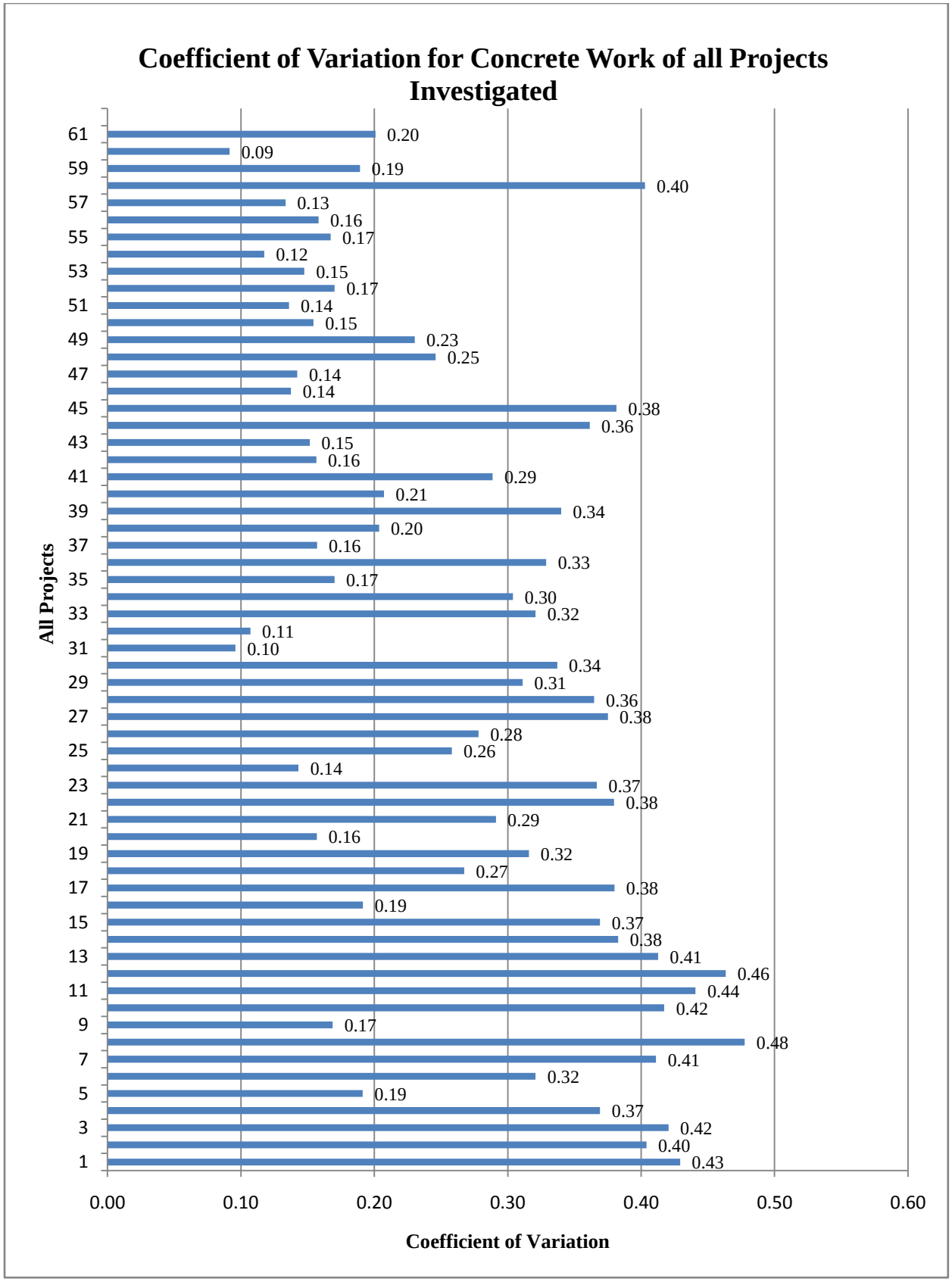
Values of Project Waste Index in for all Projects for Block Work Trade



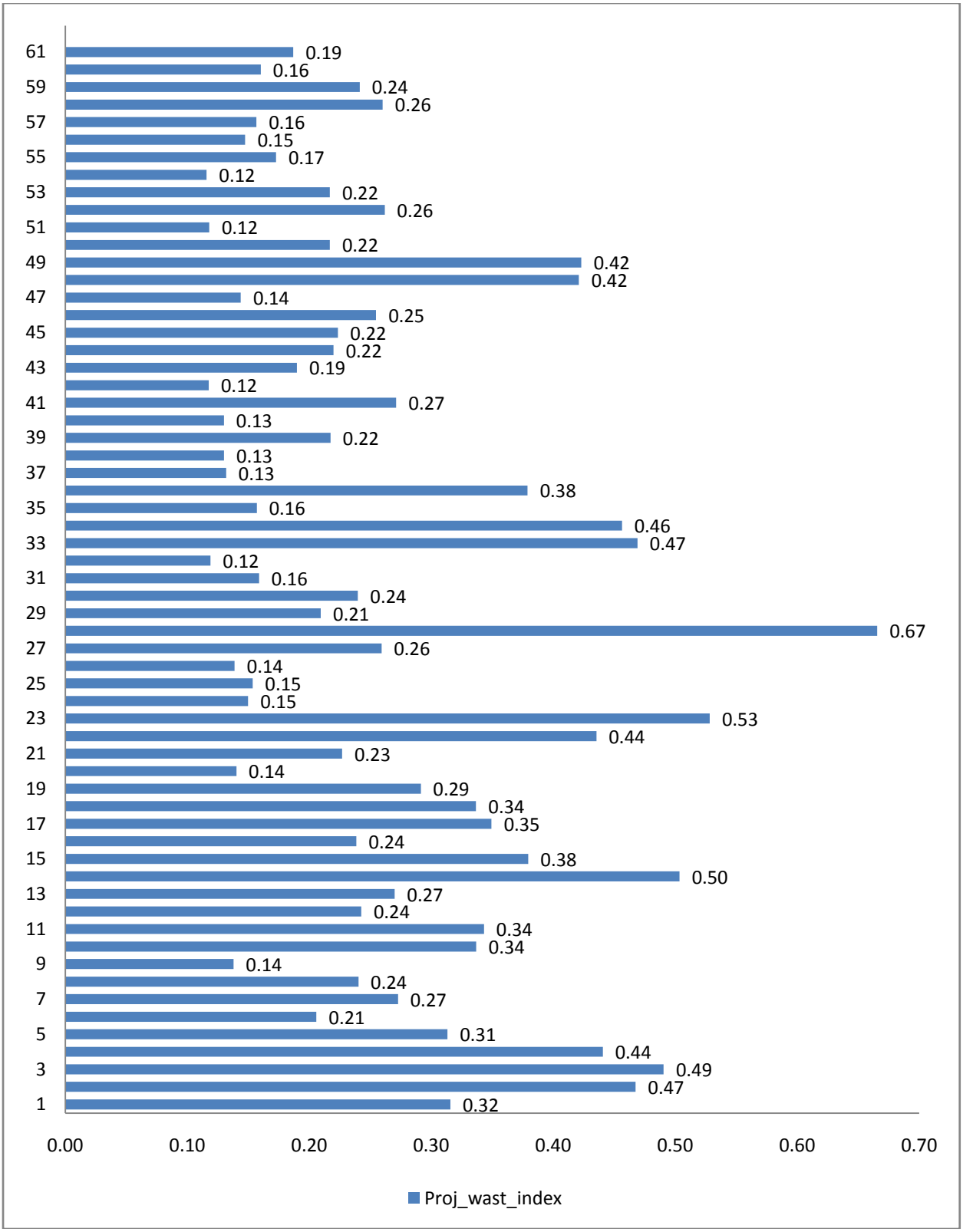
Variation in Average Daily Quantities for all Projects for Block work Trade



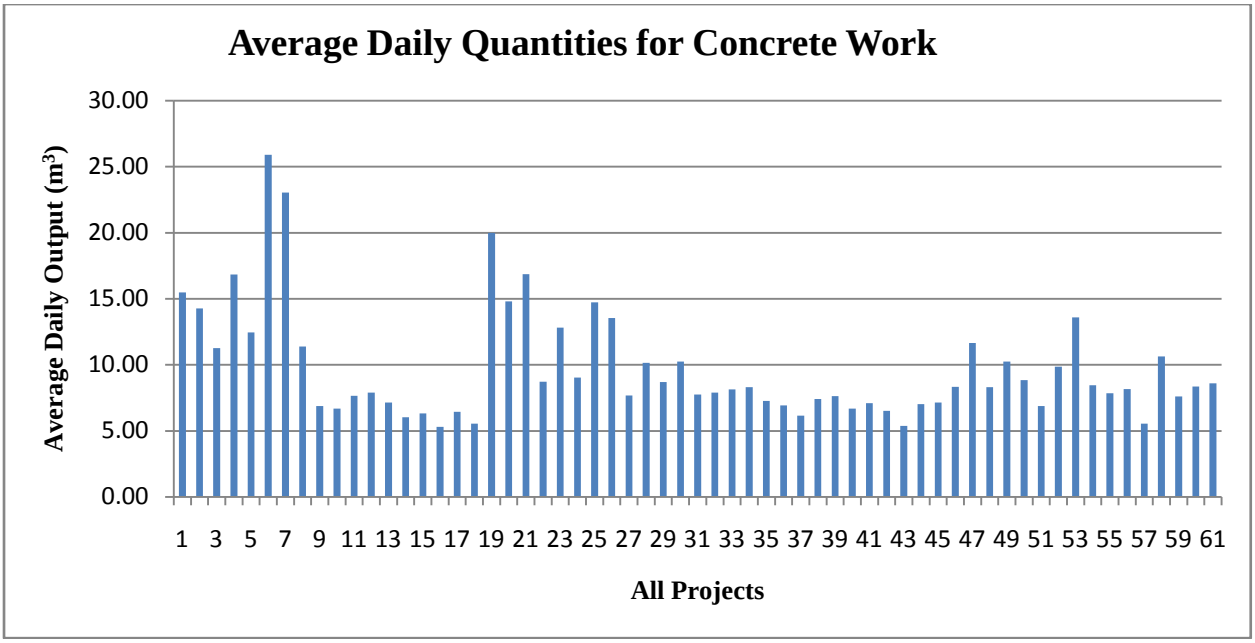
Cumulative Distribution of Project Waste Index (PWI) for Block Work Trade



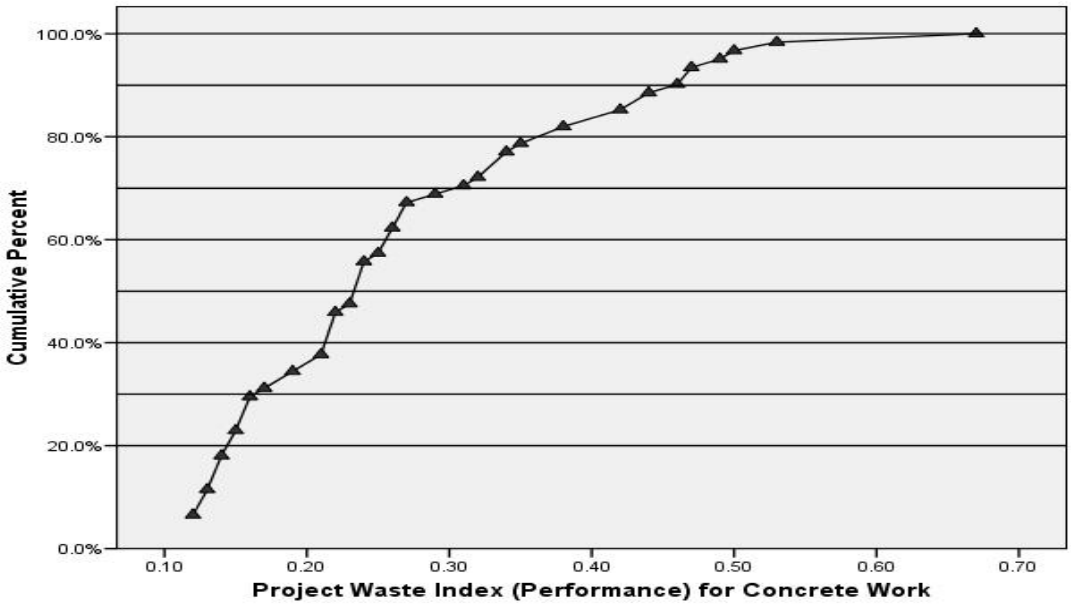
Values of Coefficient of Variability in Daily Labour Productivity for all Projects



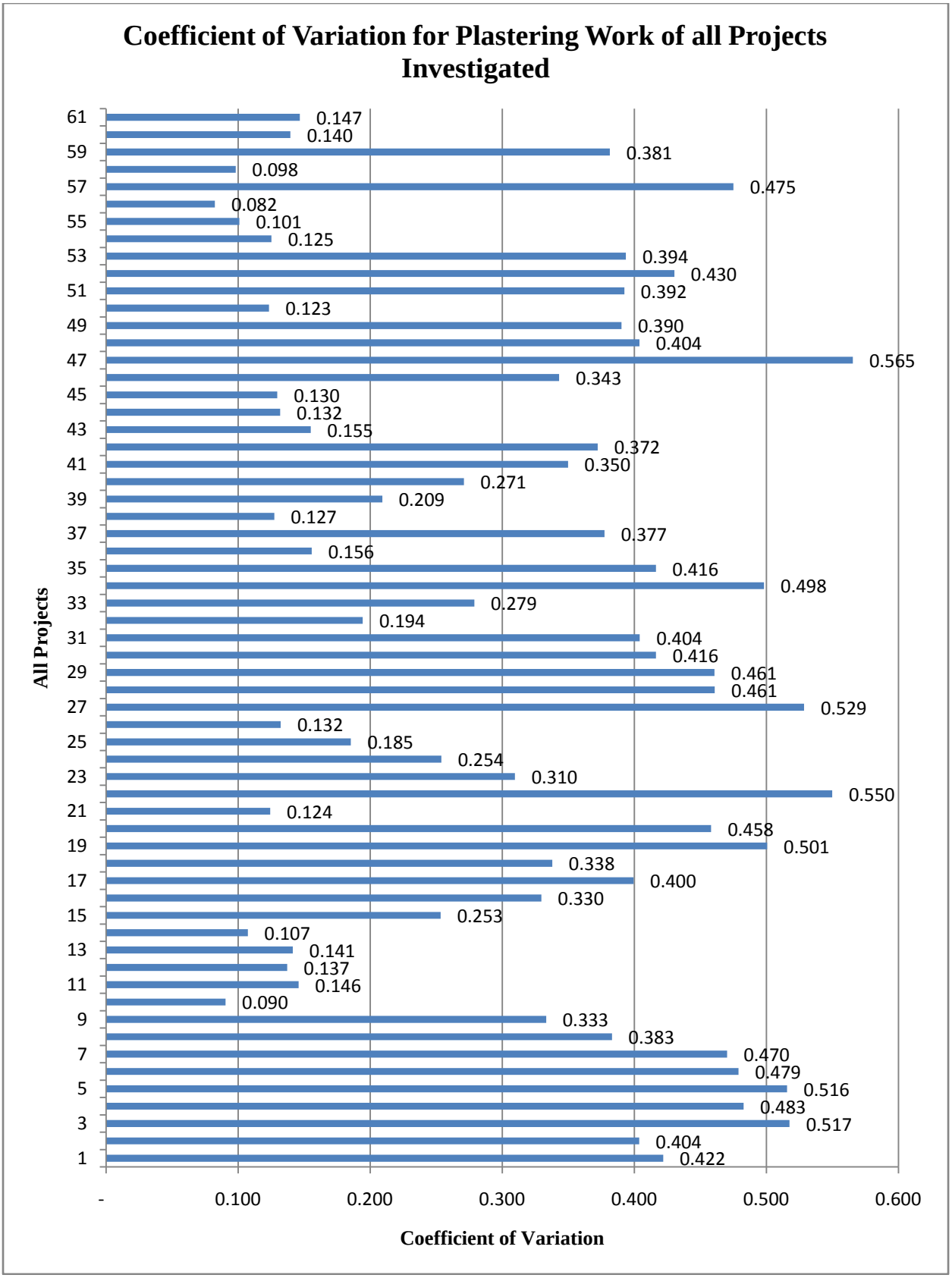
Values of Project Waste Index in for all Projects for Concrete Trade



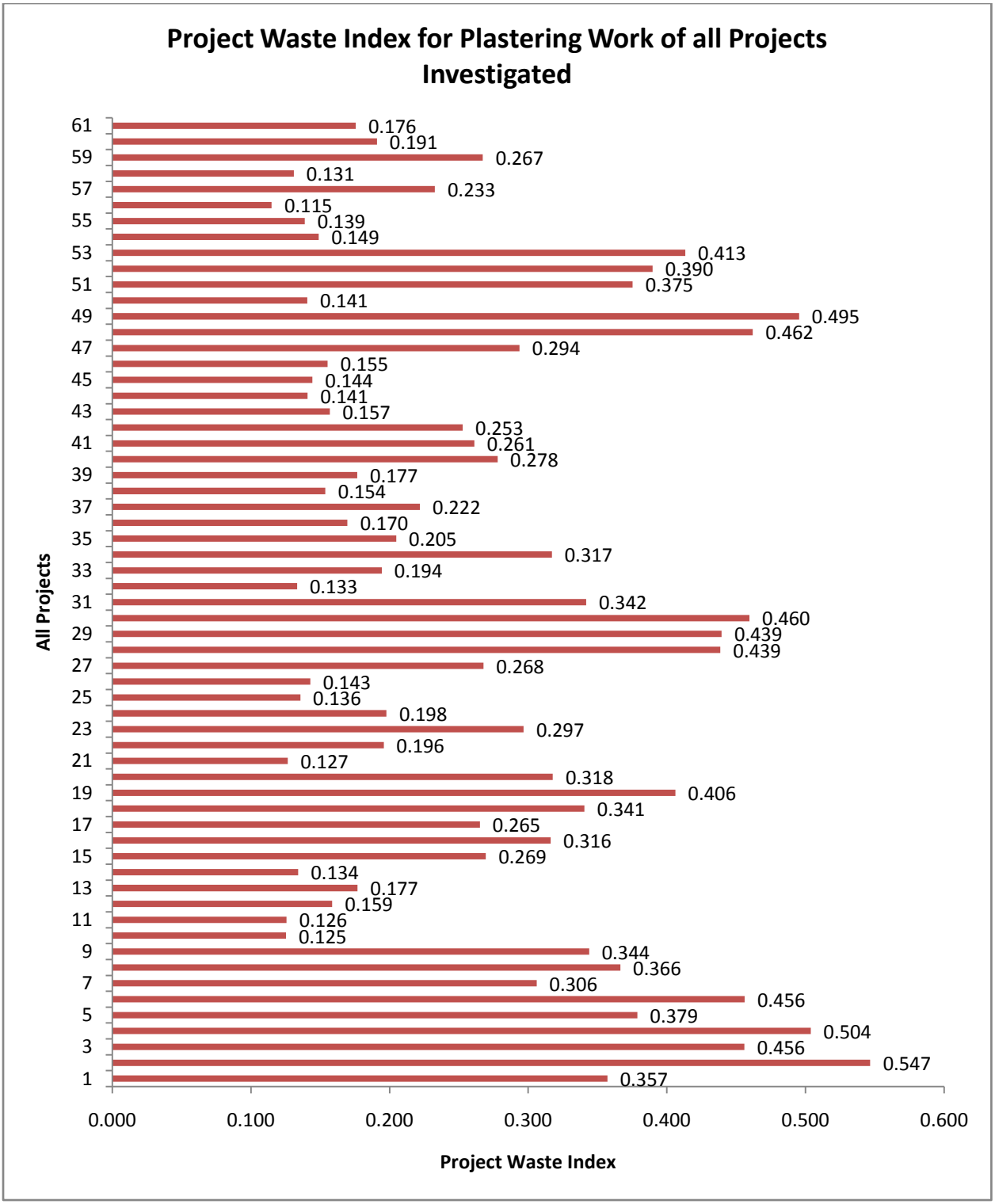
Variation in Average Daily Quantities for all Projects for Concrete work Trade



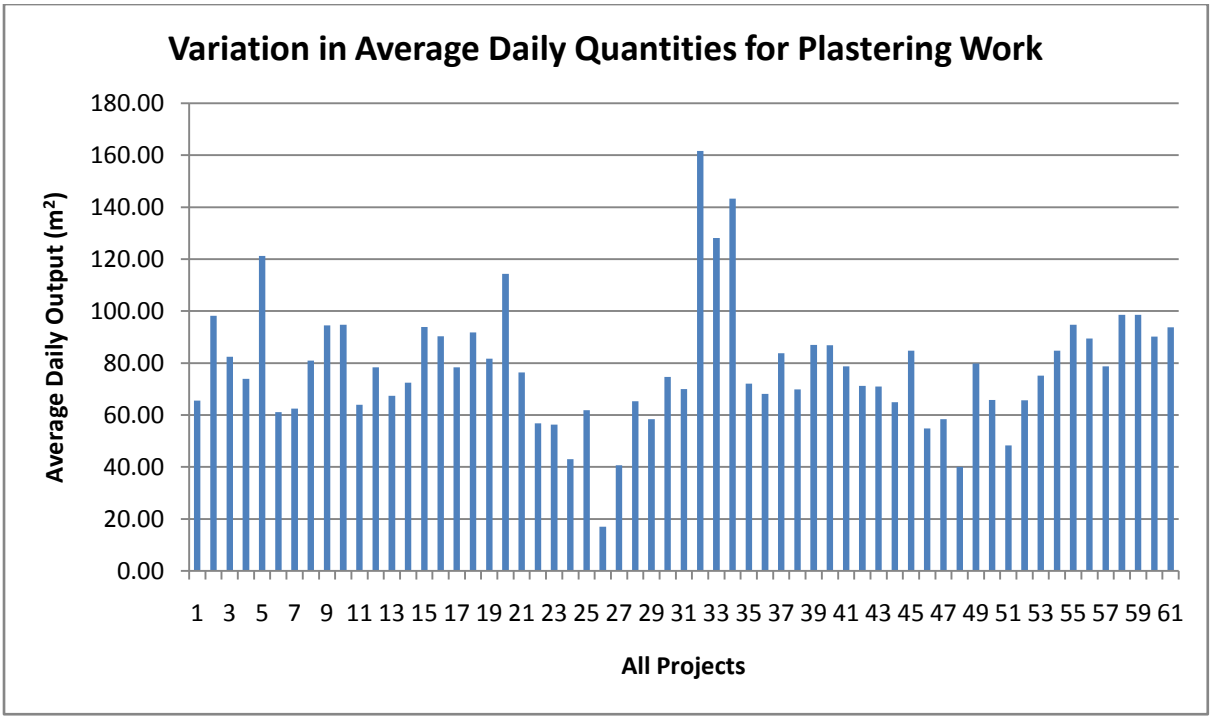
Cumulative Distribution of Project Waste Index (PWI) for concrete Work Trade



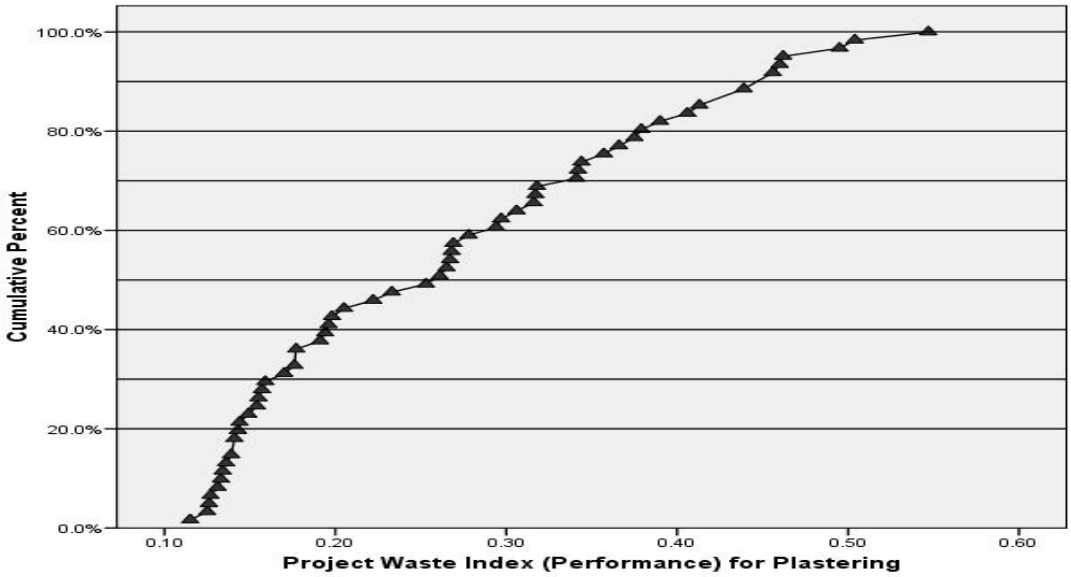
Values of Coefficient of Variability in Daily Labour Productivity for all Projects



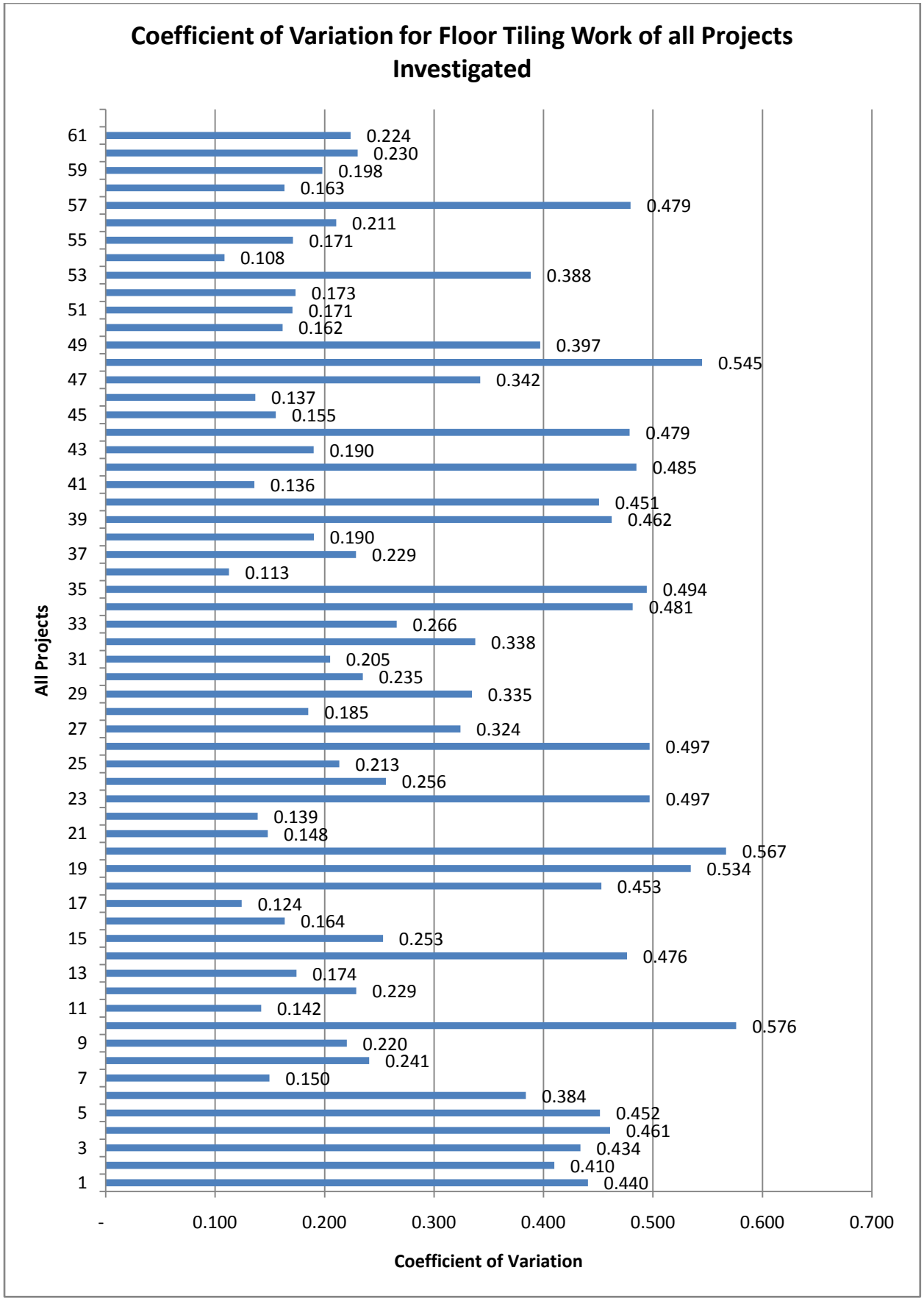
Values of Project Waste Index in for all Projects for Concrete Trade



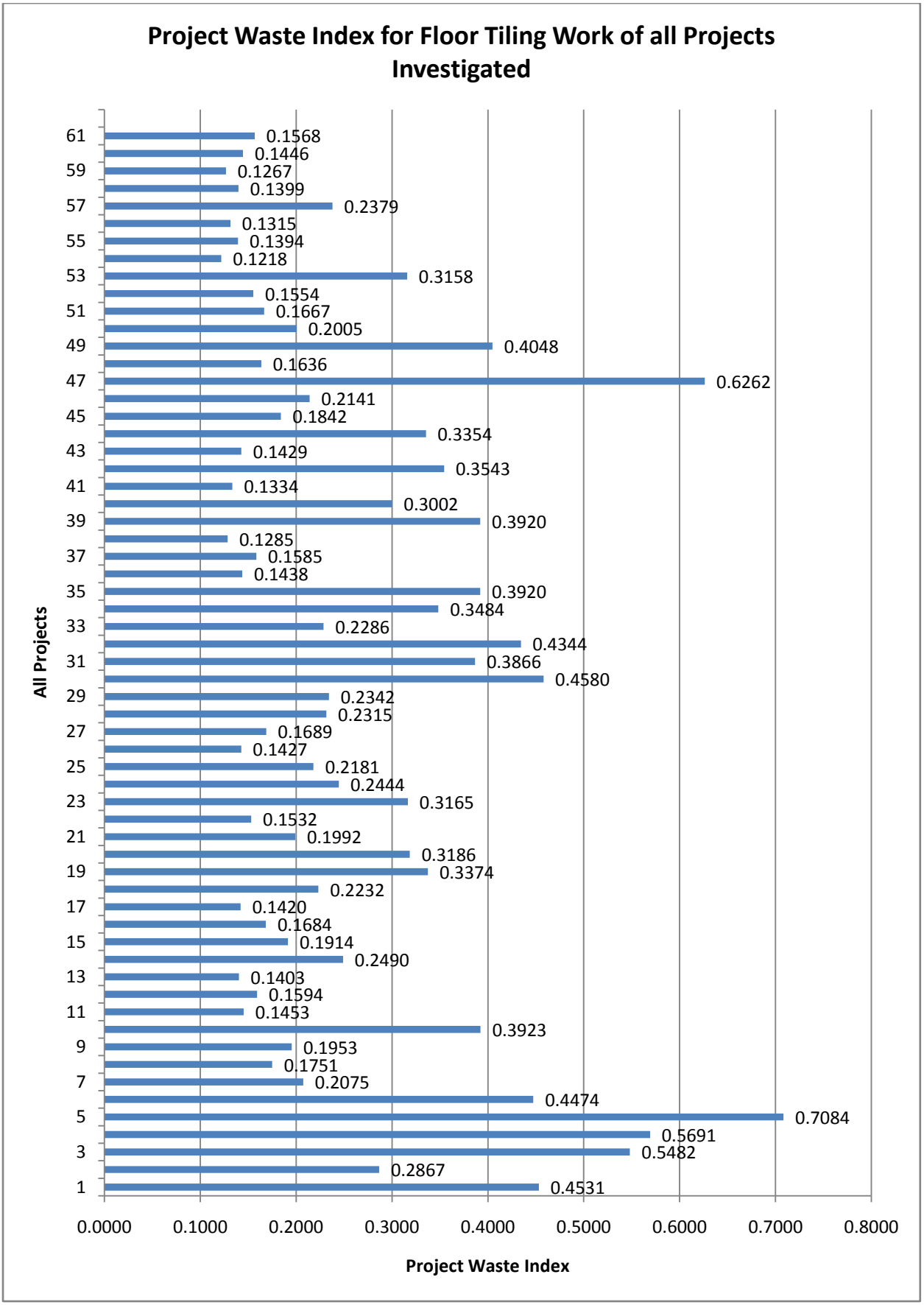
Variation in Average Daily Quantities for all Projects for Concrete work Trade



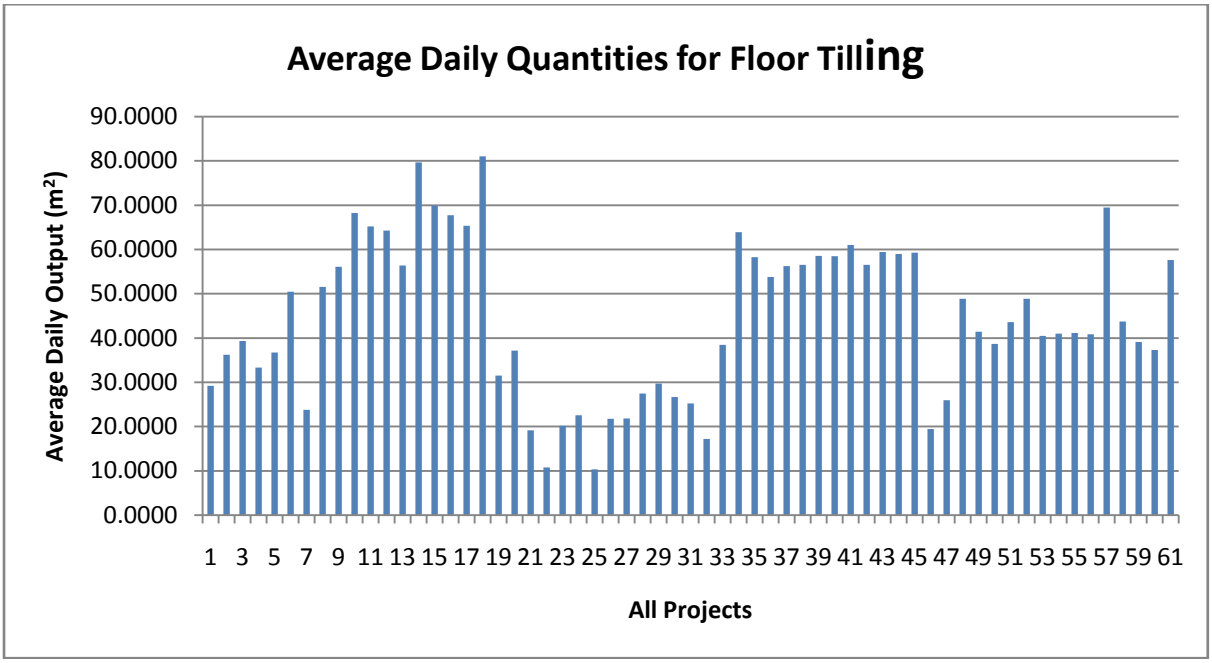
Cumulative Distribution of Project Waste Index (PWI) for Wall Plastering Trade



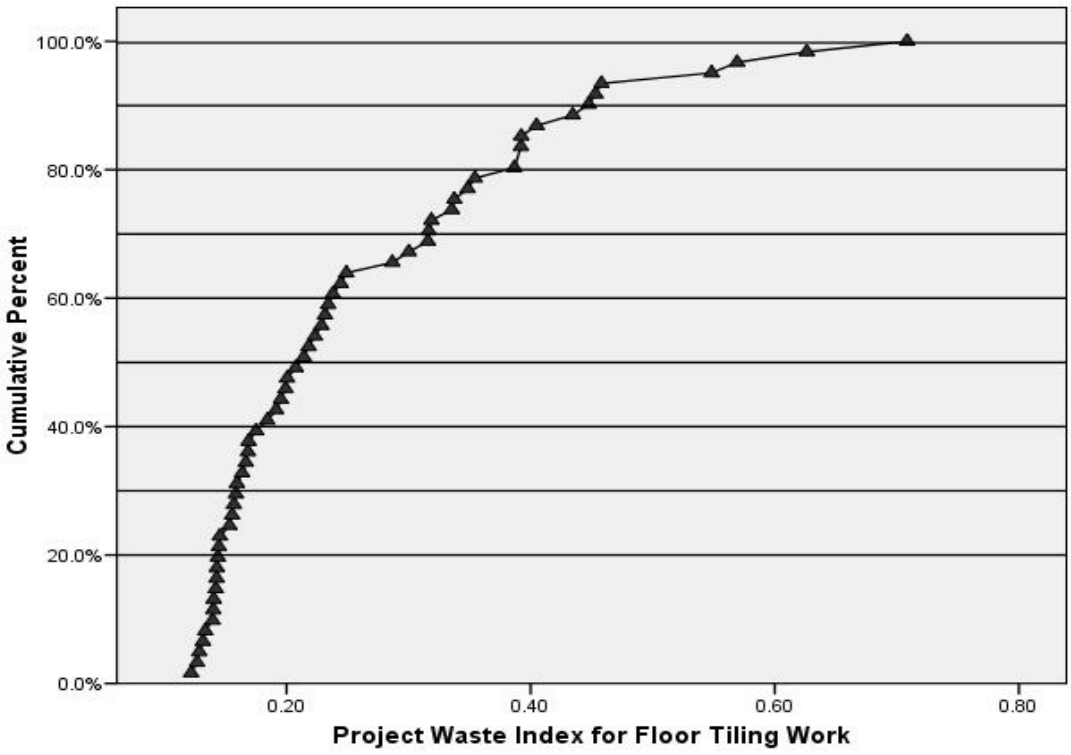
Values of Coefficient of Variability in Daily Labour Productivity for all Projects



Values of Project Waste Index in for all Projects for Concrete Trade



Variation in Average Daily Quantities for all Projects for Floor Tiling work Trade



Cumulative Distribution of Project Waste Index (PWI)

APPENDIX VII

Daily Data Collation sheet

Wall No:	Project Name					Day:		Date:	
	Work Start		Work End:			No of Stories:		Floor No.	
	No of Labour:		Skilled Labour			Helper:		Forman:	
	Wall Dimensions (m)		Window:			Window		Door:	
	Length	*Height*	*Thick*	*Length*	*Height*	*Length*	*Height*	*Length*	*Height*
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Source: Abdul-Razek (2007)

Data Collation sheet for each project

Day	*Crew Size*	*Work hours (h)*	*Daily Quantities (m^2)*	*Labour daily productivity (h/m^2)*	*Baseline days*	*Abnormal days*
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
Sum						

Source: Abdul-Razek (2007)

APPENDIX VIII

Statistical Analysis for Block work

Descriptives

			Statistic	Std. Error
Labour Productivity for Block Work	Mean		1.1898	.01249
	95% Confidence Interval for Mean	Lower Bound	1.1653	
		Upper Bound	1.2143	
	5% Trimmed Mean		1.1788	
	Median		1.0900	
	Variance		.176	
	Std. Deviation		.41918	
	Minimum		.43	
	Maximum		2.17	
	Range		1.74	
	Interquartile Range		.68	
	Skewness		.425	.073
	Kurtosis		-.964	.146

Correlations

		Project Waste Index for Block Work	Commulative Productivity for Block
Project Waste Index for Block Work	Pearson Correlation	1	.591(**)
	Sig. (2-tailed)		.000
	N	61	61
Commulative Productivity for Block	Pearson Correlation	.591(**)	1
	Sig. (2-tailed)	.000	
	N	61	61

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

Correlations

		Project Waste Index for Block Work	Coefficient of Variation for Block Work
Project Waste Index for Block Work	Pearson Correlation	1	.630(**)
	Sig. (2-tailed)		.000
	N	61	61
Coefficient of Variation for Block Work	Pearson Correlation	.630(**)	1
	Sig. (2-tailed)	.000	
	N	61	61

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

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Project Waste Index for Block Work	61	.69	.12	.81	.3427	.15775	.555	.306
Valid N (listwise)	61							

Statistics

Project Waste Index for Block Work

N	Valid	61
	Missing	0
Median		.3320
Percentiles	50	.3320

Correlations

		Project Waste Index for Block Work	COV_Daily_produc
Project Waste Index for Block Work	Pearson Correlation	1	.278(*)
	Sig. (2-tailed)		.030
	N	61	61
COV_Daily_produc	Pearson Correlation	.278(*)	1
	Sig. (2-tailed)	.030	
	N	61	61

* Correlation is significant at the 0.05 level (2-tailed).

Statistical Analysis for Concrete work

Descriptives

			Statistic	Std. Error
Labour Productivity for Concrete Work	Mean		13.3259	.13501
	95% Confidence Interval for Mean	Lower Bound	13.0609	
		Upper Bound	13.5909	
	5% Trimmed Mean		13.3575	
	Median		13.8069	
	Variance		14.181	
	Std. Deviation		3.76575	
	Minimum		5.25	
	Maximum		20.96	
	Range		15.71	
	Interquartile Range		6.23	
	Skewness		-.247	.088
	Kurtosis		-.960	.175

Correlations

		Commulative Productivity for Concrete Work	Coefficient of Variation for Concrete Work
Commulative Productivity for Concrete Work	Pearson Correlation	1	-.716(**)
	Sig. (2-tailed)		.000
	N	61	61
Coefficient of Variation for Concrete Work	Pearson Correlation	-.716(**)	1
	Sig. (2-tailed)	.000	
	N	61	61

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

Correlations

		Coefficient of Variation for Concrete Work	Project Waste Index (Performance) for Concrete Work
Coefficient of Variation for Concrete Work	Pearson Correlation	1	.601(**)
	Sig. (2-tailed)		.000
	N	61	61
Project Waste Index (Performance) for Concrete Work	Pearson Correlation	.601(**)	1
	Sig. (2-tailed)	.000	
	N	61	61

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

Correlations

		Project Waste Index (Performance) for Concrete Work	Coefficient of Variation for Quantities of Concrete Work
Project Waste Index (Performance) for Concrete Work	Pearson Correlation	1	-.229
	Sig. (2-tailed)		.076
	N	61	61
Coefficient of Variation for Quantities of Concrete Work	Pearson Correlation	-.229	1
	Sig. (2-tailed)	.076	
	N	61	61

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Commulative Productivity for Concrete Work	61	8.33	15.88	12.2846	1.77146	-.189	.306
Coefficient of Variation for Concrete Work	61	.09	.48	.2707	.11155	.075	.306
Valid N (listwise)	61						

Statistics

Project Waste Index (Performance) for Concrete Work

N	Valid	61
	Missing	0
Median		.2400

Statistical Analysis for Wall Plastering work

Descriptives

			Statistic	Std. Error
Labour Productivity for Plastering	Mean		1.1642	.01521
	95% Confidence Interval for Mean	Lower Bound	1.1343	
		Upper Bound	1.1940	
	5% Trimmed Mean		1.1483	
	Median		.9896	
	Variance		.193	
	Std. Deviation		.43959	
	Minimum		.51	
	Maximum		2.16	
	Range		1.65	
	Interquartile Range		.70	
	Skewness		.645	.085
	Kurtosis		-.895	.169

Correlations

		Commulative Productivity for Plastering	Project Waste Index (Performance) for Plastering
Commulative Productivity for Plastering	Pearson Correlation	1	-.048
	Sig. (2-tailed)		.715
	N	61	61
Project Waste Index (Performance) for Plastering	Pearson Correlation	-.048	1
	Sig. (2-tailed)	.715	
	N	61	61

Correlations

		Project Waste Index (Performance) for Plastering	Coefficient of Variation for Plastering
Project Waste Index (Performance) for Plastering	Pearson Correlation	1	.764(**)
	Sig. (2-tailed)		.000
	N	61	61
Coefficient of Variation for Plastering	Pearson Correlation	.764(**)	1
	Sig. (2-tailed)	.000	
	N	61	61

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

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Coefficient of Variation for Plastering	61	.08	.57	.3113	.14909	-.107	.306
Commulative Productivity for Plastering	61	.75	1.47	1.0641	.17526	.692	.306
Valid N (listwise)	61						

Statistics

Project Waste Index (Performance) for Plastering

N	Valid	61
	Missing	0
Median		.2610

Correlations

		Project Waste Index (Performance) for Plastering	Coefficient of Variation for Quantities of Plastering
Project Waste Index (Performance) for Plastering	Pearson Correlation	1	.521(**)
	Sig. (2-tailed)		.000
	N	61	61
Coefficient of Variation for Quantities of Plastering	Pearson Correlation	.521(**)	1
	Sig. (2-tailed)	.000	
	N	61	61

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

Statistical Analysis for Floor Tiling work

Descriptives

			Statistic	Std. Error
Labour Productivity for Floor Tilling	Mean		1.2156	.01631
	95% Confidence Interval for Mean	Lower Bound	1.1836	
		Upper Bound	1.2476	
	5% Trimmed Mean		1.2086	
	Median		1.1340	
	Variance		.196	
	Std. Deviation		.44283	
	Minimum		.48	
	Maximum		2.18	
	Range		1.70	
	Interquartile Range		.74	
	Skewness		.336	.090
	Kurtosis		-1.078	.180

Correlations

		Commulative Productivity for Floor Tiling	Project Waste Index for Floor Tiling Work
Commulative Productivity for Floor Tiling	Pearson Correlation	1	.028
	Sig. (2-tailed)		.830
	N	61	61
Project Waste Index for Floor Tiling Work	Pearson Correlation	.028	1
	Sig. (2-tailed)	.830	
	N	61	61

Correlations

		Project Waste Index for Floor Tiling Work	Coefficient of Variation for Floor Tilling
Project Waste Index for Floor Tiling Work	Pearson Correlation	1	.588(**)
	Sig. (2-tailed)		.000
	N	61	61
Coefficient of Variation for Floor Tilling	Pearson Correlation	.588(**)	1
	Sig. (2-tailed)	.000	
	N	61	61

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

Correlations

		Project Waste Index for Floor Tiling Work	Coefficient of Variation for Quantities of Floor Tilling
Project Waste Index for Floor Tiling Work	Pearson Correlation	1	.530(**)
	Sig. (2-tailed)		.000
	N	61	61
Coefficient of Variation for Quantities of Floor Tilling	Pearson Correlation	.530(**)	1
	Sig. (2-tailed)	.000	
	N	61	61

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

Statistics

Project Waste Index for Floor Tiling Work

N	Valid	61
	Missing	0
Median		.2141

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Commulative Productivity for Floor Tiling	61	.79	1.86	1.1063	.20509	1.564	.306
Coefficient of Variation for Floor Tilling	61	.11	.58	.3030	.14418	.366	.306
Valid N (listwise)	61						

Multiple Regression for Block Laying

Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	covlp, covquant(a)	.	Enter

a All requested variables entered.
b Dependent Variable: Pwi

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.633(a)	.401	.381	.12415

a Predictors: (Constant), covlp, covquant

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.599	2	.300	19.436	.000(a)
	Residual	.894	58	.015		
	Total	1.493	60			

a Predictors: (Constant), covlp, covquant
b Dependent Variable: Pwi

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	.099	.051		1.950	.056
	covquant	-.064	.104	-.074	-.616	.540
	covlp	1.034	.185	.669	5.602	.000

a Dependent Variable: Pwi

Multiple Regression for **Concrete Works**

Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	covlp, covquant(a)	.	Enter

a All requested variables entered.
b Dependent Variable: Pwi

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.690(a)	.476	.458	.09284

a Predictors: (Constant), covlp, covquant

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.454	2	.227	26.338	.000(a)
	Residual	.500	58	.009		
	Total	.954	60			

a Predictors: (Constant), covlp, covquant
b Dependent Variable: Pwi

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	.213	.048		4.414	.000
	covquant	-.216	.061	-.345	-3.573	.001
	covlp	.747	.109	.661	6.848	.000

a Dependent Variable: Pwi

Multiple Regression for **Wall Plastering Work**

Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	covlp, covquant(a)	.	Enter

a All requested variables entered.
b Dependent Variable: Pwi

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.764(a)	.584	.569	.07928

a Predictors: (Constant), covlp, covquant

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.511	2	.256	40.678	.000(a)
	Residual	.365	58	.006		
	Total	.876	60			

a Predictors: (Constant), covlp, covquant
b Dependent Variable: Pwi

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	.078	.029		2.714	.009
	covquant	-.018	.095	-.022	-.185	.854
	covlp	.631	.096	.779	6.594	.000

a Dependent Variable: Pwi

Multiple Regression for **Floor Tiling**

Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	covlp, covquant(a)	.	Enter

a All requested variables entered.
b Dependent Variable: Pwi

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.610(a)	.372	.351	.11036

a Predictors: (Constant), covlp, covquant

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.419	2	.209	17.201	.000(a)
	Residual	.706	58	.012		
	Total	1.125	60			

a Predictors: (Constant), covlp, covquant
b Dependent Variable: Pwi

Coefficients(a)

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta	B	Std. Error
1	(Constant)	.047	.044		1.058	.294
	covquant	.221	.141	.230	1.565	.123
	covlp	.405	.139	.426	2.904	.005

a Dependent Variable: Pwi

Kolmogorov-Smirnov and Shapiro-WilkTestsfor Normality

BLOCK WORK

Tests of Normality

	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Labour Productivity for Block Work	.118	1127	.000	.946	1127	.000

a Lilliefors Significance Correction

Test Statistics

	Labour Productivity for Block Work
Chi-Square(a)	962.525
df	644
Asymp. Sig.	.000

a 645 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.7.

CONCRETE WORK

Tests of Normality

	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Labour Productivity for Concrete Work	.077	778	.000	.963	778	.000

a Lilliefors Significance Correction

Test Statistics

	Labour Productivity for Concrete Work
Chi-Square(a)	502.237
df	563
Asymp. Sig.	.969

a 564 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.4.

PLASTERING

Tests of Normality

	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Labour Productivity for Plastering	.158	835	.000	.901	835	.000

a Lilliefors Significance Correction

Test Statistics

	Labour Productivity for Plastering
Chi-Square(a)	1059.737
df	594
Asymp. Sig.	.000

a 595 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.4.

FLOOR TILLING

Tests of Normality

	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Labour Productivity for Floor Tilling	.091	737	.000	.945	737	.000

a Lilliefors Significance Correction

Test Statistics

	Labour Productivity for Floor Tilling
Chi-Square(a)	511.305
df	448
Asymp. Sig.	.020

a 449 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.6.