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INVESTIGATING THE ROLE OF ON-SITE LEARNING IN THE OPTIMISATION OF CRAFT GANG'S PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY

Rex Asibuodu Ugulu

A Thesis Submitted to Faculty of Engineering and Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy (PhD)

Johannesburg, August 2017

DECLARATION

I declare that this thesis is my own, unaided work. It is being submitted for the Degree of Doctor of Philosophy (PhD) in Quantity Surveying in University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.



…….

Rex Asibuodu Ugulu

August 2017

ABSTRACT

This research investigates how on-site craft gangs adapt to the production environment on-site and how on-site learning is affected by prior learning in orders to optimise productivity. To achieve the aim of the study, previous experience of construction production process of craft gangs, site supervisors and the project managers working in Nigerian construction firms was evaluated.

The researcher employed a mixed method research approach utilising qualitative and quantitative approaches. The research strategies used in this investigation included interviews and observation method. A face-to-face semi-structured interviews of (15) participants comprising of craft gangs, site supervisors and the project managers was used in the qualitative method of the data collection to explore the project specific constraints and the response mechanism used to resolve the various constraints. A standard observation data form was used in all the observed seven (7) gang's blockwork craft gangs on the construction site.

The interview transcript results collected were analysed using content analysis, an objective and systematic form of data analysis applicable to analysing interview data. In the application of the learning curve model to the blockwork craft gang's, the straight-line model was used in the preliminary analysis of the application of learning curve theory to blockwork craft gang's. In this study, the ordinary least squares technique, frequently referred to as linear regression was used for the data analysis. 0.05% significance level was used as a satisfactory degree of the inferences in the observation part of this study. Blockwork craft gang's observed at the site shows approximately an overall average learning of 94.21%, resulting in 5.79% improvement in blockwork gang's productivity. In addition, substantial impact on productivity of blockwork construction was achieved in wall construction.

This research work is fundamental in construction management by way of developing an understanding into the changing aspects of on-site blockwork craft gangs learning and its impact on productivity. The repetitive nature of blockwork activities has an important influence on the optimisation of productivity.

Construction craft gangs productivity constraints and response mechanism generated in this study provides a methodological instrument for addressing the major constraints influencing craft gangs productivity. This instrument will also permit future research on the project specific constraints and the response mechanisms used to resolve the constraints.

Keywords: On-site Learning; Construction Productivity; Learning Curves Theory; Work Measurement; Craft Gangs and Blockwork.

RELATED PUBLICATIONS

Ugulu, R. and Allen, S. (2015). Investigation into the Factors that Influence Construction Productivity- A Review of the Literature, Proceedings of the 12th International Post Graduate Research Conference, School of the Built Environment, University of Salford, Manchester UK, 10th -12th June, pp. 682-689.

Ugulu, R. A., Makhotso, M., Mahlatse, R., Morongoa S. and Allen, S. (2016). the Influence of Motivation on Labour Productivity on Building Construction Projects in South Africa. International Journal of Scientific & Engineering Research, Volume 7, Issue 3, pp. 1066-1073 http://www.ijser.org/researchpaper

Ugulu, R. A. and Allen, S. (2017) Investigation into the Role of On-site Learning in Block Laying Craft Gangs Productivity: A paper submitted for publication in American Society of Engineers (ASCE) Construction Engineering and Management Journal.

Ugulu, R. and Allen, S. (2016). Productivity Concepts Theories and Evaluation: the Applicability to the Construction Industry. 7th Cross-Faculty Graduate Research Conference/Symposium, University of the Witwatersrand, Johannesburg. 1st- 2nd March, 2016.

DEDICATION

This research work is dedicated to Almighty God for his mercy and in memory of my father Mr. Samuel, Okonicha Ugulu.

ACKNOWLEDGEMENTS

I remain grateful to Almighty God whose guidance, protection, and provisions, direction and sustenance remain priceless. I wish to acknowledge the support and guidance given to me in carrying out this research project by a number of individuals. My special appreciations go to my research supervisor, Dr Stephen Allen, for his care, feedback, patience and support during this research study.

Special thanks to the Head of School of Construction Economics and Management, Professor David Root, whose excellent guidance and encouragement have led to the success of this research study. I wish to also extend my thanks to the Coordinator of Postgraduate Studies, School of Construction Economics and Management, Dr Obinna A. Ozumba, for his valuable feedback during the course of this research study. Also, my appreciation goes to the staff of CEM, University of the Witwatersrand for their cooperation, assistance and empathy.

My sincere thanks also go to the Director of Public Building of the Federal Capital Development Agency (FCDA), Abuja, Nigeria, Arc Ikenna Ekeledo, the Deputy Director, Arc Ademo O. and the Assistant Director, Arc. Uchenna I. Anigbogu for their assistance and cooperation in gaining access to the FCDA project sites during the data collection exercise.

I must also express my appreciation to Mr Bruno Dalloz, for his assistance and cooperation in providing access to the site and provision of the good working environment throughout the data collection period.

I am particularly thankful to the Project Managers and Site Engineers for their support during the data collection stage. My greatest appreciation goes to the on-site blockwork craft gang's and foremen who assisted in the field work.

The financial support from my employer, Federal University of Technology, Owerri, Nigeria and Prof. G. N. Onuoha, the Ex-Dean School of Environmental Technology, for encouraging and supporting this research study. I cannot thank them enough.

My appreciation also goes to my colleagues at Postgraduate Research Centre for their support and encouragement during the course of this research study. My sincere thanks also go to my friend and colleague, Mr Sampson Igwe for his contribution during the statistical analysis of this research.

Finally, my gratitude goes to my mother, Mrs Grace Ugulu, my wife, Mrs Mabel Ugulu, and my most beloved offspring: Divine, Emmanuel, David and Daniel for tirelessly lifting me up morally and prayerfully throughout the duration of the research work.

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LIST OF ABBREVIATIONS

AEC Architectural Engineering and Construction

ACI American Concrete Institute

BNL Bouygues Nigeria Limited

BRS	Building Research Station
BS	British Standards
CCGP	Construction Graft Gang Productivity
CLP	Construction Labour Productivity
DF	Degrees of Freedom
EPSRC	Engineering and Physical Science Research Council
EU	European Union
FCDA	Federal Capital Development Agency
FCT	Federal Capital Territory
FIRS	Federal Inland Revenue Service
GDP	Gross Domestic Product
ILO	International Labour Organisation
KWP	Knowledge Worker Productivity
LCT	Learning Curve Theory
MH	Man-hours
NGCF	National Gross Capital Formation
OHS	Organisation Health and Safety
PR	Performance Ratio
SE	Standard Error
TIB	Theory of Interpersonal Behaviour
TRA	Theory of Reason Action
VIF	Variance Inflation Factor

CHAPTER 1

1.0 INTRODUCTION

Construction is a challenging industry that uses much capitals, it accounts for an important amount of gross domestic product (GDP) of some advanced and emerging countries (Tucker, Park, & Thomas, 2005). In advanced European countries, the building industry accounts for 10% of the GDP and even more in emerging countries (Chen, 2009; Hassan & McCafferR, 2002). Infrastructure provision is an important measure of growth and improvement of the infrastructure to provide for the varying demands of a fast evolving world is important for economic activity and growth (Attar et al., 2012).

The European Construction Industry Federation (ECIF, 2011) stated that "the building industry contributes 9.7% of the GDP in the European Union (EU) with a total building value of 1186 billion in 2010, providing 6.6% of Europe's total occupation" (ECIF, 2011). The building engineering is projected to have contributed 5.6% of the GDP in Canada in 2010 (Statistics Canada, 2011). In the United States (US), the building industry contributed for 5.3% of the GDP in 2011 (Bureau of Economic Analysis, 2012; US Census Bureau, 2012). The US Bureau of Labour Statistics (2008) noted that practically 11 million persons, or approximately 8% of the US total workers, were engaged in the building engineering (Bureau of Labour Statistics, 2008). For that reason, the efficiency of a sector like building engineering in a national economy is of great significance for trade and industry development.

Labour costs contribute to a large portion of the total contract cost of a construction project compared to other cost elements such as equipment and material and also, the Labour contract costs have the greatest probability of being reduced by competent management (Odesola & Idoro, 2014). An upturn in efficiency has a tendency to reduce the overall workforce cost of the construction project (Hanna et al., 2008). An important aspect of the management of labour in the construction industry is that if not properly handled it could contribute to both

the time and cost overruns. Prior investigation on effects of time and cost overruns of building projects point out that construction industry in some developed and developing countries experience delays and cost overruns in construction productivity due to labour problems (Alinaitwe et al., 2007; Durdyev & Mbachu, 2011; Hanna et al., 2008; Odesola & Idoro, 2014).

Construction productivity is an important issue to operation and production managers and greater construction efficiency can be improved through improved application of current resources. Encyclopaedia (2010) stated that ‘’productivity is the index of development and measures of effectiveness, wages in addition to prices’’. Alinaitwe et al. (2007) ranked deficiency in crafts worker’s knowledge and incompetent supervision as top two significant factors causing differential productivity of craft workers in developed and developing countries, In the same way, Odusami and Unoma (2011) stated that the differential output can relate to inadequate and poor knowledge of workers in the construction industry. Moselhi (2010) identify constraints to productivity on a daily basis to include 1) craft gangs training; 2) crew composition; 3) weather; 4) height of work and 5) construction method.

1.1 Context

Craftsmen learning systems perform a significant function in enhancing construction workforce productivity, and conventional learning platforms occur in the construction industry union sectors in the US (Wang et al., 2010). Nevertheless, these conventional programmes are unreliable and enjoy insignificant support from the government. The official traineeship platforms in Canada are regulated and maintained by the management in the relationship with the private sector and unions and related formal preparation programmes exist in other advanced nations of the world. This problem of deficiency of building craftsmanship infrastructure learning in the US can be related to the likely cause for discouraging US production growth in the building engineering industry (Wang et al., 2010).

According to Industrial training fund, the improvement of primary skills and developed experience will be undertaken through independent practical assignments under the direction of an instructor or company apprentice supervisor at the company level (Industrial Training Fund, 2005). “An apprenticeship is described as learning required becoming an experience trained person. The programmes comprise of work experience and learning on-the-job with similar instruction in the academic aspects for the apprentice on the job, who will enhance steadily during the period of the training programme” (Dantong, 2007).

Usman et al. (2012) classified causes of construction projects failure in Nigeria as contractor’s poor performance which is characterised by 1) poor workmanship; 2) rework; 3) low output; 4) late accomplishment; 5) cost overruns; 6) high accident rate; 7) poor labour practice and 8) conflict. Usman et al. (2012) carried out a qualitative and quantitative study and identify inadequacy of knowledge in workmanship as a part of the factors affecting the success of productivity in the Nigerian building industry. Furthermore, construction industry is concentrating on the company profit and undermining the workers who actually perform the work (Usman et al., 2012). According to Dantong (2007) the construction industry is affected by the following problems: 1) how to resolve the need for a supply of improved manpower capable of greater productivity in carrying out simplified sequential operations, 2) maintain a considerable number of the craftsmen capable of experienced skilled work and 3) enhancing the training of craftsmen will assist in addressing these problems in project delivery in Nigeria.

Learning is providing training and procedure to a craft gangs or workers in order to improve the worker or craft gang to an anticipated standard of performance, productivity or bodily condition (Obiegbu, 2003). Obiegbu (2003) stated that ‘’learning is presenting a worker to regulations and instruction, to train, to produce good performance and conduct”. The problem associated with the development of the human resource and its persistent effects suggest the need to improve both managerial and technical skills.

Experience has revealed that a dissatisfied craft gang or workers have failed to improve good service, and as a consequence, the construction industry is

hampered with a poor impression, the anticipation of every employer, nevertheless, is an experienced, skilled, vastly encouraged work force whose trademark would be the achievement of company objectives (Dantong, 2007). Learning provides the opportunity for improving the capability of the workers through enhancement of their experience and accordingly contributes to the craft gangs productivity optimisation in the construction industry.

In a related study, Jarkas (2010) stated that "the acquisition of knowledge in the labour-concentrated organisation is anticipated to be more important in the perception that automated equipment cannot profit from the prior knowledge and as a result, would not discover to move rapidly or raise the quantity of production". Previous research into the relevance of learning curve theory in building erection firms attested the significance of this theory to craft gangs workers' efficiency (Couto & Teixeira, 2005; Thomas et al., 1986). Couto and Teixeira (2005) calculated the knowledge of craft gangs work in a sixteen (16) floor case study and identified that the learning outcome occurred in no more than five-floor repetitions construction and lasted until floor 16.

Furthermore, Granerud and Rocha (2011) stated that learning comprises of the enhancement of innovative experience, expertise and performance, the corrections of errors and enhancement of modern method, and also the improvement of recent standards. Arashpour et al. (2010) carried out a research on organisational learning and noted that is projected to lead to constant development enhancement. The study also suggested that opinion, methods and knowledge from inside or outside the industry are combined to enhance the company performance.

Arashpour et al. (2010) evaluated the methodology employed by Malaysian construction industry in learning and established that even though construction industry favoured inside learning method they likewise used outside learning method. They identified various stages of managerial learning and their features are: "reproductive learning, handling of routine problems; basic creative learning, assessment of outcomes and negligible rectifications; advanced productive learning, experiments inventions and test solutions; and creative learning" (Arashpour et al., 2010).

Labour has become one of the major concerns of the Nigeria building industry as is generally labour-demanded and enhancing labour performance will be advantageous for the construction industry (Tran & Tookey, 2011). Tran and Tookey (2011) stated that "building and construction is one of the top five sectors used in measuring GDP of any country and its impact on every other sector makes it an important frontier for viable development".

Oluwakiyesi, (2011) indicated that the last few years in Nigeria have experienced a boom in construction output. There has been an expansion in public sector developments such as rehabilitation of infrastructures, highway and public housing schemes (Isa et al., 2013). However, despite these construction projects in the country, the construction sector is struggling with many fundamental issues, ranging from incompetent technological and supervisory knowledge, insufficient craftsmen experience and skills and low-technology tools (Ameh & Odusami, 2002; Ofori, 2000).

Previous research has indicated that there is a recent deficiency of experienced manpower and this is giving many building industry difficulties in dealing with the recent improvement in building work and the full amount of work they now have (Alinaitwe et al., 2007; CIOB, 1987; Odusami & Unoma, 2011). However, there is need to understand the relationship among skill absence and learning? For the reason in the change to sub-contract labour, the training role by main contractors has been abandoned. The subcontractors' who would have been anticipated to take it up have not; as a result, the level of the usual traineeships has fallen too low to meet today's labour condition (Ameh & Osegbo, 2011; Enshassi et al., 2007). Olomolaye and Ogunlana (1988) stated that the migration of conventional craftsmen from the construction industry since the boom of the '70s, it is not amazing that the trade now has deficiencies in the experience craft gangs workers needed to do its labour for the reason of deficiency of experience trained men, the ones left behind must be kept and one of the ways towards achieving this is through the use the of on-site learning method.

There has been previous research interest all over the world in productivity studies because of the significance of this in the management and control of project costs

(Aki et al., 2011; American Association Of Cost Engineers, 2013; Bureau Of Labour Statistics, 2006; European Association of National Productivity Centres, 2005). In developing countries research has shown that the amount of construction is exceeding the estimate, delays and loss of production related to the approach of most important construction project and several investigators have recognised poor organisation practice resulting in low productivity such as: deficiency in craftsmen knowledge, poor and inadequate training of construction skill workers, gang size, crew composition, lack of planning and scheduling, incompetent supervision among many other factors (Ameh & Odusami, 2002; Granerud & Rocha, 2011; Ofori, 2000; Wang et al., 2010).

Identifying and evaluating the constraints and mechanisms that optimise construction labour productivity are critical issues facing construction managers. In view of this, this research is being undertaken to seek to provide answers about how prior learning and on-site learning impact productivity, within a project-specific environment.

1.2 Problem Statement

Deficiency in craftsmen knowledge, adoption of basic hand tools and delay in supply of materials during construction process reduce the operation of contractors craftsmen, variability process can lead to reduction in output of productivity and increase the duration of the construction (Alinaitwe et al., 2007; Odesola, 2012; Odusami & Unoma, 2011). Low productivity can cause a failure to meet project objectives and allied time and cost overruns (Ameh & Odusami, 2002; Association of Senior Civil Servants of Nigeria, 2001; Couto & Teixeira, 2005; Jarkas, 2010). Previous studies on construction labour productivity have been limited to identifying the factors affecting labour productivity and determining their impact upon craftsmen performance. These studies have mainly utilised perception surveys and interviews focusing on the key constraints and attempting to quantify the performance of the craftsmen. One would expect that on-site gangs learning impacts on the productivity, subject to the production project specific constraints. However, no studies have been conducted on how blockwork craft gangs respond to the project specific constraints in the production

environment to maintain or improve their output, and how on site learning is affected by their prior learning.

1.3 Research Questions

- Main Question**:**

How do on-site blockwork craft gang's learning impacts productivity within the production environment and how do the gang's deal with the inevitable problems that arise on-site in order to optimise their productivity?

- Sub-Questions:
    1. What are the project-specific constraints blockwork craft gang's may need to respond to, in order to optimise their productivity?
    2. What is the relationship between the response mechanisms of blockwork craft gang's to specific project-based factors?
    3. How can the impact and relative influence of on-site learning be measured on blockwork craft gang's productivity?

1.4 Aim of the Study

The main aim of this research is to investigate how on-site blockwork craft gang's learning impacts productivity within the production environment and how the craft gang's deal with the inevitable problems that arise on-site in order to optimise their productivity.

1.4.1 Objectives of the Research

1. To identify the project-specific constraints blockwork craft gang's may need to respond to, in order to optimise their productivity.
2. To investigate the relationship between the responses of blockwork craft gang's to specific project-based factors.
3. To measure the impact and relative influence of on-site learning on the blockwork craft gang's productivity.

In this research, the independent variables are the cycle numbers and the dependent variables are the observed recorded time labour productivity. An independent variable is a variable that is changing or orderly in an experiment to test whereas a dependent variable is a variable that is being tested and calculated in a scientific experiment (Saunders et al., 2012).

1.5 Scope and Delimitations

This observation study focused on a single trade (block layers) with multiple craft gang's on a single site. This trade was selected for the reason that it is a common craft found in large number on building construction projects, in addition, this craft could easily be grouped as masonry trades, that is, construction activities performed by artisans popularly referred to as masons. The continuous direct observation method adopted for the work study was carried out daily for 60 days and focused on seven blockwork craft gang's on the site. This technique was selected because it has the benefit of providing accurate time inputs and detailed data for analytical purposes (Noor, 1992). However, it has the disadvantage of being laborious, expensive and restrictive in the number of operatives or gangs that can be monitored. Therefore, the period of observation and number of operatives that was monitored was limited to seven blockwork craft gang's on a single project with seventeen office floors and fifteen floors of parking. Conventional 225 x 225 x 450 mm sandcrete hollow block walling was the material utilised for the blockwork activity.

The study was limited to Federal Capital Development Agency (FCDA) projects. The limitation was due to the availability and near-uniformity of the following:

- The nature or type of employment (which is generally tenure)
- The conditions of employment of the labour in the sector.
- The quantifiable total annual work output of the site operatives.
- The conditions of service and measurable quality and quantity of work output.

Data collection was limited to the FCDA projects in Abuja. This is because the majority of consultants and contractors have their operation with the FCDA and more importantly FCDA has a great level of development and there are the developmental policy makers in the Federal Capital Territory Abuja, Nigeria. Also, because of logistical reasons and ease of collecting relevant data, the study was limited to projects executed by FCDA in Nigeria.

1.6 Research Assumptions

The main assumption underlying this study is that productivity optimisation generally occurs, through prior and gangs-learning of collective implementation of a set of tasks that are linked through scheduling to pre-tasks, post-tasks, materials and equipment, site level supervision, and project level monitoring, evaluation and control. Additionally, assumptions are as follows:

1. That the unchanged craft gangs or crews are involved in the repetitive task or activities or cycles.
2. Participants for the study will co-operate and allows access to their premises, site, documents and records as required by the study.
3. That the target participant will provide valid information for the study.
4. That methods/practice for improving productivity will be measurable on identified construction projects during the data gathering period.
5. Behaviour stages of change theory are a good model for describing behaviour change, it is less effective at planning to effect change in construction productivity and not considered.
6. The theory of interpersonal behaviour (TIB) was of interest but again beyond the ability to be tested in the context of construction productivity and was consequently not adopted as a guiding theory.
7. Finally, it is assumed that the learning curve model application will be applicable to the blockwork craft gang's as stated in the model that "every time the quantity number of a product doubles, the unit or the cumulative average rate or price necessary for construction i.e. man-hours, rate, or time, declines by a certain fraction of the former unit or accumulative

average proportion and this proportion is referred to as the 'learning rate' which identified the knowledge attained in the method."

1.7 Organisation of the Thesis

This research work is structured in a standard presentation for mixed method investigation concerning investigating the role of on-site learning in the optimisation of blockwork craft gang's productivity in the construction industry. It comprises of the following chapters:

The chapter one presents the contextual to the research, the research problem, aim and objectives, scope, delimitations and the research assumptions.

Chapter two presents the literature review on construction productivity, concepts, measuring productivity, techniques used for measuring and monitoring construction productivity, the factors influencing construction productivity and conceptual models for investigating construction blockwork craft gangs productivity.

Chapter three reviews productivity theories in the following: motivation, the theory of reasoned action, the transformation theory, the lean construction method, knowledge-worker productivity theory and learning curve theory (LCT).

Chapter Four presents the research method, the philosophical paradigm, the justification of the study and the research strategies. It also, present the description of the project observed, methods of construction and methods of sites observation and procedures. Finally, it presents the method of data analysis for the interview data collection and the observation data collections, including validity and reliability procedures for the data.

Chapter Five presents the interviews data analysis to understand the nature of the prior learning of the blockwork craft gang's and the project constraints and the response mechanism used to resolve these constraints by the craft gang's.

Chapter Six presents the data analysis collected from the observation study to determine how prior and on-site learning assist the blockwork craft gang's to deal with the project constraints in order to optimise their productivity.

Chapter Seven presents the findings of the research in relation to the literature findings. It also, presents the project constraints that the craft gangs may need to respond to in order to optimise their productivity, the relationship between the responses mechanisms to the project constraints and how prior and on-site learning assist the blockwork craft gang's to deal with the project constraints.

Chapter Eight summarise the thesis, its conclusions and recommendations.

1.8 Chapter Summary

This chapter presents the introduction of the research background and the context. The research problem was stated and the main question was to investigate how blockwork craft gangs adapt to the production environment on site to maintain productivity. The aim, objectives and the scope of the study were presented and the main assumption underlying the study was outlined.

CHAPTER 2

2.0 REVIEW OF LITERATURE

2.1 Productivity in the Construction Industry

The productivity of labour in the construction industry has long been a major issue confronting construction project managers as they seek to optimise productivity (Attar et al., 2012). Understanding the issues that both positively and negatively affect productivity is necessary for the improvement of labour output in the building industry and ultimately project performance (Attar et al., 2012; Enshassi et al., 2007). Supporting this statement, Jergeas (2009) noted that productivity in major capital construction projects in the world is associated with delays and losses causing cost overruns.

Several contributions have been made and proposed, however, these suggestions are yet to be adopted in a method that will enhance in reasonable productivity improvement in construction project performance (Jergeas, 2009). In a related study conducted by Attar et al. (2012) observed that management inadequacy during construction is a major primary cause of construction low productivity, their study also, identified the following barriers to improving construction labour productivity: "1) lack of alignment of goals, 2) contractual conflicts and difficulties in measuring productivity, 3) weak commitment to continuous improvement and 4) lack of labour force." In another related study, Enshassi et al. (2007) carried out an intensive investigation into the various challenges influencing labour productivity and found that researchers are yet to agree on an acceptable set of constraints with important influence on labour productivity.

Furthermore, Kazaz et al. (2008) investigated the factors influencing construction labour productivity and categorised these factors into four groups such as physical factors, socio-psychological factors, organisational factors and economic factors originating these four factors from the motivation theory. A study conducted by Jergeas (2009) on construction labour productivity improvement, classified construction labour productivity into following: 1) labour management, 2)

conditions and relations, 3) project planning, 4) management of construction and support, 5) effective supervision among others. Their investigation recommended management of labour and relations, in addition to working with the various unions and skills learning for labour productivity improvement in the construction industry.

A study investigated by Adamu et al. (2011) on factors influencing productivity among skilled workers in indigenous construction companies in the Nigeria North-Eastern States, observed that inadequate materials, low wages and an unfriendly environmental working condition arising from hot weather had the most influence on construction productivity. In a related study, Durdyev and Mbachu (2011) investigated the key factors influencing improvement measures for construction on-site labour productivity, employing Fifty-six sub-factors. These factors were classified into eight broad groups of both external and internal factors such as labour-related factors, project finance, workforce, statutory unforeseen events, technology/process, project management/project team characteristics, compliance and other external factors.

In a related study, Attar et al. (2012) investigated a research on the factors influencing productivity in the construction industry and categorised the factors under 15 groups such as: material factors, equipment factors, design factors, execution plan factors, labour factors among the ten top factors influencing construction labour productivity of medium-sized and small-size companies, large companies and all general companies and it was found that labour-related constraints influence all the groups.

Previous research studies conducted by Idoro (2011) and Jimoh (2012) on the Nigerian construction labour productivity found that the "productivity of indigenous contractors in the Nigeria construction industry is significantly lower than the foreign counterparts." In another related study carried out by Oluwakiyesi (2011) observed that a number of minor indigenous construction firms have developed and with others still developing, the building industry in Nigerian is still mostly controlled by multinational building companies.

Ayodele et al. (2011) investigated the important factors influencing the productivity of labour in the Nigerian construction industry, their study found that the consultants, contractors, and public clients in Nigeria supported the following factors as the top four significant factors influencing the productivity of Nigeria's construction industry such as " inadequate payment of completed works, poor contract management arising from inadequate experience and managerially training, low level of productivity and shortage of materials arising from fluctuations, long waiting times and delivery uncertainties as well as inadequate logistics."

2.2 Productivity Concepts

Productivity in its broader sense is the relationship between a given output and the means used to produce it, this relationship represents the global productivity factors, expressed as a fraction, of which the numerator is a measure of output and the denominator a measure of all factors combined. The combination of the factors of production (capital, labour, raw materials and power) is always heterogeneous, and values must be introduced to find an expression for it (Development, 2009). It is easier to relate output to a single factor than to a combination of factors. Labour is the factor considered in most cases, but it may be capital or a given raw material for example.

Productivity is defined by the Concise Oxford Dictionary as "the power of being effective, productive, and the rate at which goods are produced." In the definition, there are three distinct components in this definition of productivity. It can be deliberated that the dominant resource in productivity is the workforce. A study investigated by Jarkas (2010) observed that the operatives are the most productive resource; therefore, productivity in the construction industry is dependent primarily on human performance and effort. Construction labour productivity is an important productivity index due to the numerous number of human labour required to carry out and complete a particular task. Researchers in the field of economists will agree on the significant of productivity to an industry, an individual enterprise or the national economy, however, there have not been any agreement on the actual measurement techniques of productivity.

There have been several definitions of construction labour productivity (CLP) that point towards the various perception of the productivity in the construction industry. The European Association of National Productivity Centre's (EANPC, 2005) described productivity as "how efficiently and effectively products and services are being produced, efficiency in this context can be seen as doing things right or utilizing resources to accomplish desired results." Productivity is also, defined by the American Association of Cost Engineers (ASCE, 2013) "as a labour efficiency of relative measure, either bad or good when related to a recognised base or norm." Allmon et al. (2000) stated that "the comparative nature of construction productivity generate most challenges in tracing it as a complete significant over time, it is feasible to gather information on the arrangement of the recognised base, or benchmark." However, the professionals in the construction industry and project managers defined labour productivity as a proportion of expected over actual productivity, this is mathematically expressed as:

$$\text{Performance Ratio (PR)} = \frac{\text{Actual Productivity}}{\text{Expected Productivity}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.1)$$

Allmon et al. (2000) noted that when a performance ratio (PR) is higher than the unity, it means that the daily based quantities require more work hours than the normal average day baseline; also it implied that the productivity of that day was worse than the baseline productivity. The importance of this method is that progress is based on the constructed work and not the hour work utilised, and productivity can be measured despite the type of work done. The Bureau of Labour Statistics (BLS, 2006) defined labour productivity as "output per real worked hours and the term hours refers to the actually worked hours and this measure excludes holidays, vacation, and sick leave, however it includes paid and unpaid overtime."

A study investigated by Akindele (2003) stated that "productivity measures how resources are employed efficiently, it is defined as the proportion of a specific measure of input per unit of labour to a specific measure of output and usually measured as total output divided by the numbers of units of labour employed to produce that output." Akindele, (2003) further described labour productivity as

man-hour output per day, which is often reduced by poor provision of inadequate tools and equipment, delayed, unclear or inadequate instructions, unbalanced work gangs, wrong working method, inadequate incentives, and non-delegation of authority from senior supervisors to lower supervisors.

According to Aki et al. (2011), productivity definitions seem to be dependent on the context and the researcher's opinion on the study. Previous studies on engineering, technology and economics classified productivity into three broad industry groups, the various groups' defined productivity from their various viewpoints (Aki et al., 2011). Tangen (2005) noted that definitions of productivity are aimed at explaining "what the term means while mathematical explanations are used as a basis of measurement; in the former case, the major objective is not to explain, but rather to increase productivity."

The operational definition of productivity appropriate to this research study is the volume correlation relating to work-hours utilise and production. It is also, the correlation relating to quantities of input factors utilised by a system to produce output and the output produced by a system. This definition is in a relationship with other researched definitions by various institutions and authors (Akindele, 2003; Allmon et al., 2000; American Association of Cost Engineers, 2013; Bureau of Labour Statistics, 2008; Jarkas, 2010; Long, Nguyen, & Nguyen, 2013).

$$\text{Labour productivity} = \frac{\text{output produced}}{\text{work-hour}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.2)$$

From equation 2.2, the output can mean any outcome of the process, either a product or service, whereas work-hour consists of the hours utilised in a process. However, the relationship between a variety of output components and work-hour is very complex; there is no single measure that would answer all the questions raised, there are numerous aspects to each of the relationships. Measurement of productivity presents practitioners and academics with a variety of challenges.

2.3 Measuring Construction Productivity

Attar et al. (2012) stated that labour productivity measurement in the construction projects is a difficult task, in most cases productivity is usually taken to mean labour productivity, this stems from the fact that projects in the construction industry are labour intensive using basic equipment. The investigation conducted by Attar et al. (2012) observed that productivity described the quantification of how well operatives use available resources to produce outputs from inputs. In a related study, the American Association of Cost Engineers (AACE, 2013) defined productivity as a "relative measure of labour efficiency, either good or bad, when compared to an established base or norm."

A research conducted by National Institute of Standards and Technology (2011) stated that construction industry productivity measurement is complex and challenging when comparing productivity in the construction industry between nations (NIST, 2011). In a related study conducted by Abdel-Wahab and Vogl (2011) on productivity indices used to adjust output and input numbers so that productivity measurements can be contrasted over time and between industry sectors and countries found that these indices vary between nations. For instance, output in the construction industry is complicated when compared and quantified within a nation due to complexity in comparing single-family houses to roads, schools to bridges, or shopping centres to office buildings.

The National Research Council (2009) noted that "international productivity comparisons have similar challenges, such as the heterogeneity of outputs and inputs." Abdel-Wahab and Vogl (2011) stated that combining data to an organisation level causes the loss of valuable information on the heterogeneous nature of construction outputs. In addition, the National Research Council (2009) noted that "an industry productivity analyst varies on whether productivity in the construction industry is decreasing or improving." According to the National Research Council (2009), "productivity has been declining for over 30 years however, other construction projects and construction tasks studies document investigated improved in their productivity in the US industry productivity analysis.

Arashpour et al. (2013) observed that variations in building processes degrades the performance measures of contractors labour when variation is present with construction process times no longer being deterministic. In another study conducted by Doloi et al. (2011) noted that variability processes decrease the ability of the production network and inflate the construction duration. In a related study, Love and Smith (2003) stated that rework flow is a significant cause of variability in construction projects that cause procedures to be unpredictable. However, a study investigated by Hwang et al. (2014) observed that in building projects, rework can be caused by construction errors revealed through formal stage inspections or informal on-site observations. Furthermore, they stated that another type of rework is "client-related rework, which is caused by changes in project scope, plan, and design by the client."

El-Adaway (2012) observed that construction on-site are environmental dynamic and subjected to a high level of variability and external variability can be caused by constraints outside the project environment, such as extreme conditions of weather while internal variability can be caused by various sources of unstable motivation, workflows, and quality issues causing rework. A research investigation conducted by Arashpour et al. (2013) noted that variability presence influence the possible increase in the production rate by improving bottleneck processes. Previous research studies conducted by Mawhinney (2008) and Mubarak (2010) on variability have shown that increasing the accessibility of resources and levels of engagement in the construction has not enhanced productivity significantly.

Previous literatures in engineering management studies have revealed that the two major mechanisms for controlling variability workflow are: variability caused by rework which can be minimised by application of efficient monitoring and quality inspection (Kraft & Molenaar, 2014; Sullivan, 2011). In a related investigation conducted by Walsh et al. (2007) observed that workflow levelling approaches produce consistent workloads for trade contractors, workflow levelling in construction productivity can be applied in various ways, there also stated that the start based model can only start the rate of the first activity for each

floor/apartment is monitored and evenly spaced. Furthermore, Bashford et al. (2003) carried out an investigation and observed that in the activity based model, an equally spaced schedule is upheld for all activities. In order to tackle these problems of unnecessary rework, ineffective time, certain management techniques have been evolving which is known as 'time and motion study' but are now termed work study (Calvert et al. 2012).

2.3.1 Techniques Used for Measuring Productivity in Construction

A research study carried by Fondhal (1960) shows that there are three major methods used in the measurement of productivity in the construction industry such as:

1. Visual recording method,
2. Physical recording method, and
3. Interviews and Questionnaires method

2.3.1.1 Visual Recording Method

Fondhal (1960) stated that visual recording is a technique used in monitoring the performance of workers on sites continuously and it can be considered as a discoverer in the use of the visual recording technique for productivity checking purposes. In a related study, Parker and Oglesby (1972) observed that this technique involves the use of photography time lapse with the use of a camera focused on a particular work area and a photograph is taken at systematic time intervals ranging from 2 to 8 seconds. This technique has some benefits over others providing correct, lasting and indisputable records that can be useful for the purpose of teaching in the determination of construction claims and contract disagreements, evaluating craft gangs performance and estimating the productivity of construction techniques. Nevertheless, this method is associated with some detriments such as generating unrest between the workers being constantly observed, having an inadequate coverage area and the requirement for numerous cameras on big sites.

The investigation conducted by Parker and Oglesby (1972) noted that video tape recording system is another type of visual recording technique that executes

similar task, but captures all or most simultaneous activities allowing for fewer observers on site. The study found that “although, this method is an expensive technique, it requires educated observers to be physically present on site for the purpose of monitoring and recording work performed by operatives.” In addition, Parker and Oglesby (1972) stated that the “basic methods employed in this technique are: activity sampling, daily visits and continuous observation, activity sampling technique, also referred to as work sampling.”

Parker and Oglesby (1972) further stated that activity sampling technique “is an intermittent observation method that involves observing a small percentage of project activities that is large enough to have statistical significance. However, it involves an observer who would stroll through the site and records workers' activities, it is used to provide a tool for determining how the operatives spend their time on site and it is often assumed that work accomplished or output is correlated with the amount of time spent on direct work.”

In a related study conducted by Thomas (1991) noted that activity sampling has been used widely and tested by several researchers and important results were presented in many technical articles, one of the main importance of the method is that several crafts can be concurrently observed by an observer on site while the main drawback accompanying this method is the assumption that the amount of direct time spent is related to the outputs.

Thomas (1991) investigation on the US plants construction using an extensive analysis of the data collected by activity sampling, established there was no relationship amongst the direct working time spent and the outputs. The investigation found that work sampling technique does not differ between actual and busy work and concluded that direct work cannot be used to forecast productivity. Parker and Oglesby (1972) noted that the method shows how busy the operatives are. Another type of method according to Naoum and Hackman (1996) is the daily visit technique which is also known as intermittent observation method that encompasses the observer to collect data from site visit on a day-to-day basis.

Naoum and Hackman (1996) stated "that completed site work or progress is visually inspected by the observer, and if applicable, marked on drawings, this method has several importance and it also provided that construction sites are in close proximity to one another, and the observer can monitor several sites during the same day." In addition, Naoum and Hackman (1996) observed that "this technique helps to avoid the unrest accompanied by workers being monitored and clock-watched and assists in maintaining a good relationship between the observer and site operatives. Their study concluded that data collection by this method depends on the precision and accuracy of the information provided by the site personnel, the continuous observation technique can be subdivided into direct observation method and work study method."

2.3.2 Physical Recording Technique

An investigation conducted by Nilson and Winter (1986) observed that the direct observation technique is also a physical method of observation that consist of a researcher physically observing the site for the total duration of the operational day and the observer concentrate his devotion on a gang of skilled craft members and records direct and contributory time spent on the work and the time that is not spent at work such as late starts and early quits, attending to personal needs and breaks are recorded. According to Drewin (1985) the technique offers a correct data and is very advantageous in determining the time inputs distribution used to accomplish certain outputs, the major disadvantage of this method comprise dissatisfaction and mistrust between the workers or group being constantly monitored, which might cause incorrect or inflated productivity and also, on big projects sites, it might necessitate more than one observer to efficiently observe the tasks rendering this method expensive.

2.3.2.1 Work Study

The research investigation on the procedure of improvement on work study conducted by Calvert et al. (2012) noted that "work study support the parallel method study and work measurement techniques, which is a systematic method of obtaining the best possible use of material and human resources." In a related investigation conducted by International Labour Office (2006) concluded that

"work study is one of the most potentially useful tools of management and with its continued use, ordinary men can achieve exceptional results by minimising wasted effort, time, and setting a proper standard of performance."

According to Naoum and Hackman (1996) the work study method is similar to the direct observation method, however, it varies in the time of monitoring by the observer on site, in this technique, observation relates to the work cycle of the task examined. According to the British standard glossary (BS 3138) work study can be defined as "a management service based on those techniques, particularly method study and work measurement, which are used in the examination of human work in all contexts, and which lead to the systematic investigation of all the resources and factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement" (Naoum & Hackman, 1996).

2.3.2.2 Method Study

The International Labour Office, (2006) stated that "method study measures the effectiveness of the technique and work approach employed in order to provide systems of analysis geared toward the development of productivity procedures and conditions of working."

Drewin (1985) research study stated that work study originated from the manufacturing industry, an industry with a controlled production process that has a well-defined environment and a known input and output. However, the International Labour Office (2006) observed that "the construction industry is characterised by its uncontrolled environment, non-repetitive nature and is affected by various external and internal factors that influence the workers causing increase in variations in productivity, the aim of method study is to evaluate the best method of doing work in order to recommend the best efficient technique of production". Although the detailed analysis may become more complex, the basic procedure is summarised in Figure 2.1, principal application of method study.

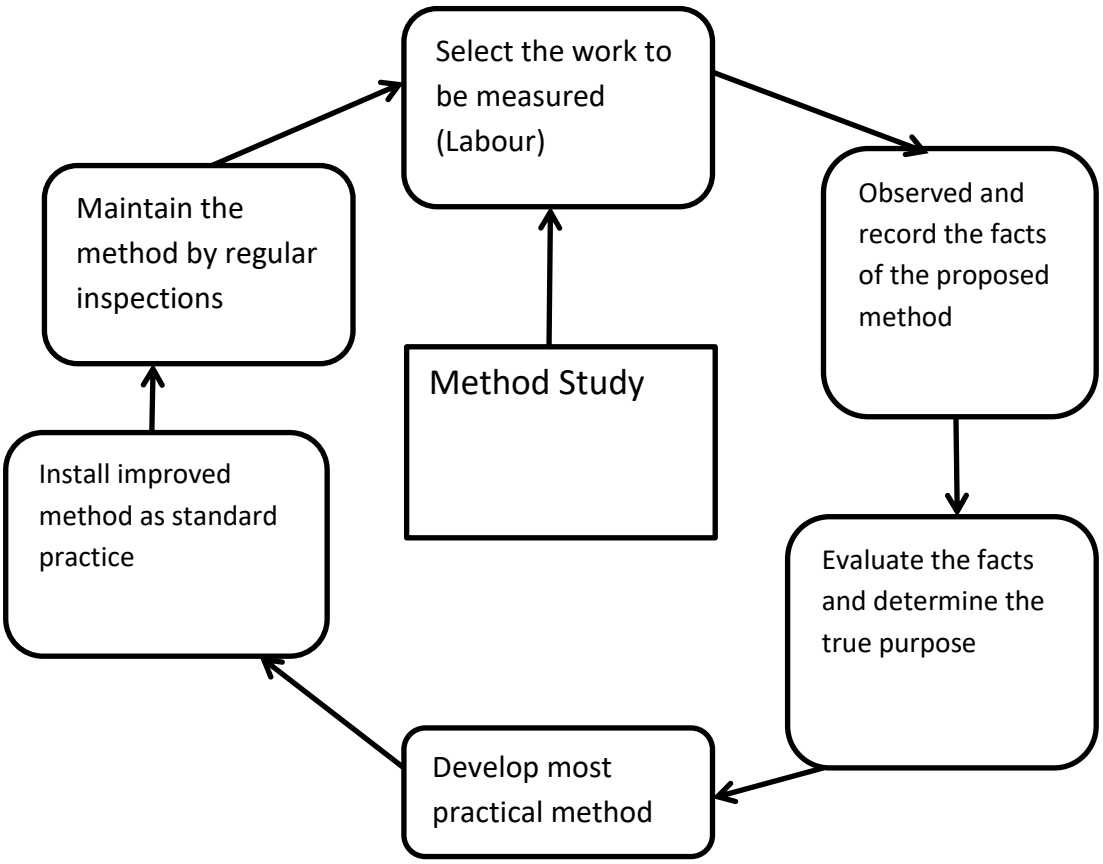

Figure 2.1: Application for method study: Adapted from ILO (2006)

2.3.2.3 Work Measurement

A work measurement compliments method study in order to derive the maximum benefits from a systematic study of work activities. While method study is related to the approach in which work is performed, work measurement is interested with the human resources involved in the job. Although work measurement and method study are interdependent, they cannot be separated from each other (Calvert et al., 2012). Although the mental approach of work study is primarily the application of common sense, assessment of the expected time needed to carry out a specific task by work measurement, because of the special technique employed, is mainly the field of the trained and experienced expert. Nevertheless, a project manager must have an adequate understanding of the principle involved if he is to employ work study successfully. Since work measurement seeks to reveal the shortcomings of management and to show up the behaviour of workers, it is often met with resistance, so that an understanding of human factors involved

is important. It is worth noting that time study provides a record of a particular operation, and not a check on an individual's performance (Calvert et al., 2012).The general procedure for work measurement is illustrated in Figure 2.2.

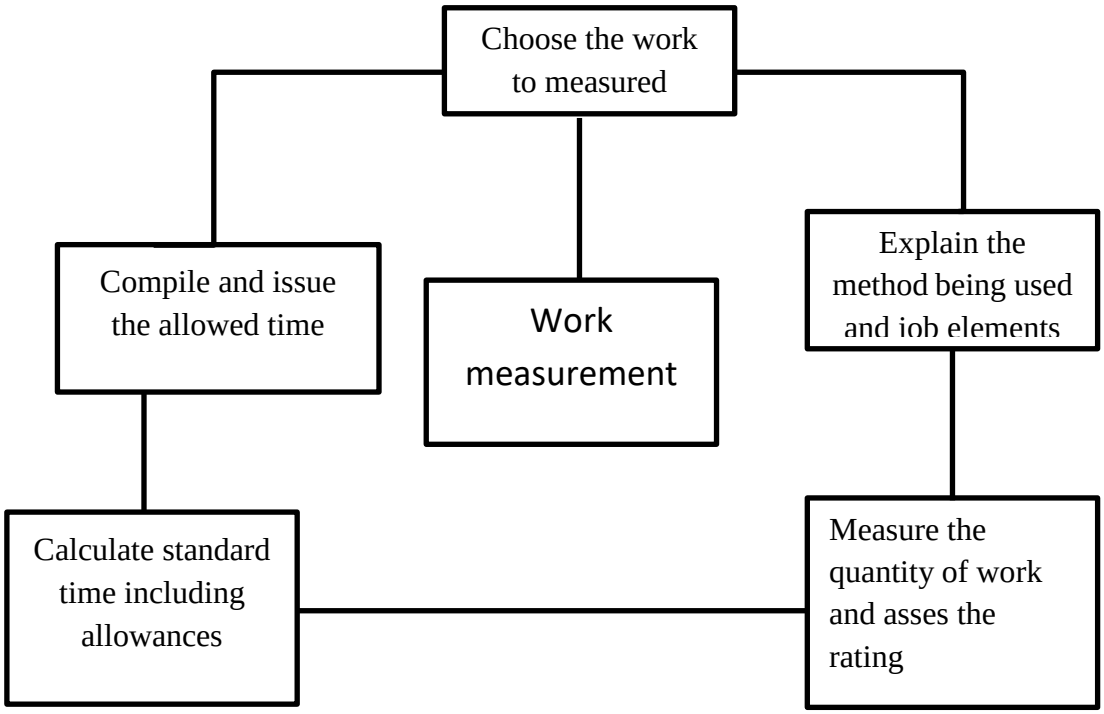

Figure 2.2: Application of Work Measurement: Adapted from ILO (2006)

The International Labour Office stated that work measurement can be carried out by the advanced method; Time study is the basic technique: Timing is usually performed with a watch unless the extremely accurate measurement is required, when devices such as the cine camera or portable paper tape machine may be used. The watch can be a good wrist or pocket type with a second hand, but a stopwatch is better and more convenient. The purpose of work study is to optimise productivity from the manpower and materials available, and since it is management's responsibility to see that the best use is made of organisations resources, it is, therefore, building managers who must be convinced of the value of work study application on building operations (Calvert et al., 2012). Process study can be employed since this covers such technical decision as the system of

building and the kind of materials at the design stage, or the type of plant to be utilised during construction

2.3.3 Questionnaires and Interviews

Olomolaiye et al. (1998) stated that interview techniques involve "collection of information through interviews from workers and supervisors in the construction industry with the primary aim of investigating the constraints which severely influence workers' productivity, they noted that the two types of surveys that are mainly used by observers are: the Craftsmen's Questionnaire Survey and the Foreman Delay Survey.

2.3.3.1 The Craftsmen's Questionnaire

According to Chang and Borcherding (1985), the craftsmen questionnaire survey is an intermittent observation method that is used for evaluating management productivity and to identify challenges influencing craftsmen's productivity and motivation, this method involves a regular basis, the craftsmen are requested to provide an approximation of the loss of time on sites, rank the severity of the challenges and recommend mechanism to these challenges and subsequently, managers would be able to recognise challenges caused by delays and their possible administrative recommendations to these challenges. Chang and Borcherding (1985) also, noted that this method produces job happiness and motivation between the workers as it expresses the emotion of involvement to the improvement of the job rather than being just a tool for its accomplishment.

This technique has its own disadvantages according to Chang and Borcherding (1985) due to that information collected is usually based on the recollections of workers and on estimates rather than on accurate and specific current information, another disadvantage stems from the fact that workers are not in a position to objectively identify the causes of some delays as they are not in liaison with management, which renders the process subjective and prone to inaccuracy and work may also be disrupted when workers are called upon to complete the forms in privacy for anonymity purposes, in addition, the process becomes complicated and tedious when each worker has to complete a form.

The investigation conducted by Chang and Borcherding (1985) recommended a new method which is related to the activity sampling method. Chang and Borcherding (1985) stated that in this method craftsmen are selected randomly and are requested to fill the questionnaire form based on their most recent activities, this method leads to enhanced accuracy and reduced work disruption as workers are approached by the observer at their working area to complete the form on the spot.

2.3.3.2 The Foreman Delay Survey

Tucker et al., (1982) stated that the basic principle of the foreman delay survey method is to assist foremen, being closer to their work in order to determine and calculate the losses due to time at the end of each working day with acceptable correctness. This technique according to Tucker et al. (1982) involves the foremen been requested to complete a list for daily delay report in the observed project and the obtained information is measured and a summary of time lost shown stipulating all the levels of site management, including the foremen who contributed to the data.

Tucker et al. (1982) noted that there is a concrete indication of the impact of administrative items and cost delays which are more than the foreman control, but have a leading influence on the gangs' productivity; decisions concerning application of solutions are facilitated. In addition, Tucker et al. (1982) stated that this technique creates job happiness and motivation for foremen and their crews as they appreciate the fact that their judgments are valued by site management. Furthermore, they observed that the foreman delay surveys does not consider the availability of data on the efficiency of work approaches in a job and the capability of the labour force or the level of productivity attained, also, It offers a reasonably priced technique of finding input times activities.

The above various techniques highlighted and discussed are used in the observation of construction productivity measurement, in observation study the method of data collection selected mostly depends on the following: the purposes of the study, the sample size and types of data required.

However, if the observation of numerous sites is required to acquire the requisite data, then it is better to employ the method of intermittent observation technique. In view of this, and since a single site with multiple blockwork crafts gangs was observed concurrently throughout the data gathering phase of this study, the continuous observation technique was carefully chosen and used for data gathering for the productivity monitoring and measurement.

2.4. Input Measurement

A study conducted by Herbsman and Ellis (1990) on productivity measurement noted that in productivity measurement, researchers should be very careful in choosing an appropriate suitable method of measurement of inputs, the three ways that inputs can be measured are as follows:

1. Total time inputs,
2. Available time inputs and
3. Productive time inputs.

According to Ellis (1990), total time can be defined as the total paid time and is mostly used for approximation purposes. Available time can be defined as the total times subtract unavoidable delays'. Unavoidable delays can be described as delays which include breaks paid and inclement weather. Available time normally used to evaluate the performance of management. Productive time can be explained as the available time subtracts avoidable delays. Avoidable delays arise as a consequence of inefficient site management practices, for example sequencing problems, poor site coordination, inadequate materials and delays in given instruction.

The aim of this study is to investigate how on-site blockwork craft gangs learning impacts productivity within the production environment and how the craft gang's deal with the inevitable problems that arise on-site in order to optimise their productivity. Productive time was used to measure the blockwork craft gang's productivity inputs, where all the unavoidable delays or avoidable delays were discounted and only time spent in achieving the outputs were used in quantifying

the blockwork craft gang's productivity for blockwork under investigation. Productivity outputs were recorded using the observation physical work study measurement as earlier stated. However, it is important, to differentiate the two types of delay experienced during the site observation study:

1. Interruption: These arise from circumstances that are severe and capable of "causing a temporary halt to the progress of the activities as well as the production process" (Talhouni, 1990).
2. Disruptions: These are delay that is normally "caused by events imposed on the blockwork craft gangs or the work area at the crew level, causing slow progress of work, but not a complete stoppage, for a minimum duration of one-half the work shift, i.e. typically four hours or more" (Talhouni, 1990).

Horner and Duff (2001) conducted a research in the Construction Management Research Unit (CMRU) at the University of Dundee and noted that interruptions that are fewer than fifteen minutes had little or no influence on site production. They also observed that little breaks may be necessary for the workers to attend to individual needs and avoid tiredness in order to perform effectively for the whole shift. Horner & Duff (2001) concluded that delays with little or no effect can be thrown away in the intermittent quantification of inputs for building productivity observation determinations.

An investigation conducted by Odesola and Idoro (2014) on the measurement of blockwork noted that the areas of blockwork erected in most times are not the same. Therefore, calculating the quantity of blockwork erected in such cases becomes challenging and needs processing of further data on dimensions about the perimeter of the uneven area. This becomes strenuous for research assistants to detect and keep exact records of the number of blocks laid by a Mason if it is directly related to the quantity of blockwork done (Odesola, 2012).

In measurement of blockwork, Odesola (2012) noted that it is better to use the number of blocks laid by a mason as an alternative option for attaining data that could be processed to give the quantity of blockwork laid in a day by a mason. In

a related study, Idiake and Bala (2012) carried out a research on the cumulative blockwork baseline productivity for 6 projects in Nigeria Abuja capital, the investigation shows that an average base line ranges between 1.92M^2 and 1.00M^2 /hour. However, these studies did not specify or note vital constraints that might influence the productivity of the blockwork like the size of the block and the method of construction used in the investigation.

2.5 Constraints Influencing Construction Productivity

Construction is a complex engineering that uses dynamic processes. It demands successful coordination of business entities with multiple individuals like tradesmen, trade unions, professionals, trade contractors, local authorities, manufacturers and specialists (Keane & Caletka, 2008). Construction projects when completed successfully can lead to improved standard of living, social economic growth and creation of wealth (Memon et al. 2011). Developed and developing nations are classified based on the quality and quantity of construction projects completed in their nations (Abdullah et al., 2011).

A historical review of the major infrastructure projects shows that the projects experienced cost overruns in the majority of the project evaluated (Jergeas, 2009; Ruwanpura et al., 2006). According to a research study conducted in Alberta in Canada at the APEGGA 2004 conference revealed that in the majority of the 50 projects evaluated shows evident of 100% overruns (Association of Professional Engineers and Geoscientists of Alberta, 2004). In a related study conducted by McTague and Jergeas (2002) observed the labour productivity losses and cost overruns on mega infrastructure construction projects are caused by majority of factors such as lack of leadership, material, equipment's, tools, scaffold, quality, cost, time, management and deficiency in managing scope among many other factors (McTague & Jergeas, 2002).

Although, Da Silva and Ruwanpura (2006) opined that variability in pouring concrete was the cause of productivity losses in concrete operations arising from the restructuring of the site layout and the transportation of concrete trucks on project site during concreting. In a related study a research was conducted based

on Liberda et al. (2003) fifty-one constraints influencing construction productivity, these constraints were categories, prioritised and clustered into nine groups, these groups are: worker motivation, communication inadequate, changes in design, skill of workers, information non-availability, inadequate supervision, lack of planning, adverse weather conditions and congested work areas (Hewage & Ruwanpura, 2007).

A research conducted by Gannaruwa (2008) on the effective working time of two construction project site average working time observed that the largest no-tool time activities were moving around the project site as illustrated in Figure 2.3, the study categorised walking as: looking for supervisor, looking for materials, carrying tools and equipment's, walking in and walking to the office, walking to the washrooms and chatting with fellow workers. The study noted that after walking for a long time, it is important to have some break for smoking. However, the research stated that the break should not last more than 10 minutes because the productivity may be affected seriously.

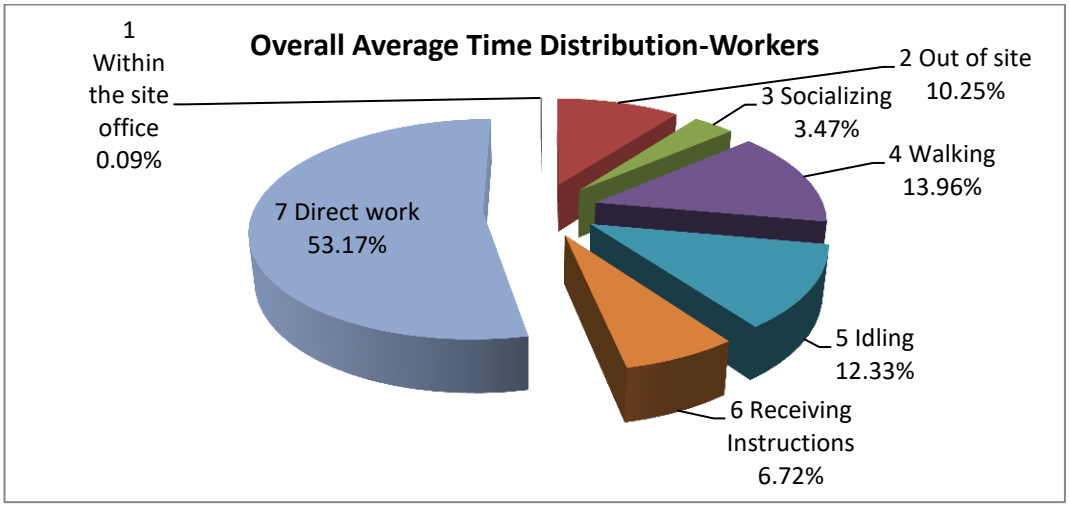

Figure 2.3: Workers' Total Working Time Distribution (Gannaruwa, 2008)

The construction project productivity is affected by several factors which are inter-related, most of these factors are somehow referred to as success critical factors or failure factors (Fortune & White, 2006). The evaluation and identification of these critical factors influencing productivity in the construction have been a critical challenge facing project managers in relation to improving

construction productivity (Attar et al., 2012). Investigating the success critical factors influencing productivity both negatively and positively has been noted to be important for the improvement of labour productivity in the construction industry project performance (Attar et al., 2012; Enshassi et al., 2007). Reflecting this perspective Jergeas (2009) stated in his findings that there are delays and losses of productivity and undue cost overruns that are associated with the completion of most capital projects in the construction industry everywhere in the world.

The study conducted by Jergeas (2009) found that several studies have identified inadequate management practices that result in poor performance, such as design errors, scope changes and omissions, inadequate proper planning and scheduling and inadequate tools management, equipment's, labour and materials, to mention but a few factors. Some recommendations and insights have been suggested that are yet to be implemented in a way that will enhance improvement in a productivity that is tangible and expected project performance (Jergeas, 2009). In another related investigation Attar et al. (2012) observed that the following are barriers affecting productivity improvement such as ineffectiveness of management as one of the primary cause for low productivity, lack of alignment of goals, contractual conflicts, weak commitments to continuous improvement and a lack of labour force focus, difficulties in measuring productivity as barriers to improving productivity.

However, Enshassi et al. (2007) stated that despite the intensive study on the various constraints influencing construction productivity of labour, there has not been an agreement on a set of universally accepted factors with an important influence on productivity nor has there been any agreement reach on the classification of these factors. However, these researchers have grouped these constraints influencing construction labour productivity into 10 categories as follows: supervision, project, safety, quality, manpower, motivation, time, leadership, materials, tools and external factors. A study conducted by Kazaz et al. (2008) classified the factors influencing productivity under four groups such as

physical factors, socio-psychological factors, organisational factors and economic factors derived from the theory of motivation.

A study carried out by Jergeas (2009) classified the factors affecting construction labour productivity into 10 improvement categories such as management of labour conditions and relations; project front-end planning and work face planning; construction management and support; management of engineering; supervision effectiveness and leadership; communication; contractual strategy and selection of contractors; engineering design and constructability; government influence; and modularisation, prefabrication and pre-building in shops. The investigation emphasised on the management of labour and relations and working with unions as areas for improvement in construction labour productivity.

Additionally, Odesola and Idoro (2014) evaluated the influence of the labour related factors in Nigeria six south-south geographical states from the opinion of project supervisors, engineers and craftsmen. The result of the investigation proposed that improved management of labour practices are an important strategy for productivity improvement that will optimise the productivity of labour in the construction industry.

Over the years studies on factors affecting labour productivity have witnessed several classifications with some appearing similar except for the usage of different terminologies. Some identified labour productivity factors from previous studies are presented in Tables to identify and understand the root factors of labour productivity on the construction project. Therefore, the information accruing from the aforementioned studies on constraints influencing labour in the construction industry provides a platform for this study to actualise its objectives. Based on the input-out paradigm, Equation (ii) in 2.2 productivity concept illustrates that the constraints influencing construction productivity could be one or more of the following groups:

1. Human constraints
2. Technology constraints
3. Project management constraints

4. External/Health and Safety constraints

The related human /motivation constraints from the summarised literature review are listed in Table 2.1, below.

Table 2.1: Human/Motivation Constraints Identified from Publications

Human/Motivation Constraints	Sources
Salary and benefits paid on time	(Ankrah, 2009), (Akindele, 2003), (Ameh & Odusami, 2002), (Liberda et al., 2003)
Promotion as motivation	(Mansfield & Odeh, 1991), (Hewage & Ruwanpura, 2007), (Zhou, Jergeas, & Ruwanpura, 2006), (Fayek, Revay, Rowan, & Mousseau, 2006), (Liberda et al., 2003), (Adedokun, Ibironke, & Olanipekun, 2013), (Monese & Thwala, 2014)
Delay in Payment	(Mojaheed, 2005) (Monese & Thwala, 2014) (Enshassi et al., 2007), (Adedeji, 2009),
Workers dissatisfaction	(Fayek et al., 2006), (Liberda et al., 2003)
Worker's personal problem	(Liberda et al., 2003)
Place of eating	(Rucklidge & Farrell, 2005), (Enshassi et al., 2007)
Increase in age	(Prskawetz, 2006), (Verhaegen & Salthouse, 1997), (Enshassi et al., 2007)
Being given due recognition	(Kazaz et al., 2008), (Cox, Issa, & Koblegard, 2005), (Olomolaye & Ogunlana, 1988)
Staff housing	(Cox et al., 2005), (Kazaz et al., 2008)
Transport for workers	(Kazaz et al., 2008), (Cox et al., 2005), (Enshassi et al., 2007)
Breaks and lunches	(Kazaz et al., 2008),
Learning/training	(Couto & Teixeira, 2005; Norfleet, 2004). (Thomas et al., 1986), (Abdulaziz & Radosavljevic, 2013), (Jarkas, 2010), (Wong,

	Cheung, Yiu, & Hardie, 2012)
Rework	(Koskela, 1992), (Fayek et al., 2006), (Zhang, Mao, & Abourizk, 2009), (Love, David, Edward, & Smith, 2005)
Inadequate skill of worker	(Abdulaziz & Radosavljevic, 2013), (Kazaz et al., 2008), (Boyd, 2006), (Zhou et al., 2006), (Liberda et al., 2003)

2.5.1 Human Constraints

The driving force behind the success of any project is the human factors, several projects have failed due to inadequate motivation and no regards for human factors. When emotional and intellectual needs are met and there is a various mechanism in place to support those needs, enormous productivity and human energy are created and when people are forces or in conflict to align into with the processes, the tremendous benefits are lost (Steyn et al., 2009). A project manager who can encourage creativity, spot talent, create inspiration, and can create an atmosphere of hope, excitement and motivation in the workplace, may be able to ensure project success (Steyn et al., 2009).

The influence of labour with increase productivity at every developmental stage of a project plays an important role in the successes of the project. Decisions from management can influence the productivity of labour and the successful completion of the construction project due to reasons that a significant proportion of the project budget is allocated to labour cost (Hanna et al., 2008). A related study conducted by Skitmore et al. (2004) observed that 40% of the direct capital cost is accounted to site workers, therefore, it's important to maximise the labour productivity of construction projects. Construction labour productivity improvement can go some way toward eliminating cost and time overruns (Kaming et al. 1998). A research study carried out by Zhou et al. (2006) on construction management professional motivation noted that motivation if combined with workers knowledge or experience and education is a significant factor in enhancing performance.

Construction workers in developing countries mostly have low levels of education and are generally unskilled (Ameh & Osegbo, 2011; Hanna et al., 2008; Kazaz et al., 2008). It is, therefore, necessary to train construction workers in order to improve productivity. Enshassi et al. (2007) identified and evaluated the factors affecting construction worker skills upgrading in Palestine. The results of this study show that mentoring is the preferred training approach and that decision making; problem-solving, communication and goal setting are important skills.

An unskilled worker, although motivated, may not have the required ability to perform well and improve construction productivity; motivation may only improve construction productivity if the worker has the abilities and skills needed for the job. Hanafi, et al. (2010), found that competency of site supervisors is an important contributing factor influencing labour productivity in installing on-site prefabricated components. Skill may be required in the follow-up and organisation of labour, in the inspection and approval of completed work, as well as in the organisation and coordination of work, including sub-contractors' work. Fayek et al. (2006) point out those apprentices, who are employed on a construction site, needs adequate instruction and supervision, Mentorship, work instruction and supervision could be achieved through face-to-face communication between supervisors and workers in ways which may allow for their training and development in a way that skill and knowledge may be passed on to the worker (Fayek et al., 2006).

A study investigated by Chigara and Mangore (2012) in Zimbabwean noted that inadequate manpower skills and inexperience labour negatively influence the productivity of labour, their study observed that the Zimbabwean building industry suffered from the mass exodus of skilled personnel to greener pastures in neighbouring countries and across continents between 2000 and 2008. This period, the Zimbabwean experienced a great depression in the economy due to inadequate skill; the remaining skilled workers are now producing less than the required gazetted industry standard output. In another related study conducted by Enshassi et al. (2007) observed that experience improves both the physical and intellectual abilities of the skilled labour force, which directly improved labour

productivity. A research study conducted in Turkey by Durdyev et al. 2(013) on the factors affecting construction labour productivity noted that lack of experienced local labour was ranked 1st among the 24 factors investigated thus making lack of experienced labour the most important factor influencing construction labour productivity in Turkish construction industry (Durdyev et al., 2013). According to Durdyev & Mbachu, (2011) they stated that manpower related factors such as working for long periods and absenteeism have less influence on Zimbabwe construction labour productivity.

Blockwork productivity can be constrained by a work rate/productivity scheme, where workers earnings are determined based on their output. However, despite the number of working hours spent on a task, payment will be calculated based on the unit output completed. According to Khanna (2007) he noted that most often an average skilled Mason is required to lay a hundred (100) sandcrete blocks per day, his findings revealed that this system is associated with some problems, he noted that it's conceivable that the skilled worker may consider his present need and only work that much. The height of place of work and environment are factors influencing the masonry worker's output due to the techniques involved in the transportation of materials, the distance, scaffolding, and unskilled labour type, the materials position, access to the workplaces as the work progress and frequently obstructions can lead to delay wastage and generally inconvenience. Work is influenced not only by the technique or method by which it is performed but also the environment in which it is performed (Khanna, 2007). Table 2.2 & 2.3, below shows the average productivity output of masonry worker's in Nigeria.

Table 2.2: Construction workers average output in Nigeria

S/N	Concrete work	Output per 8hr/day
1	Mixing by hand and placing of concrete to a height not exceeding 3.0m above ground level	0.50 m^3/day (Unskilled)
2	Mixing by machine and placing of concrete to a Height not exceeding 3.00 ground level	0.60 m^3/day (Unskilled)
3	Tampering and spreading of concrete in columns and walls.	10.00 m^3 /day (unskilled)
4	Tampering and spreading of concrete in floor roof or slabs	80.00 m^2 /day
	Blockwork	
6	Laying 100 mm block wall (1 No Mason + 1 No labour)	8.00 m^2 /day (Gang
7	Laying 150 mm block wall (1 No Mason + 1 No labour)	8.00 m^2/day (Gang)
8	Laying 230 mm block wall (1 No Mason + 1 No labour)	7.00 m^2/day (Gang)
9	Pre-cast concrete screen wall laying (1 Mason N0 + 1 labour)	10.00 m^2/day(Gang)
10	Clay screen-block wall laying (1 No Mason + 1 No labour)	12.00 m^2/day(Gang)
11	Glass block wall Laying (1 No Mason + 1 No labour)	10.00 m^2/day(Gang)

Source: (Consols, 2010).

Table 2.3: Construction average workers output in Nigeria

S/N	Finishing	Output per 8hr/day
1	Wall plastering	18.00 m2/day (Skilled)
2	Ceiling soffit plastering not exceeding 3.5m high	10.00 m2/day (Skilled)
3	Plastering 4 sided columns 600-1000 mm girth n. e. 3.50 m high	6.00 metre/day (Skilled)
4	3 sided beams plastering not exceeding 3.50m high	6.00 metre/day (Skilled)
5	Screeding of floor 50 mm thick	25 m2/day (Skilled)
6	Tiling with screed floor bed 300 mm x 300 mm	10 m2/day (Skilled)
7	Wall tiling with 300 mm x 300 mm	8 m2/day (Skilled)
8	Dressing of single door frame and building in	2 No./day (Skilled
9	Dressing of double door frame and building in	1 No /day (Skilled)
10	Dressing of window and building in from, 1200 mm x 120 mm	2 No/day (Skilled)
12	Building in and dressing of window frame 1800 mm x 1200 mm	1. No/day (Skilled)

Source: (Consols, 2010).

2.5.2 Technology (Plant and Equipment) Constraints

A study carried out by Goodrum and Haas (2004) observed that in North American the construction industries have experienced dramatic changes in the core processes for the past 25 years; they also, noted that well technology understood and managerial advances have enhanced the manufacturing sector to steadily increase its productivity and its profit margins. Goodrum and Haas (2004) research investigation observed 200 construction activities for the influence of technological equipment on their construction labour productivity between 1976 to 1998, the study investigated the changes in technological equipment's and were measured using a technological index consisting of five technology change factors. The study findings noted that activities with important experience changes in technology equipment have observed significantly better long-term

enhancements in labour productivity than those that have not experienced a change in equipment technology (Goodrum & Haas, 2004; Liberda et al., 2003).

Smerecnik and Andersen (2010) examined all the five sustainability attributes in the context of technology in their study and adopted the five (5) characteristics proposed by Rogers (2003) for sustainability adoption, these characteristics are: compatibility, relative advantage, observability, trialability and complexity.

According to Rogers (2003), relative advantage can be defined as the degree to which a technology innovation is perceived as being improved more than the idea it supersedes. Recent research studies conducted in the field have found it to be important variables, which are positively related to both in the adoption and implementation stages of innovation (Hameed et al. 2012; Songip et al. 2013). In addition, other research studies have videntified the advantage of relative sustainability studies as a strong predictor that is positively related to adoption (Smerecnik & Andersen, 2010; Zhu et al., 2012).

A study conducted by Premkumar and Roberts (1999) noted that the degree of compatibility between the current practices of the organisation and technology innovation's characteristics also influence new technology adoption (Premkumar & Roberts, 1999). Sustainability according to Zhu et al. (2012) is compatible with procurement criteria of time, quality or price, their study found it to be in relation to sustainable procurement adoption. Furthermore, Hameed et al. (2012) supported that “there is a positive relationship with compatibility at initiation, adoption decision and implementation stage of innovation.”

According to Rogers (2003) “complexity is defined as the degree to which technology innovation is perceived as relatively difficult to understand and use”. A study conducted by Premkumar and Roberts (1999) stated that “the adoption of new technology or idea can bring in significant changes to the work practices of organisations”. Persson (2009) acknowledges the complexity of sustainability implementation in construction works by industrialised countries. According to Smerecnik and Andersen (2010), the adoption of complexity of sustainability innovations to changing values can be inherent in the paradigm shift that is taking

place. Organisations tend to consider a smaller amount of complex innovations in the commencement and adoption-decision stages (Hameed et al., 2012; Zhu et al. 2006).

Rogers (2003) defined observability as the "degree to which the results of technology innovations are visible to others". The study concluded that observability has a significant influence in the implementation of innovation. Hameed et al. (2012) stated that "innovations observability is more important in the adoption decision making stage of innovations". In addition, Hameed et al. (2012) opined that "organisations that have the opportunity to observe others using the innovation have a more positive view of the innovation and are more likely to adopt the technology." According to Rogers (2003), "trialability is defined as the degree to which a technology innovation may experiment with limited basis". In a related study, Hameed et al. (2012) noted that "trialability is positively related to adoption". An investigation conducted by Shaw et al. (2010) on sustainability practices found that sustainability can be implemented successfully in one enterprise and their success can be extended to other enterprises.

A study conducted by Nyakazeya (2012) noted that plant and equipment related factors are among the top rated group of factor influencing labour productivity. According to the investigation conducted by Nyakazeya (2012) on the 40 factors influencing labour productivity, the study found the following factors: adequacy of plant and equipment; breakdown of the plant; tools shortage and equipment were ranked 2nd, 7th and 9th accordingly. The inadequacy of suitable plant and equipment influence labour productivity since labour depend on plant, equipment and tools to aid the construction process (Nyakazeya, 2012). In addition, the accessible plant is costly to procure and is therefore beyond the reach of many indigenous contractors (Nyakazeya, 2012).

Nyakazeya (2012) noted that the problem of plant and equipment's in Nigeria is problematic due to plant failure as a result of old age and unavailability of spares. A study conducted in USA, UK, Indonesia and Palestine observed that deficiency of tools and equipment was also prominent to have a strong consequence on

labour productivity (Enshassi et al., 2007). The findings of the investigation conducted by Enshassi et al. (2007) in the Gaza Strip shows that shortage of tools and equipment has a significant influence on productivity of labour and was ranked 10th out of the 45 factors investigated, these interpretations shows that productivity of labour is accompanied by accessibility of plant, tools and equipment. The related technology and equipment constraints from the summarised reviewed literature are presented in Table 2.4 below.

Table 2.4: Technology and Equipment constraints

Technology & Equipment constraints	Sources
Inadequate plant and equipment to do the work	(Ankrah, 2009), (Alinaitwe et al., 2007), (Enshassi et al., 2007).
Level of Technology	(Ankrah, 2009), (Smerecnik & Andersen, 2010; Zhu et al., 2012), (Hameed et al., 2012), (Rogers, 2003), (Shaw et al., 2010).
Small tools and construction equipment	(Ankrah, 2009), (Alinaitwe et al., 2007), (Enshassi et al., 2007).
Expertise in design	(Ankrah, 2009).
Inspection delay	(Alinaitwe et al., 2007).

2.5.3 Management Constraints

According to Liberda et al. (2003), inadequate management is mentioned as the major cause of poor construction output rather than unmotivated or unskilled workers. This would suggest that both skill and motivation are requirements for influencing desired behaviours for improvement of construction productivity. An unskilled worker, although motivated, may not have the required ability to perform well and improve construction productivity. Parkin et al. (2009) stated that motivation may only improve construction productivity if the worker has the abilities and skills needed for the job. Hanafi et al. (2010) found that competency of site supervisors is an important contributing factor influencing labour productivity in installing on-site prefabricated components. Skill may be required

in the follow-up and organisation of labour, in the inspection and approval of completed work, as well as in the organisation and coordination of work, including sub-contractors' work.

In a related study conducted by Abdul et al. (2005) on factors influencing the labour productivity of Malaysian construction industry stated that the top five significant factors influencing labour productivity in the construction of residential projects in Malaysian are: shortage of material on site, stoppage of material delivery to site due to non-payment to suppliers, consultants change order, consultants late issuance of construction drawing, and contractors incapability site management or inability or contractor to organise site activities. However, the five most occurring factors observed are: inadequate materials on project site, inadequate payment to suppliers with consequence of stoppage of material delivery to site, client late issuance of progress payment to the main contractor, inadequate foreign and local workers in the market, and problem of coordination between the main contractor and subcontractor (Abdul et al., 2005).

Previous studies conducted in Zimbabwe by Chigara and Mangore (2012) revealed the inability of the building materials manufacturing industry to supply the building industry with all the required materials (Chigara & Mangore, 2012). According to Nyakazeya (2012), the problem is further compounded by the internationalisation of designs where most of the designers are incorporating materials that are not manufactured locally. However, it is against this background, that there has been an advocate for laws that will encourage the locally manufactured materials to be in the design material specification (Nyakazeya, 2012). In addition, Nyakazeya (2012) noted that one of the factors affecting construction labour productive time is the late delivery of materials on projects and this is related to poor material supply chain management which subsequently delays delivery of materials.

An investigation carried out by Chigara and Mangore (2012) noted that a major challenge facing the delivery of construction project is the material related challenges which are among the significant factors influencing the cost management efforts of Zimbabwe building contractors. These outcome from the

findings are in relationship with other findings from other nations such as: Thailand and Palestine, Nigeria, USA, UK and Indonesia where inadequate materials on site was noted as one among the top factor influencing construction labour productivity (Enshassi et al., 2007; Kaming et al., 1998; Olomolaiye & Ogunlana, 1988). The related project management constraints from the summarised literature review are presented in Table 2.5, below.

Table 2.5: Project Management constraints

Project Management constraints	Sources
Working in a confined space	(Enshassi et al., 2007)
Interference from supervisors	(Alinaitwe et al., 2007), (Enshassi et al., 2007)
Construction method	(Enshassi et al., 2007), (Tabassi, Ramli, & Abu Bakar, 2012)
Delay in material availability	(Thomas, Riley, & Messner, 2005), (Kazaz et al., 2008; Nyakazeya, 2012), (Thomas et al., 2005)
Inspections delay	(Alinaitwe et al., 2007) (Enshassi et al., 2007)
Specification and standardisation	(Makulsawatudom, Emsley, & Sinthawanarong, 2004)
Working overtime	(Alinaitwe et al., 2007), (Enshassi et al., 2007), (Kazaz et al., 2008)
Inadequate supervision,	(Liberda et al., 2003)
Crew composition,	(Liberda et al., 2003)

2.5.4 External /Health and Safety Constraints

A study conducted by Chan and Kaka (2007), on construction Project Managers conception of their work, revealed that the physical environment affects the construction of projects. Generally, construction activities take place in an environment that is open. However, the condition of the environment can have an influence on the job conditions of sites as well as workers. An investigation conducted by Thomas (1991) observed that unfavourable conditions of weather

can influence labour productivity to decline to as much as 30%. In a related study conducted on highway construction projects by El-Rayes and Moselhi (2001) noted that highway construction are influenced by rainfall that will lead to the complete suspension of work or an operation arising from unworkable soil or saturated soil that will take some days to dry. This can also be related to concrete casting in projects, whether it is on the site or on high rise building thereby causing productivity decline unless that management devises a method to mitigate the influence of rain. They also noted that the "thermal environment has physiological and the psychological influence on the human body, working in temperatures out of the comfort zone may reduce productivity" (El-Rayes & Moselhi, 2001).

Hoejmose et al. (2012) stated that environmental factors include external stakeholder's pressure; industry/sector; regulation; and competitive environment, their study also noted that competitive pressure has been empirically supported in previous literature for sustainability adoption as a major constraint in the context of the environment. Sustainable procurement is sometimes adopted because it can be used as a mechanism to respond to emerging competitive threats (Zhu et al., 2006). In another related study conducted by Hameed et al. (2012) on the stages of innovation adoption found that competition is more significant for innovation.

The regulatory environment has been recognised as a critical factor influencing construction innovation decision (Zhu et al., 2006). Bose and Luo (2011) conducted an investigation in the context of sustainability and concluded that "regulatory support in terms of supportive government or state policies and legislation on the national level can help organisations achieve sustainability." The study proposed a supportive environmental regulation to enhance sustainable procurement.

The construction sector has received increased attention to move to sustainable practices (Glass et al., 2012). Policies, laws and regulations have pushed the sector to adopt sustainable construction innovation in terms of products and processes to encourage more sustainable buildings (Hellstrom, 2007). Stakeholder pressure and a desire to reduce the risk of negative publicity have been described

as a key external driver influencing sustainability technology adoption (Seuring & Müller, 2008). Yen and Yen (2012) stated that government stakeholders and customers give rise to pressures toward sustainability upon the focal company in a supply chain.

A survey from the UK noted that safety and health was ranked 2nd and 6th among 37th factors that influence construction productivity in the public building and civil engineering works respectively, these includes: knowledge in using dangerous substances, knowledge in noise control, accident book, implementation of all safety and health regulations, safety records and the company safety policy (Wong, 2007). The construction industry Organisational Health and Safety (OHS) according to Mustapha et al. (2015) have not been managed effectively due to lack of comprehensive national OHS policy, inability to partner with organisations responsible for the implementing the OHS activities, inability to ratify the ILO convention number 155, inefficient institutional frameworks responsible for Health and Safety standards and inadequate government support for regulatory institutions. The existing OHS legislation has not covered some key economic sectors. It is fragmented and limited in coverage (Annan et al, 2015).

Kheni et al. (2008) in their view indicated that "the lack of skilled human resources, inadequate government support for regulatory institutions and inefficient institutional frameworks responsible for Health and Safety standards" as the major challenges facing OHS practices in the construction industries. Several researchers (Annan et al., 2015; Laryea, 2010; Puplampu & Quartey, 2012) have confirmed the implementation challenges of OHS in the construction industry in Ghana. The OHS implementation challenges in the construction industry in Ghana has also been confirmed by Annan et al. (2015) on their study on occupational, industrial safety and health in Ghana and concluded that the increasing rate of urbanisation has raised the workforce. Hence, the high rate of the workforce has led to the exposure of hazard to the workforce.

In Nigeria, the availability of consistent data on building work safety and health associated occurrences remains a challenge. Construction work health and safety record is not readily available; because contractors do not readily record, keep or

report safety incidences and accidents to the appropriate regulatory authority. Safety incidences and accidents on construction sites are made public only when it results from building collapse or it becomes obvious and makes media reports. Oketola et al., (2014) reported the incidence on the "collapse of a building under renovation in Edo State which occurred on the 19th of September, 2014 killing 3 site workers. A similar incidence occurred in Lagos when a church building under construction collapsed killing 80 people of varying nationalities" (Oketola et al., 2014). The unavailability of statistics on incidences and accidents on construction sites in Nigeria does not translate to the non-occurrence of accidents on the various sites.

Agwu and Olele (2014) suggest that many construction workers have died as a result of various degrees of accidents and injuries sustained from construction sites. While the issue of safety remains a serious concern to construction stakeholders across the nation, studies investigating causes of accidents on construction sites in Nigeria are inadequate (Dodo, 2014; Idoro, 2011).

Previous research on safety and health has observed that "a safer and more effective working environment can be achieved through proper management commitment, planning and establishment" (Agwu & Olele, 2014; Dodo, 2014). According to Dodo (2014) an accident can be defined as "an unplanned event which has the capacity to cause injury or damage and is attributed to either unsafe acts or unsafe conditions, it could also, result in damage to plant or product, loss of production, increased cost, pollution of the environment and injury to persons, few of which may prove fatal or even lead to death". The related environmental health and safety constraints from the summarised review literature are presented in Table 2.6, below.

Table 2.6: Environmental Health and Safety constraints

Environmental Health & Safety constraints	Sources
Different languages spoken	(Dai, Goodrum, Maloney, & Srinivasan, 2009)
Unworkable soil	(El-Rayes & Moselhi, 2001)
Rainfall	(Thomas, 1991)
Political insecurity (e.g. insurgency)	(Alinaitwe et al., 2007)
Youth interference	(Alinaitwe et al., 2007)
Poor site conditions	(Alinaitwe et al., 2007)
Cultural differences	(Ankrah, 2009), (Kazaz et al., 2008)
Disruption of power/water	(Alinaitwe et al., 2007)
Union rules and Influences	(Liberda et al., 2003)
Adverse weather conditions	(Liberda et al., 2003)
Noise	(Liberda et al., 2003)
Dust	(Liberda et al., 2003)
Radiation	(Liberda et al., 2003)
Policies, laws and regulations	(Glass et al., 2012), (Seuring & Müller, 2008). (Yen & Yen, 2012).
Accidents at work sites	(Zakaria, Hussin, Noordin, & Zakaria, 2010), (Agwu & Olele, 2014; Mustapha et al., 2015), (Annan et al., 2015), (Dodo, 2014), (Wong, 2007)
Health and safety resources	(Liberda et al., 2003), (Idoro, 2011), (Kazaz et al., 2008)
Poor health condition of workers	(Alinaitwe et al., 2007)
Health and safety induction for employees	(Annan et al., 2015)

2.6 Conceptual Framework for On-site Craft Gangs Productivity

The conceptual framework presented in Figure 2.4 summarised the discussions on the constraints that can influence on-site craft gangs productivity. The constraints presented in Figure 2.4 which is by no means exhaustive, has been compiled from the literature review of some articles on factors influencing construction labour productivity improvement. Having reviewed the literatures presented by researchers in the field (Dozzi & AbouRizk, 1993; Edwards et al., 2007; Liberda et al., 2003) it can be deduced that the majority of the work was conducted in different countries, mainly focused on the level of importance attached to factors for improving productivity. No study has been made on the assessment of these factors on objective site productivity and there is a need to measure how particular variables impact on metrics of productivity. Based on these facts, the aim of the study is to investigate how on-site blockwork craft gangs learning impacts productivity within the production environment and how the craft gangs deal with the inevitable problems that arise on-site in order to optimise their productivity.

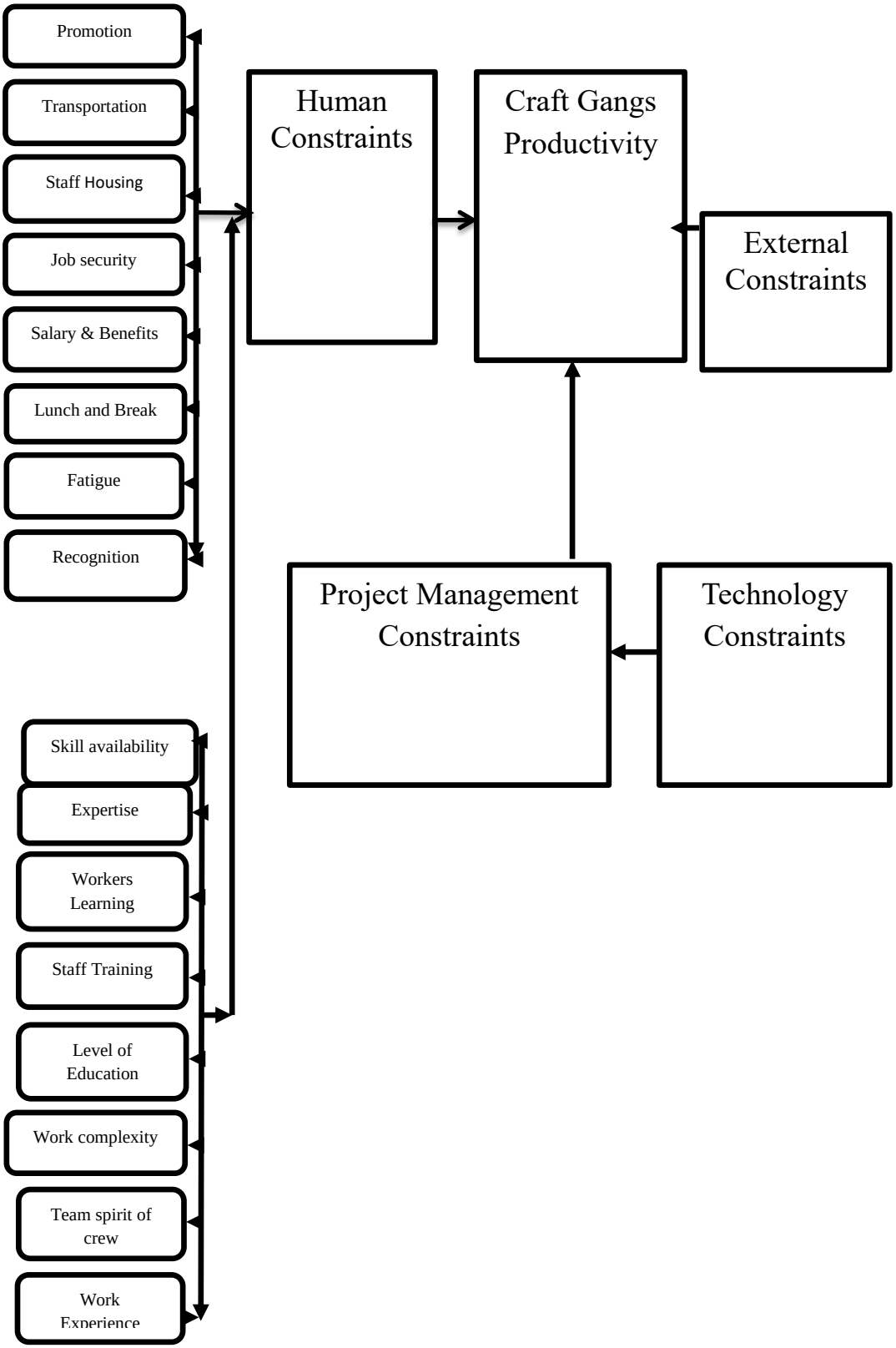

Figure 2.4: Conceptual Framework for Investigating CCGP

2.7 Summary of Chapter

This section presents the summary of the literature on construction productivity. It also explains the productivity concepts and several meanings of productivity were also discussed. The technique used in measuring productivity in the construction projects was also presented. There are three major methods that were reviewed for monitoring and measuring productivity in the construction industry. The first of which relates to visual recording technique that involves the used to constant record of the workers performance output on sites, the second is the physical recording technique which involves a direct surveillance technique that includes a qualified observer actually observing the site for the full duration of the working day, the observer concentrations is on a group of workers and records the time used up on direct work. On big sites, more than one observer may be needed to efficiently observe the operation of work using work study, method study or work measurement. The third measuring technique is the use of questionnaires and interviews which involve information gathering through an interview from supervisors and workers working in the construction industry with the aim of exploring the constraints which unfavourably influence workers' productivity. Finally, the project specific constraints affecting the labour productivity in a construction project were review and discussed. The next chapter presents the theories underlying the study of productivity.

CHAPTER 3

3.0 PRODUCTIVITY THEORIES

The theories underlying the study of productivity over the years have revolved on the measurement of productivity. This chapter provides a review of various theories of productivity. These theories considered are:

1. Motivation Theories;
2. Environmental Social Psychology Theories;
3. The Transformation Theory;
4. The Lean Construction Method;
5. Knowledge-worker Productivity Theory, and
6. Learning Curve Theory (LCT).

3.1 Motivation Theories

Barnett, (2011) defined motivation as the acting forces within a person that influence the encouragement, path, and determination of goal-directed, voluntary effort. Although motivation can be generally regarded as a force, some researchers may attribute the force to the availability of reward (Parkin et al., 2009).

Al-Aamri (2010) defines motivation in two ways: the first as: “the willingness to exert high levels of effort to reach organisational goals, conditioned by the effort’s ability to satisfy some individual need”, the second: “A set of independent and dependent relationships that explains the direction and persistence of an individual’s behaviour holding constant the effects of aptitude, skills, understanding of a task and the constraints operating in the work environment.”

Another definition of motivation is defined by Akoi-Gyebi Adjei (2009), as direction and persistence of action, concerning why a person chooses a specific way of accomplishment in preference to others, and why this person continues using the selected action, regularly over a long period, and in the face of complications and teething troubles.

Ramlall (2004) stated that motivations can be related to an unsatisfied internal state of an individual that creates tension and stimulates a drive that makes certain outcomes appear attractive. A study conducted by Kazaz et al. (2008) clearly stated that motivation is an arrangement of processes and the mechanisms which support to direct worker behaviour in a particular way, or with a more precise context. It can be define as all the considerable and inspiring engagements which help workers to accomplish their jobs enthusiastically in order to meet project objectives. The concept of motivation seems to be concerned with the forces and desires that explain why and how human actions are activated in accordance with work task requirements (Barnett, 2011).

Motivation involves direction, strength and persistence of actions of people (Akoi-Gyebi Adjei, 2009). Motivation may provide an explanation why some construction workers are better performers than others and may also explain the belief that the prosperity of a business entity depends on the performance of its workers since the desired (positive) worker behaviours may be related to the level of motivation (Cox et al., 2005). Knowledge and provision of motivational factors to construction workers may improve construction productivity. Identifying positive (desired) worker behaviours may indicate the level of worker motivation and satisfaction necessary for improving construction productivity (Parkin et al., 2009).

Cox et al. (2005) noted that a motivated employee may constantly strive towards an attainable goal or sets of goals. Motivation may also influence employees to acquire positive (desired) behaviours that may influence productivity (Parkin et al., 2009). According to Cox et al. (2005) some of the desired worker behaviours for improving productivity may be listed to perform more work than expected, respond promptly to requests, correct problems, complete task at hand on schedule, plan own work, speak of company with positive regard, speak of own job with positive regard and abide by company policy.

Motivation is considered a complex but an important construct, which could be applied through an appropriate motivational theory to encourage desired construction worker behaviour towards improved construction productivity –

usually through the presence of an incentive. This incentive can be an encouraging outcome or prevention of an adverse outcome (Kazaz et al., 2008). Knowledge of need of workers and provision of motivational factors to construction workers may improve construction productivity. Identifying positive (desired) worker behaviours may indicate the level of worker motivation and satisfaction necessary for improving construction productivity (Parkin et al., 2009). In order to understand motivation and motivational factors and how they relate to the motivational behaviours, the following motivational theories are reviewed:

1. Hierarchy of 'Needs'
2. The 'Expectancy' Theory
3. 'Goal Setting' Theory
4. Theory of "Reinforcement'
5. Theory 'X' and 'Y'
6. Theory 'Z'

3.1.1 Needs Theory

The hierarchy of Maslow's needs theory is regularly illustrated with a pyramid comprising of five levels (Maslow, 1943). The needs theory state that people strive to fulfil the following basic needs:

- Physiological,
- Security,
- Societal or belonging,
- Pride, and
- Self-actualization.

These needs are prepared hierarchically. The bottom most human requirements are the physiological needs, followed by safety need, which includes security of the body, employment, etc. The third level is the interpersonal needs. The next level comprises social needs like affiliation and self-esteem. The affiliation desires consist of social interaction, team spirit, appreciation and participation. The esteem needs include praise and awards, responsibilities, training and participation. Self-actualisation needs include challenges, creativity and

ownership of ideas and leadership and is the highest level of human needs as represented in Figure 3.1 (Maslow, 1943).

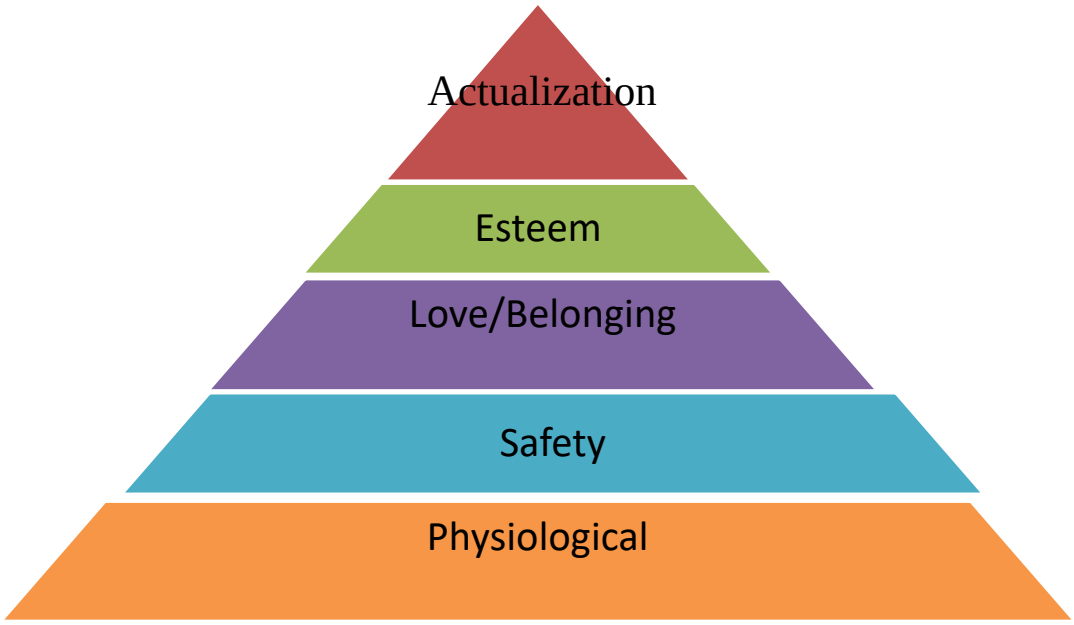

Figure 3.1: Hierarchy of Needs (Maslow, 1943)

3.1.1.1 Hierarchy of Needs Theory in Construction Industry

Maslow's need theory is built on the prepotency value of five basic classes of needs. The need theory is logical but it has not been subjected to any serious scientific certification. Therefore, it is not amazing that majority of these theory applications are the conceptual base for motivating construction operatives rather than been subjective and at best descriptive.

A study conducted by Schrader (1972) and Haseltine (1976) utilised the Maslow need theory as a base for enhancing construction operative. According to Schrader, an American construction worker believed he can meet his physiological needs when engaged because they receive enough money to pay for their lowest scale of importance. In construction today with reference to Maslow's ranking, there is no evidence to substantiate this. Haseltine (1976) come to an agreement, observing that most employed people have satisfied these elementary needs and are now only encouraged by upper needs. Another type of need is the

safety need which includes job safety, shelter against danger; risk and dispossession are also fulfilled for many of the U.S. construction workers. Schrader opined that the safety needs, especially the work safety percentage are persuader but not as strong as compared to other industries mainly for the reason that building construction employees have turn out to be used to moving from one job to another.

The last need according to Maslow's is the self actualisation needs; a study conducted by Schrader's in his descriptive work is of the view that these self-actualization needs are hardly satisfied in the construction operatives. For instance, some employees, who may perhaps have been promoted, stick to their craftsmanship since they want to continue their craft without the accountabilities of foreman.

The main important weakness in these studies is that not any of them tried to show any evidence of the importance of needs theorised by Maslow. They are relatively personal and, in most cases, merely interpersonal. Nobody is substantiated or contradicted. In addition, it gives the impression that the authors' submissions for increasing efficiency are debatable as they addressed working incentive from their personal perception - not the operatives'. Individuals' opinion of needs vary and in several circumstances are unique.

3.1.2 The Expectancy Theory

The expectancy theory believed that a worker is encouraged to perform in ways that produce positive behaviours (Kreitner & Kinicki, 2007). According to Vroom and Deci (1964), a worker chooses between different ways of action, which are properly related to physiological happenings taking place contemporaneously with performance. In addition, an operative's conduct results from sensible choices among options and these varieties are thoroughly related to psychological procedures, above all perception and the development of approaches.

According to Vroom and Deci (1964) there are three mental components when investigating and directing worker performance. These can be regarded as valence and expectation. Valence can be described as the active (expressive) orientations

individuals hold in relation to outcomes (Vroom & Deci, 1964). Valence is related to the task expectations in terms of the challenge and interest derived from the task, instrumental to the belief that there is sufficient skill to perform the task successfully and sufficient expectancy to the overall reward associated with the task (Vroom & Deci, 1964). The above theory seems to be based on attitudes, beliefs, fairness or equity, depending on the worker's ability and experience. This theory seems to suggest that for a worker to be motivated to improve productivity there should be a work culture and leadership which encourage high self-esteem, ensure equal opportunity for growth and development, fair treatment and an equitable reward system. The theory works on the person's belief that accomplishment at a specific level will lead to the accomplishment of an anticipated result. Workers are likely to be more satisfied when they feel their good performance will be equitably rewarded.

The expectancy theory is criticised for difficult testing methods used to measure effort and motivation. The method contains an implicit hypothesis that all incentive is conscious. Individual workers may not at all times be aware of their purposes, expectations and perceptual procedures. The expectancy model does not speech sub-conscious motivation. Some of the expectancy models tested has flaws such as inadequate and improper research populations and poor measuring instruments, making the generalisation of such research results difficult. The expectancy model appears to be closely linked to Western cultures where individual workers want to control their destiny. It could be difficult to apply this model in other cultures where the individual worker's control of destiny is limited (Porter & Lawler, 1968).

This theory implies that in order to help a construction worker improve productivity, the worker's effort and expectancies should be enhanced. Such an enhancement could be by providing the reward for good work, on the job training and coaching, in order to increase the workers' skills and capacity to perform the necessary task. Such behaviour may improve productivity and could be used as an indicator for worker motivation and satisfaction levels.

3.1.2.1 Expectancy Theory to Construction Industry Operatives

A research study conducted by Maloney and Mcfillen (1983) noted that the method of the presentation of the theory to the construction industry workers was more systematic and fewer unguarded. Their method was somehow distinct that, they advocated different exploration methods that should be taken when applying the theory to construction workers. Maloney and Mcfillen (1983) stated that with the evidence from social sciences, they are convinced that the expectancy model is applicable to the construction workers. Their study supported that laborious pragmatic investigation into employee performance and incentive, as dynamically associated in the expectancy model, if the building construction industry is concerned about enhancing employee performance.

In addition, Wesley-Lees (1976) demonstrated the concept of wholesale to construction workers in the U.K. Wisley-Lee work did not verify or negate this theory as a satisfactory demonstration of workers performance and incentive in construction. The assumed that the main possible motivators to high productivity are monetary incentives and job safety, and the study concludes that monetary encouragements can positively raise output only if workers motivation is the main determining factor of output. Furthermore, his conclusion displays a basic fault in applying the expectancy theory in the construction. The expectancy model is holistic and it is not likely to single out a motivator - monetary encouragement - as being principal and more or less illustrative of entire motivation.

3.1.3 Goal Setting Theory

The goal setting theory suggested by Locke (1968) is a procedure with an actual practical use; his opinion is that a person's conscious objectives and purposes are the main determining factor of performance. This means that when an individual starts a task, a job, or a new project much effort will be made until that goal is achieved. The theory is based on the importance of conscious objectives in the explanation of behaviour that is motivated. The conception of goals and conscious objectives to recommend and provide support for the notion that inflexible conscious objectives result in developed levels of performance if these objectives are acknowledged by the individual.

According to Akoi-Gyebi Adjei (2009), this theory may be applicable to improving construction productivity research on workers incentive approaches. The study revealed that task-based work, sub-contracted works and identification with work goals were important motivators to the workers. The theory also implies that in order to help a construction worker improve construction productivity, the work should be allocated to the worker in suitable pieces so as to attract interest with clear instructions on its specificity and also with a good reward to influence performance commitment.

3.1.4 Reinforcement Theory

Kreshel (1990) stated that reinforcement model is used to illustrate motivated performances that occur as a result of reinforcers which are products resulting from the performance that makes it more likely that the performance will recur. The model recommends that it is needless to study wants or cognitive procedures to appreciate incentive; however, it is essential to examine the behavioural outcomes. Positive (desired) rewarded performance that is strengthened and expected to carry on, but unrewarded performance is less to be expected to be recurring (Barnett, 2011). Ramlall (2004) stated that Herzberg proposed a set of indicators that ought to be built into works in order to be sustaining and inspiring. One proposal was that work tasks should be horizontally enlarged by the simple addition of tasks so as to be enriched to provide motivation. According to Hackman et al., (1975) task is key to workers motivation.

A study conducted by Kreitner and Kinicki (2007) illustrated by maintaining that an unexciting and boring job suppresses motivation to do well, while an interesting job increases motivation. Their study noted a number of criticisms of this theory. Firstly, reinforcement seems not to change worker behaviour as misuse of reward may tend to corrupt workers' behaviour. Secondly, workers have beliefs, values, and mental processes, so reinforcing behaviour without acknowledgement of these human factors is a wrong way to view human behaviour. Thirdly, workers may also become obsessed with extrinsic reinforcers (e.g. remuneration) making behaviour heavily dependent on reinforcers in such a way that work may not be performed without a promise of the reinforcer. The

theory should not be used for identifying any of the factors that influence positive (desired) behaviours for improved productivity as it only emphasised behaviours which may be modified by organisations to improve performance.

3.1.5 Theory X or Theory Y

McGregor (1970) suggested a leadership/management philosophy which may be applied to manage and direct individual workers' motivational behaviours, aimed at directing human energy for organisational success. The theory assumes that an average worker is lazy, lacking the goal, hating accountability, and self-seeking, uninterested to managerial needs, resilient to transformation and naive. For instance, the theory X management methods consist of force and intimidations, close direction and constricted controls over worker behaviours. The reasons are extrinsic and basic (Parkin et al., 2009). This hard management style may lead to restricted output, mutual distrust, unionism, and sometimes even sabotage of work.

Theory X is criticised for representing the extreme end of human behaviour. Most workers and managers may not acquire these undesired behaviours and as such may lead to workers being blamed without consideration of other factors such as the system of work, company policies and training for skill improvement. This type of management style could cause diseconomies of scale in large businesses (Barnett, 2011).

Theory Y supports the idea that workers will perform well and that majority of workers will meet their anticipations when properly encouraged in an understanding environment; and that workers are innovative, creative, go-getting and dedicated in achieving organisational objectives through self-disciplined, self-directed, and receive them cheerfully; and are encouraged by accomplishment of their own needs. Theory Y assumptions are based on the physical and mental power involved in labour is natural and also, that employees vigorously seek to participate in work. In addition, it assumes that close direction and the intimidation of penalty are not the best ways or the best means, for making employees exercise productive effort. As a substitute, if given the prospect,

workers will demonstrate self-motivation to put forth the effort necessary to attain the organisational objectives.

Theory X is criticised for representing unrealistic extremes of human behaviour. Also, empirical studies have not clearly demonstrated the relationship between the assumption in the theory and the managers' work styles and controls which support McGregor's ideas. Theory Y supervisors simply appear to engage in a form of manipulation as managers seem to be focussed on processes of production rather than processes of workers' welfare. Unless employees share in the monetary profits of their increased production, they will have only been duped into working harder for the same remuneration (Barnett, 2011). According to Barnett (2011), motivation can only be applied as a way to enhance self-control and direction.

3.1.5.1 Theories X and Y Application to Construction Operatives

A model developed by Haseltine (1976) on construction workers motivation in line with McGregor (1960) noted that the outdated organisation methods of providing worthy wages with good working environments, admirable remunerations and unbroken employment are not efficient ways for motivating in construction. The study noted that the provision of good wage can only satisfy the first and second needs which cannot motivate construction workforces. He emphasised in his conclusion that effort should be made on satisfying the higher needs that are capable of motivating higher production. However, this satisfaction was contradicted by Brayfield and Crockett (1995) stating that the relationship between productivity and satisfaction is complex and varies with individuals.

A study conducted by Schrader (1972) suggested various motivation techniques, the study emphasised on higher needs that are the basic elimination of theory Y. In a related study, Haseltine (1976) supported a progressive theory Y method for construction industry operatives. In another study, Maloney (1981) disagreed with the fundamental theories suggested by Macgregor's noting that it is incorrect to propose and categorised theory X or Y as the best method of enhancing workers performance. As a replacement, he suggested that behaviour should be regarded as a variety of expectations since individuals differ.

3.1.6 Theory Z

Theory Z is aimed at building trust, integrity, openness, worker involvement, integrated organisation, information sharing using the collectivism of Japanese culture and combining it with an American culture based on individualism, freedom, risk taking and quick decision making (Ouchi, 1981). Theory Z aims at influencing the positive behaviour of the individual worker. It also suggests that workers should be directed and controlled through trade beliefs. This belief is based on American and Japanese managerial principles that it's aimed in creating a strong organisational culture that is responsible for a source of social relationship and harmony, thus encouraging employee motivational factors that improve productivity. The culture of Japanese, which gives emphasis to communal harmony, is compared in relation to that of America, which focuses on individuality; the advantageous features of every one are joined in the theory of Z (Parkin et al., 2009).

A research conducted by Horowitz (2001) on Theory Z organisations underperformance has generated mixed outcomes. Horowitz findings suggest that theory Z organisations accomplish remunerations together in employee satisfaction, incentive and obligation as well as in relations to monetary performance (Horowitz, 2001). In another related study, the findings conclude that type 'Z' organisations do not outperform other organisations (Gogia, 2011). Another criticism raised against Ouchi's Theory Z is that although, the theory claims that America's productivity is stagnant and declining, corporations based in America, instead of learning from the Japanese corporations, have dismissed their American workforce, and employed workers from other nations to work for low wages. According to Horowitz (2001), the profits made by these organisations are not stagnant or decreasing. However the profits are increasing, this view is in disagreement with the principle of Theory 'Z' (Horowitz, 2001).

3.2 Reasoned Action Theory (RAT)

RAT was developed by Ajzen and Fishbein (1980) in order to show the relationship between attitudes and behaviour. This work explained that in order to predict how an individual is going to behave a number of factors needed to be

understood. RAT incorporates the discrete elements or components of behaviour leading to action without the cascade or moral elements of other models. For these reasons, RAT became the adopted theory for the trial with the Environment Agency and other partners.

RAT is driven by the ideas concepts of compatibility and behavioural intent. The theory relies on an individual to form the intention to act, based on an understanding and attitude about the issue (compatibility), and whether it is worth putting the effort into reacting to the issue (behavioural intention). In other words, the theory assumes that people rationally weigh up a situation according to their comprehension and the consequences of acting. Attitude is born from the mix of emotions, thought and a predisposition to do something about it. The effort is calculated depending on how other people will react to their beliefs or actions. These are referred to as subjective norms. This work is not only helpful in explaining the barriers that inhibit action, but it can be summarised to show policy-makers how to shape campaigns by addressing five questions that persons examine earlier before performing:

- Have I understood that there is a problem?
- Have I cared about the problem?
- Can I solve the problem?
- Will my solution work or make a change?
- How will others think of me if I act?

RAT was criticised for a gap in its understanding of the role that society plays in influencing an individual's behaviour. As a response RAT was refined later into the Theory of Planned Behaviour or TPB (Ajzen, 1991). This incorporated a supplementary feature, perceived behavioural control, which determines a person's insight of exactly how simply a particular conduct could be accomplished (Ajzen & Madden, 1986).

3.3 Transformation Theory

The theory of transformation was derived from the economics (Walras, 1952). Wortmann (1992) and Rolstadas (1995) stated that this theory is a construction principle established from the views of manufacture in economics. Their study observed that the theory is "made up of technical coefficients, which is equal to the ratio of transformation between the amount of a certain production factor and the amount produced of a given product." Nevertheless, there are restrictions concerning this theory and in order to overcome these restrictions the following views were suggested (Wortmann, 1992 & Rolstadas, 1995).

- The product graph (P-graph): the product graph is called the production theory that illustrates the means by which assembling the product into components and subassemblies can be presented as well as the system of operations. It also defines the work to be done.
- The R-graph: the R-graph deals with the organisational structure of resources. The study used the R-graph to explain how the resources are joining together into factories, department and groups. The resources provide the capacities and competences.
- The third broad view supports the Walras (1952) production theory to a vigorous control model, this theory acknowledged the following three activities: organisation of resources, the organisation of product, organisation and harmonisation in relation to the allocation of resources to products.

Rolstadas (1995) noted that the "connection between the r-graph and p-graph can be described as management of production." The aim of management is to issue and monitor job orders for construction and production (Rolstadas, 1995). In a similar study, Turner (1993) stated that scope management is an activity for the project manager. According to Turner (1993) scope is defined as the work breakdown structure and the purpose are as follows:

- To determine the sufficient or adequate amount of work done.
- To determine unnecessary work that is not done.

- To determine the work that is done delivers the stated business purpose.

However, it is important to note that the function of management in a project is purely based on the theory of transformation and its principles of hierarchical breakdown structure.

3.4 The Lean Construction Method

International Group Lean Construction (2015) stated that the vision of lean construction method is "to better meet customer demands and dramatically improve the Architectural, Engineering and Construction (AEC) processes as well as product". The main issues that usually face the construction industry are the waste, risk, difficulties in attaining the required value and meeting customer needs. The Australia Engineers stated that one of the lean construction tools is called the Last Planner System (LPS). The LPS is a construction control system for projects managers (Australia Engineers, 2012). The LPS substitutes a typical management system based on activities and a well-defined schedule created by a project manager. LPS has helped contractors to reduce project delivery times and at the same time encourage specialty contractors to advance the utilisation of their resources (Australia Engineers, 2012). The LPS is a method that provides work breakdown and responds to building construction project variables (Salem et al., 2005).

In Lean Construction, philosophy waste is described as any inadequacy requiring an increase in the application of resources over and above those that are necessary required in the construction of a structure without creating value for the client (Koskela, 1992). Arising from this definition, poor project cost performance can also be viewed as a product of waste. Therefore, any direct or indirect action within the project delivery process that results in additional cost above the minimum that would have been required to deliver the project is referred to as waste. The core elements in lean construction are hinged on waste reduction towards improved project delivery cost performance. According to the Lean construction institute (2015), Lean construction is defined as the application of the lean method of construction during the design and construction stage in order to

improve delivery that will meet the need of clients and also enhance the productivity of contractors.

3.4.1 Work Flow Process

According to Hope and Spearman (1999) work flow is described as activities movement of a process of work. In building construction industry, the practice is based on individual unit of work project-based which may differ in size, measurement and complexity. A study conducted by Bertelsen (2004) noted that the outline of the concept of work flow is most likely that the most significant influence to the appreciation of the construction process made by the research made in Lean Construction Community. Construction in the building is considered as the assembly-type and there are several types of flows associated with the end product. In a similar study Jongeling (2006) submitted that capital flows are of comparative high variability and as a consequence, the chance that they adversely impact the task end result is rather high. In another related study conducted by EPSRC (2004) noted that the main purpose of workflow is to equate two versions of a workflow requirement in order to identify the variances in terms of a series of workflow procedure.

A research study conducted by Odesola & Oladokun (2015) observed that blockwork processes activity are alike apart from the choice of material type, the technique of mixing the mortar and the procedure for transporting material to the place of work (Odesola & Oladokun, 2015). The procedure outlined in Odesola and Oladokun (2015) was used for investigating the role of on-site learning in the optimisation of blockwork craft gangs work processes activity in the observed project site selected for the study as shown in Figure 3.2.

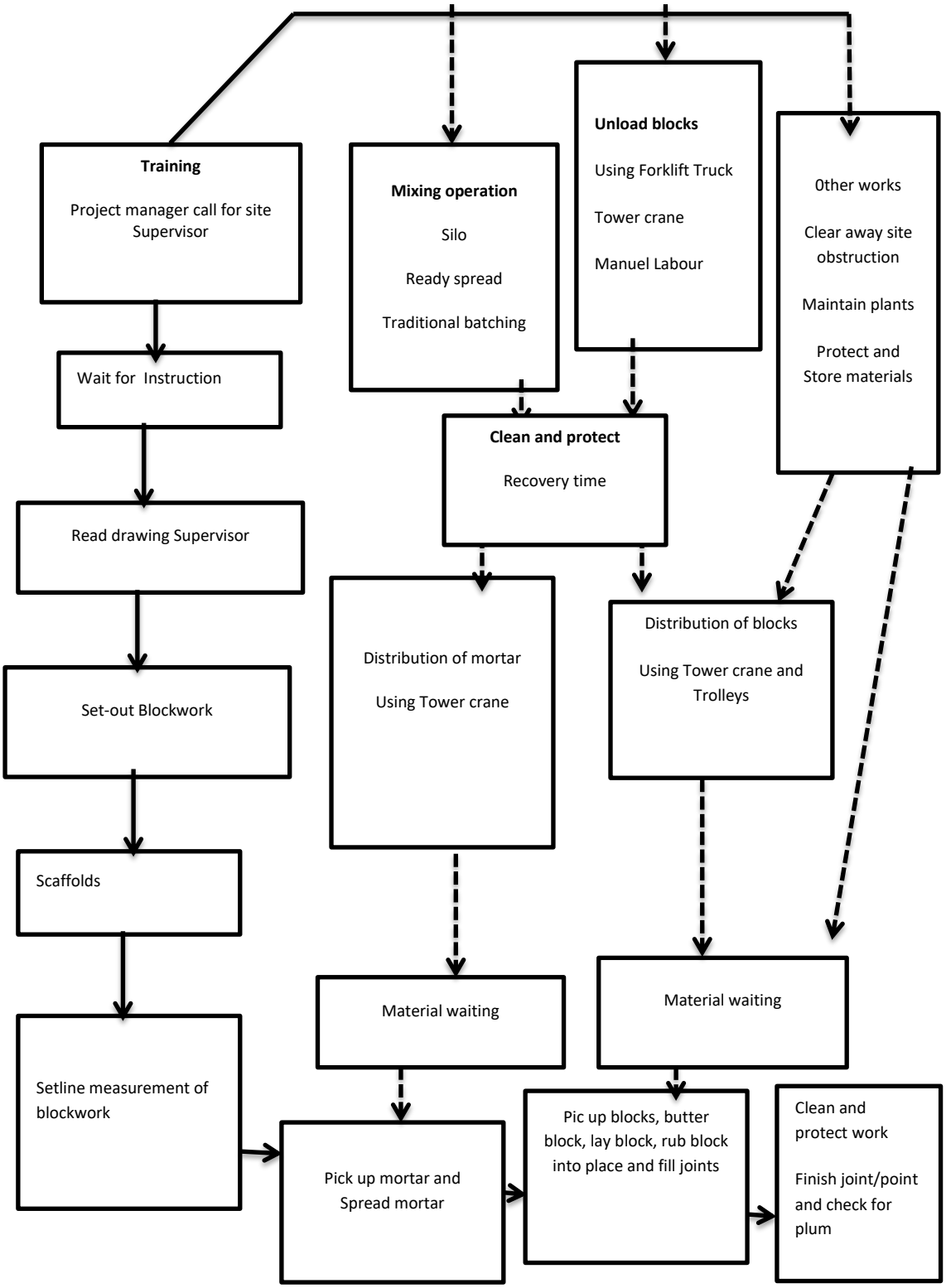

Figure 3.2: Blockwork production process

Source: Adapted from Odesola and Oladokun (2015)

3.5 Knowledge-worker Productivity (KWP) Theory

KWP theory is an improvement on the out-of-date productivity enhancement method established according to Taylor's (1911) systematic technique (Drucker, 1999). In a study conducted by Wong (2012) on Drucker's six major factors examined the practitioner's methodology to the steps required for understanding-intensive organisations to integrate into the following:

- The demand for KWP to respond to the question: "What is the task?"
- The demand for maximising knowledge-worker productivity by imposing the accountability for production on workers knowledge themselves and also, the KWP has to be independent and manage them.
- The need to create uninterrupted improvement as part of the work, the task and the accountability of knowledge workers. Uninterrupted improvement has to be built into a knowledge worker's job.
- The need for continuous learning and teaching as required by the theory of KWP.
- The need for quality and not just quantity of output as an important requirement of KWP.
- The need to see workers and treated as an asset and not just a cost and not like labour-intensive workers, the majority of knowledge workforces own most of the means of the construction which they use to produce wealth in their organisation. The knowledge workers will want to work for an organisation in preference to other options as a requirement of the KWP theory.

A study conducted by Wong et al. (2012) on improving KWP suggested some key survival prerequisite needed for today's organisations knowledge-based economy. Wong et al., (2012) noted that in the application of Drucker's six major factors for determining KWP organisations and suggested the need to examine their level of willingness and aliment problems when incorporating their processes of work with the Drucker's six key determining KWP factors.

According to Drucker (1999), the world is moving to an era of extraordinary transformation, he stated that the knowledge worker is the major challenge facing the 21st-century organisation. In technologically advanced nations a growing knowledge worker is the first sustainability condition for firms. The main objective of the KWP is consequently; about how to discover the greatest way to fulfil customers' desires since the customer is the one who defines what the business is (Drucker, 1999). In addition, Drucker's theory shows that work on knowledge worker productivity has just started.

3.6 Learning Curve Theory (LCT)

The theory of learning curve has its origin in the aircraft industry in 1936 when Wright conducted a research and published an article in Aeronautical in February 1936 according to Norfleet (2004). Notwithstanding the presence of diverse terms for the theory of learning curve, at the elementary level, the whole terms explain the same phenomenon: The quantity of produce unit's rises, the capitals necessary to complete the production unit per man-hour or cost decline (Norfleet, 2004).

The study conducted by Thomas et al. (1986) stated that organisational knowledge can result from repetition and variations in approach, processes, and management. It is significant to note, nevertheless, that the theory of learning curve can be applicable if the activity is repetitive, uninterrupted, and identical, i.e., the work is a replication of the similar procedure, and there are limited disruptions and suspension (Wideman, 1994). Furthermore, the concept adopts that the unchanged persons, groups, or organisations are involved in the repetitive jobs (Couto & Teixeira, 2005).The evolution of the learning theory derived its concept from the repetitive planning approaches and this was introduced into the planning of building concept with the common understanding that carrying out the same work repeatedly, and in the similar environments, takes less time as the activity is repetitive (Gates & Scarpa, 1972). This concept is clear in many building activities and is known as the experience of learning or impact of learning, the productivity increase is mainly due to the increasing familiarity of the repetitive work.

A research conducted by Pilcher (1992) noted that using specific scheduling

techniques may be useful to the building construction projects with repetitive features, the study supported that integrating the effect of learning into the valuation of activity period in construction might have good results.

Couto and Teixeira (2002) stated that the period necessary to achieve same activities sequentially and in the same environments is anticipated to decline to a definite significance value; therefore, considering the impact of learning in carrying out an activity is the same as acknowledging an increase in construction rates from a definite number of repetitions, and at least during some subsequent repetitions. Therefore, it is possible to introduce this learning effect in construction repetitive scheduling procedures, thus bringing about an anticipated productivity increase after a first learning period.

Everett and Farghal (1994) stated that the "learning curve is illustrated graphically by the amount of cost or number of man-hours required in carrying out the activities." The emphasises on the learning curve model is on the man-hours, cost or time for completing repetitive and subsequent tasks decline in each replication according to an anticipated learning rate. The first study on the effect of the learning curve was researched by Wright (1936), he resolved "that the number of man-hours required to fix aeroplane components declined 20% each time the units are doubled." This implies that production enhanced by 20% due to the influence of learning, meaning that learning rate of 80% has taken place. Consequently, the lesser the learning, and subsequent increase in output the better the rate of learning. Therefore, a learning rate of 100% means that zero increases in productivity (Lutz, Halpin, & Wilson, 1994). Hypothetically, a learning model is divided into three logarithmic coordinate's parts as presented in Figure 3.3.

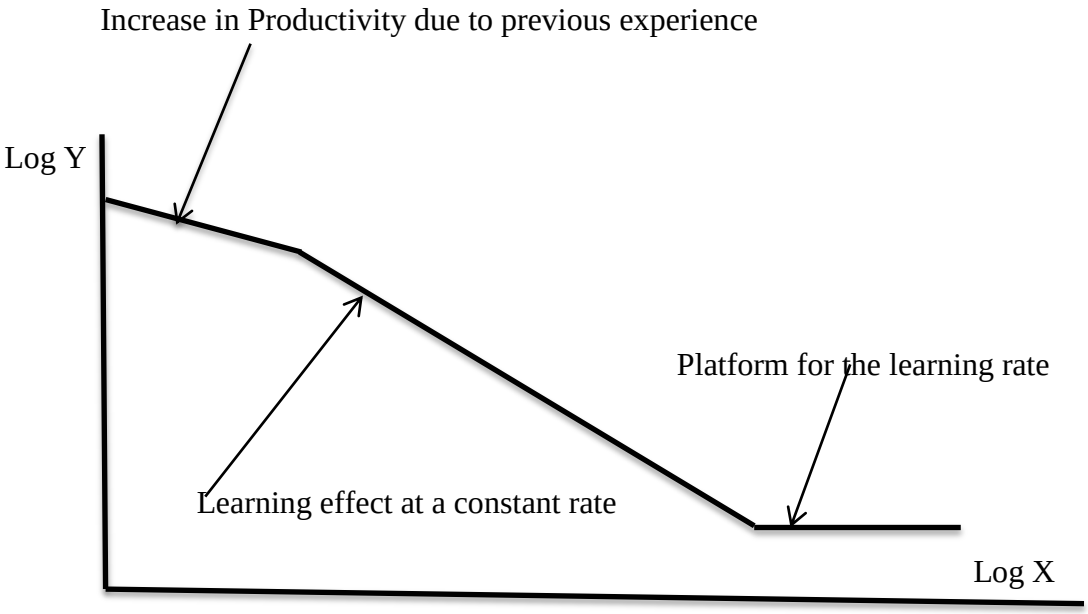

Figure 3.3: A Typical Learning Curve (Lutz et al., 1994)

In Figure 3.3, the first section represents prior knowledge; it permits for modern ways of improving productivity, as the craft gangs become acquainted with the practical procedures, the project environment, material and production increases and the rate of learning falls severely. The next section represents the horizontal line which explained the limit of productivity improvement that can be achieved once the stage is reached. Productivity can be improved only when it reaches more resourceful construction processes (Lutz et al., 1994). From Lutz et al. (1994) illustration, Y represents the man-hours, cost or time necessary to accomplish a repetitive generic unit X, the significance of the learning theory in planning has developed an interesting research topic, at first it was focused on industry and in recent times to construction. A research investigated by Couto and Teixeira (2005) proposed several mathematical models for learning, the trouble in using the conclusions of this investigation lies in choosing a suitable model for each project activity and in what manner they can perhaps inter-relate between the huge sum of activities of the ordinary building.

3.6.1 Learning Curve Models

Thomas et al. (1986) noted that in order to achieve the most profits from the development of learning theory, investigators should focus on evolving scientific models of learning curves, this model illustrates the time per cycle of repetitive

activity as a function of the activity cycle number. The purpose of the scientific models is to offer, forecast or measure the increased output in the repetitive work. Thomas et al. (1986) proposed the following five basic learning curve mathematical models:

- Straight line unit model
- Stanford unit '8' model
- Cubic unit power model
- Piecewise unit model and
- Exponential unit model

The development of Straight line unit model and Sanford unit model according to Thomas et al. (1986) were based on the "straight line and the Stanford 8 models, which were developed in 1936 and 1940 respectively, are based on the statement that the rate of learning is constant. However, the Stanford 8 theory takes into account in the adjustment of previous experience." According to Thomas et al. (1986), "the unit cubic learning model was established in 1970 to account for operatives' experience in the first few cycles and also a levelling-off in enhancement as the project approaches finishing point or as production reaches a fixed state." Although unit straight line differs from the Stanford 8 models, the cubic model takes responsibility that the learning rate may differ with time and the variable is not constant.

A study conducted by Thomas et al. (1986) from the electronics industry has shown that the cubic unit power model offer the greatest acceptable statistics for experimental data. However, the piecewise unit model according to Thomas et al., (1986), is a "linear estimate that involves three different stages, each with a continuous percentage of learning. Once the unit is plotted on a log-log scale, the model looks like a three- straight line segments, the first segment is called the operation learning stage, the subsequent stage is known as the routine developed period, and the additional stage is known as the standard construction, the standard construction stage takes place when the construction rate levels off or stops to increase, i.e. the stable state."

The development of the exponential model was established by the Norwegian Building Research Institute (1960), it is founded on the hypothesis that portion of the time per cycle is permanent and the part is subject to improve through repetition of the same task. According to Thomas et al. (1986) this model is subject to improvement if "one of the parts will be reduced by one-half after a constant number of cycles and the time per cycle will gradually approach an ultimate or lowest value." The important complications related to the theory of learning curve are as follows (Thomas et al., 1986):

- How to determine the predictive best model,
- How to understand the constraint affecting the rate of learning,
- How to estimate the parameters of the learning curve model, particularly the critical or stable start time per cycle, and
- How to quantify the delay impact on performance.

The earlier study conducted by Thomas et al. (1986) employed the use of output and construction production data collected from 65 construction labour activities to examine the best estimating model between the cubic and exponential and straight-line models, data were gathered from erection of multi-storey residential structures, a six-storey building including the construction and erection of a pre-cast segmental bridge. From their findings, they stated that " although, it was evident that although, the straight-line model has the benefit of straightforwardness, it may not be reliable since the rate of learning which is expected to be continuous in the straight-line model is not certainly a constant value from the 65 activities calculated, the cubic unit model of learning constantly resulted in a higher coefficient of determination and was the suitable model for modelling the effect of prior learning developed."

A research conducted by Duff et al. (1987) observed that the cubic and piecewise model of the learning curve has a better coefficient of determination compared to the straight-line learning model. Nevertheless, their investigation noted that either the cubic or the piecewise model of learning curve provides a reasonable benefit

in the presentation of the phenomenon of learning for the generalisation of building construction works which data were collected (Duff et al., 1987).

Having considered the various models and in order to measure the influence of on-site learning in the optimisation of blockwork craft gangs' productivity of the activities observed, the researcher employed the used of the straight-line model in the investigation of the blockwork craft gangs' productivity in this study.

3.6.2 Application of LCT to On-site Craft Gangs Productivity

A research study conducted by Parker and Oglesby (1972) shows that the projected percentage of learning in most building construction work falls among the range of 90% and 30%. According to Parker and Oglesby (1972), it means that if a craft gang or worker follows the 70% learning model and it is expected that the time to build the first unit is 1000 man-hours, it implies that in order to build the next two unit it will require 70% of 1000 man-hours or 700 man-hours, then the time to construct the subsequent units will be 70% of the previous units. However, the theory state that as the units number rises the production rate of construction stabilise since the workers or gangs' are becoming more familiar with the procedure of work (Parker and Oglesby, 1972).

Couto and Teixeira (2005) stated that applying the learning model in the building engineering is complemented with some challenges because building activities generally take place in diverse and unique environmental condition. In addition, Couto and Teixeira (2005) observed that the construction industry works are different and are not repetitive unlike the manufacturing industry where the workers have the opportunity to perform their work repeatedly. Consequently, Couto and Teixeira (2005) study argued that the main reason why building engineering shows a low level of productivity compared to other manufacturing industry is that the building tasks are characteristically different and noon repetitive.

In a related study investigated by Thomas al el. (1986) on 65 different labour-intensive productivity data from construction activities shows great coefficients of determination in the relationship among the cycle numbers and the time.

However, notwithstanding the low response rate of the building industry in the application of the model of the learning, prior research work has shown the significance of this model to construction productivity (Norflect, 2004; Couto & Teixeira, 2015). A typical arithmetical plot of the learning curve model is illustrated in Figure 3.4 and adapted from Abdulaziz and Radosavljevic (2013).

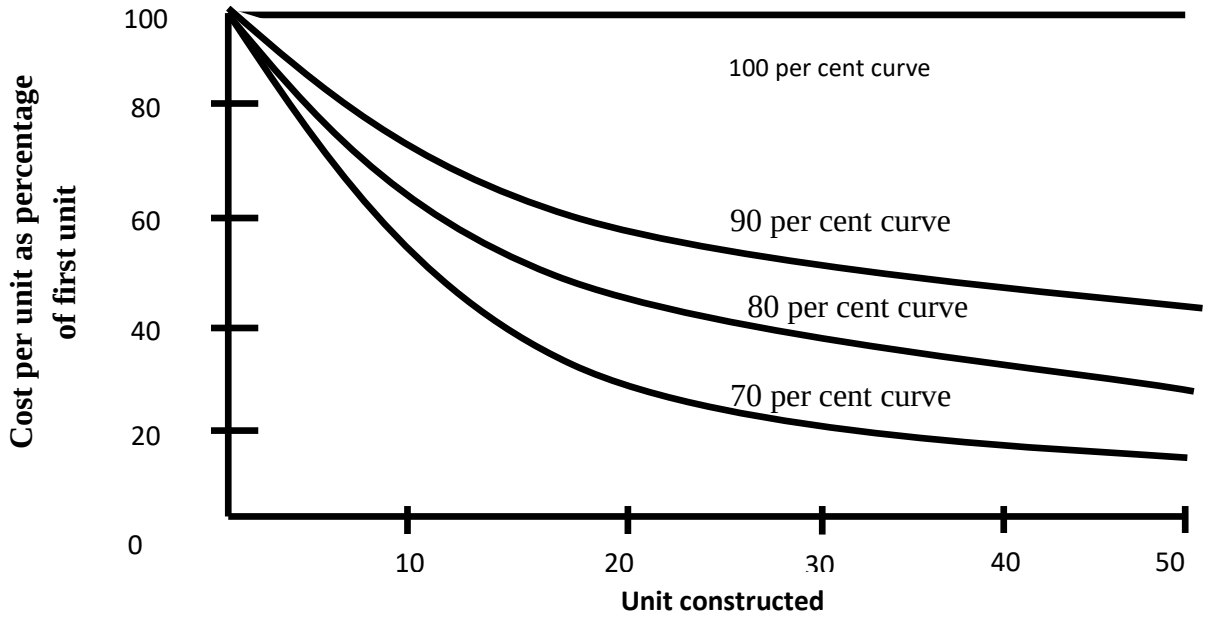

Figure 3.4: Learning Curve Model

A research study conducted by Jarkas (2010) observed the construction of spandrel beams and elevator core walls in a construction of a multi-storey facility utilising the straight line model and quantified the effect of learning on form work productivity, the study found important productivity improvement due to the repetition in form work construction. However, Jarkas (2010) noted that it is significant to distinguish between production increase arising from the effect of learning due repetition of material. The earlier may be referred to as the phenomenon of learning, while the latter can be described as material repetition effect.

Research on the influence of learning on construction industry productivity was investigated by Everett and Farghal (1994), the result of the study shows that among the productivity of 60 field operations quantified there was a high

correlation between cycle number and the time, consequently the study concluded that the theory of learning curve model is an important tool for forecasting historical and future performance.

In a related study Wideman (1994) investigated the building of a 25-storey construction concrete exploring the application of the learning model on the concrete building with identical floors and concluded that the unit straight line curve is important in several observation conducted in the project. Furthermore, Dong (1996) carried out an investigation on the effect of learning on the productivity of building construction of 18 housing unit projects; the findings reveal an overall important positive influence on the construction productivity and the learning influence.

Previous research in the building construction industry has supported that there is a significant relationship among the construction industry performance and the learning competencies (Arshad & Scott-Ladd, 2010; Wong et al., 2012). An investigation carried out by Arshad and Scott-Ladd (2010) on Malaysian construction industry vision 2020 classified the various methods to learning as "action learning, active learning, experiential learning, cooperative learning, problem-based learning, coaching and mentoring, formal and informal learning."

Arshad and Scott-Ladd (2010) observed the various methods used by Malaysian construction industry to learning and noted that the industry favoured internal learning strategies although, the external learning strategies is also been used, their study concluded that both formal and informal learning are important. In another related study investigated by Garvin et al. (2008) on the development of an instrument that will encompass the three building blocks in the measurement of an organisational learning revealed the following three building blocks:

- An environment that is encouraged by learning that has the four characteristic of openness to new ideas, appreciation of differences, time psychological, safety and reflection.

- A Formal method of Learning which has education, analysis, experimentation, information collection, training and information transfer and
- A learning that reinforces Leadership.

The phenomenon of learning curve theory according to previous researchers (Arshad & Scott-Ladd, 2010; Jarkas, 2010) has proved applicable in the manufacturing industries, especially the once involved in the mass production of automobile and aircraft assembly. According to previous study in the field of construction "the learning process in labour-intensive organisation is assumed to be more important since that automated work is challenging by the fact that machines cannot benefit from the previous experience and therefore would not learn to run any faster or increase the rate of production" (Arshad & Scott-Ladd, 2010). Several studies have investigated the application of the learning model in the building industry, this studies have revealed that the benefits of this theory to construction labour productivity are very significant (Arshad & Scott-Ladd, 2010; Jarkas, 2010).

Jarkas (2010) stated that the LCT is a "method based on a primary principle of human nature and the ability to learn from previous work experience, The phenomenon of learning model is a process that stems from a worker or gangs repeating the same work and acquiring new skill or efficiency from their past practice or experience." This experience gain is related to:

- Knowledge improved from the work being executed,
- Workers have great task familiarity,
- Work organisation improved and
- Improved coordination.

3.6.3 Organisational Learning

A research study conducted by Granerud and Rocha (2011) noted that organisational learning is a process that encompasses the improvement of new skills, knowledge and behaviour; it is also, a process of rectification of mistakes

and development and enhancement of current practices. Organisational learning according to Granerud and Rocha (2011) also means the improvement of new procedures and organisational learning can lead to the development of continuous enhancement. The investigation carried out by Granerud and Rocha (2011) observed that experience methods and ideas from outside or within the industry are combined to enhance the organisation's productivity; the study noted that organisational learning takes the workers learning outside the limits of just personal to that of the companies housing those personalities.

A similar study conducted by Arashpour et al. (2012) suggested some levels of industries learning and their characteristics are "1. Reproductive learning: handling of routine problems; 2. Basic productive learning: evaluation of outcomes and minor corrections; 3. Advanced productive learning: experiments, inventions and test solutions; and 4. Creative learning: questioning existing assumptions."

The study investigated by Granerud and Rocha (2011) examined the two main perceptions to industrial learning and made an effort to further describe it in relation to the learning organisation. The two major requirements of organisational learning are collective action of stakeholders of knowledge and knowledge sharing (Granerud & Rocha, 2011).

In a related study conducted by Fiol and Lyles (1985) recognised that there has been some misperception for years on the definition of organisational learning and defined organisational learning as "the growing insights and successful restructurings of industrial challenges through individuals reflecting in the structural elements and outcomes of the organisation itself." From this meaning, learning comprises of the improvement of awareness and structural action that will improve outcomes.

A research study conducted by Love and Josephson (2004) on the association among an organisations performance and its building projects learning competencies has proved that there is a significant association between performance and learning competencies in an organisation. In addition, Love and

Josephson (2004) acknowledged that a craft gangs learning includes the improvement of new expertise and development of manners for modification of mistakes for new practices.

This investigation considered the learning curve theory as a means to explain construction worker behaviour more realistically. A craft gang's learning is the improvement of new skilled knowledge and conduct, the modification of mistakes and enhancement of present practice. Previous researchers have acknowledged that this theory would seem most applicable to explain how construction craft gangs' adapt to the production environment on-site to maintain or improve their output, and how on-site learning is affected by prior learning (Enshassi et al., 2007; Jarkas, 2010; Kazaz et al., 2008).

3.7. Conceptual Model for On-site Craft Gangs Productivity

The conceptual model presented in Figure 3.5 summarises the foregoing discussions on the relationship between the on-site blockwork prior learning, the production environment i.e. the productivity constraints that can influence the blockwork craft gang's productivity.

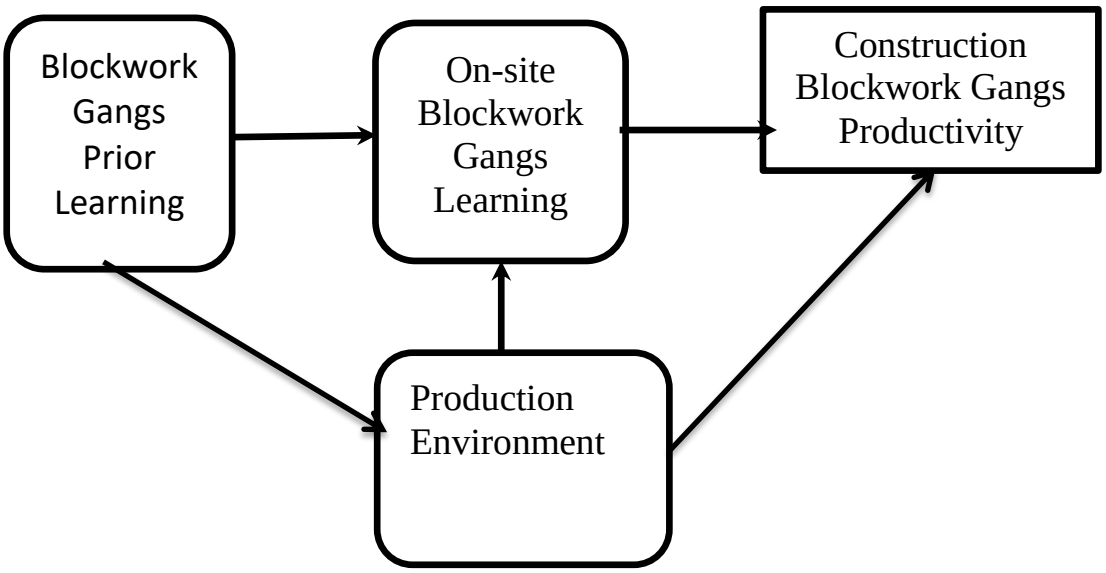

Figure 3.5: Construction Blockwork Gangs Productivity (CBGP) Model

3.8 Summary of Chapter

The summary of this chapter presents the various productivity theories. The first section of the chapter reviewed the various motivation theories concerning the development of human. Among other highlighted theories of motivations are: the 'Need theory', the ‘Goal setting theory’, 'Reinforcement theory', the concept of theory 'X and Y'. Finally, 'theory Z' motivation theory was highlighted.

The next part of the chapter dealt with the theories in the school of psychology and management theories as follows: the 'theory of reasoned action' (TRA) which incorporates the discrete elements or components of behaviour leading to action without the cascade or moral elements of other models. The transformation theory was also, discussed focusing its view from economics origin, this is a production based theory in the school of economics. In addition, the lean construction method was explained as well as the knowledge worker productivity theory developed by Drucker's was also reviewed and discussed.

Furthermore, learning curve theory, organisational learning or group learning and the learning models were discussed. The purpose of the mathematical model was to suggest and predict measure for improving productivity in the construction industry through the repetitive task. The following five models were reviewed: 1) the straight line model; 2) the cubic model; 3) the Stanford '8' model; 4) the piecewise model and 5) the exponential model. To conduct an unbiased analysis of the impact of the role of on-site craft gang’s prior learning in the optimisation of blockwork gang’s productivity within the observed craft gang's works, the use of straight-line learning curve was adopted for the study.

Finally, a conceptual model was presented. The next section moves the report to the methodology of the research and method of data analysis.

CHAPTER 4

4.0 RESEARCH METHODOLOGY

4.1 Introduction

This section contains the description of methods used in gathering, collation and analysing the data. Mixed method research approach was adopted in collecting the data. This approach, Flick (2011) stated that researchers adopt a qualitative and quantitative methodology for the interest of mixed pragmatically research, purposely to compensate the paradigmatic shortcomings in the two approaches. The statistical methodologies employed in analysing the productivity data were reviewed and presented.

4.1.1 Research Methodology

Research methodology is defined as an all-encompassing macro framework that deals with the philosophies of thinking using assumptions that are paradigmatic that validate various schools of thought (O'leary, 2010). Research methodology offers both strategies and grounding for conducting a study and this can be classified primarily as quantitative (positivism) and qualitative (phenomenology) paradigms (Denzin & Lincoln, 2011). According to Burns and Bush (2003), research method can be viewed as the blueprint which specifies the research strategies for collection of data and analysis.

4.1.2 Research Paradigm

A research paradigm is described as a basis for conducting research and it start with the philosophical paradigm and the adopted theoretical design in the field of the study. According to Saunders et al. (2012), research philosophies describe the methodology and the strategies adopted in the data collection and the techniques used in the data analysis. This was supported by Creswell (2013) noting that generally, scientific paradigm of philosophical inquiry is the philosophical foundation for determining the research design of the study in order to answer the questions of a particular research. A study carried out by Easterby-Smith et al. (2012) and Saunders et al. (2012) classified research philosophies in two groups:

1) the positivism and 2) the phenomenology. According to Collis and Hussey (2009) they noted that the positivistic is normally referred to as quantitative while the phenomenological is also referred to as the qualitative paradigms and this paradigm are different in their attitude towards the generation of understanding through collection of data: a positivistic paradigm encompasses a formal, unbiased, deductive method for solving a problem, while a phenomenological paradigm embraces an inductive, subjective and an informal methodological approach to testing theory.

Lincoln et al. (2011) described a paradigm as a basic set of principles or beliefs that protect an action. Easterby-Smith et al. (2012) stated that there are several numbers of philosophies a researcher can select from in a research study, however, there noted that there are two predominant philosophies that will guide a research study: positivism and phenomenology. Previous researcher investigation has described this philosophy as quantitative or positivism and qualitative or phenomenology paradigms (Denzin & Lincoln, 2011). Furthermore, Parkhe (2009) classified this two techniques by classifying them into deductive or positivism and inductive or phenomenology methodology of research.

4.1.3 Positivism

Healy and Perry (2000) noted that "the positivists challenge the qualitative methods to research as their perception is that science quantitatively measures independent facts about a single apprehensible reality." According to Neuman (2006), positivism is a research paradigm or techniques that consist of a deductive method with an accurate calculation of quantitative data and it also allows for the discovery of laws that will permit the prediction of the behaviour of human. This method is grounded on information acquired from the scientific technique or experimental testing. Kumar (2011) explains that the positivist research paradigm mostly involves quantitative approaches, rather than qualitative. However, Struwig and Stead (2007) maintain that every feature of quantitative research should not be attributed to positivism. However, Henn et al. (2006) stated the logic of the positivist research philosophy as follows:

- Seeking to recognise the causes and consequence of occurrences, and to experiment the theories.
- Research knowledge should be tested by observation through tangible evidence.
- Researchers should adopt scientific approaches that give control, objectivity and standardisation.

4.1.4 Interpretivism

The interpretive paradigm of research is concerned with an unstructured qualitative approach that may include observation and interview of participants' (Henn et al., 2006). Henn et al (2006) described interpretive research philosophy as a philosophy directed towards allowing study participants to present information in their own words. Believes that the study of phenomena in the natural environment is paramount and scientists cannot avoid affecting the phenomenon being studied. Interpretivism deals with a subjective interpretation and involvement in reality which allows the reality to be completely understood. The fundamental idea of the interpretive research method is to work in line with the social world by recognising its presence and recreating the meaning, avoiding distortion, understanding the meaning and incorporates these as building blocks for theorising (Goldkuhl, 2012).

4.2 Quantitative Research Method

Quantitative research is a deductive research approach (Leedy & Ormrod, 2013). To the quantitative researcher, the world is external to the researcher and there is an independent objective reality (Saunders et al., 2012). In quantitative research method, the researcher begins with theory, generates hypotheses, tests those hypotheses through observation and analysis, and then draw conclusions (Alfred et al., 2013). According to Leedy and Ormrod (2013), Quantitative research is a research type that involves the use of scientific inquiry by the researchers.

The quantitative research adopts a hypothetical-deductive approach to testing a hypothesis. Cavana et al. (2001) stated that this approaches can be broadly based on the ideas of physical science from precise quantitative data. This method is

described as the assumptions of a good research design in terms of objectivity in observation, precision in measurements, an analysis in statistics and verifiable truth (Cavana et al., 2001). The strength of the quantitative approach is that the research findings come from measurable data that are generalizable to large population (Neuman, 2006).

A quantitative method allows researchers to separate themselves from the object of study and promotes scientific objectivity (O'leary, 2010). The method of research allows for significant indicators of credibility such as validity, reliability, generalizability, and reproducibility. Quantitative research is usually considered as an objective positivist undertaking, with large scale but little depth (O'leary, 2010). The development process of the quantitative research method presents participants with clear questions which provide answers in line with research objectives (Dahlberg & McCaig, 2010). In formulating questions in quantitative research, Flick (2011) noted the fundamental concerns that the researcher should understand:

- How to formulate appropriate questions.
- Which kind of questions to be posed, and
- The purpose of asking the questions.

In a related study, Dahlberg and McCaig (2010) state the essential points to be noted by a quantitative researcher as follows:

- What do you ask?
- Why do you ask?
- Who do you ask?
- How do you ask?
- What is the answer?

The merits and demerits of quantitative research, as identified by Flick (2011) and Kumar (2011), include the following:

4.2.1 Merits of Quantitative Research Method

- The results have a high degree of generalisation.
- It permits the investigation of large numbers of cases in some aspect within a relatively short period.
- The design is specific, well-structured and can be clearly defined and recognised.
- Possesses clarity and distinction between design and method of data collection.

4.2.2 Demerits of Quantitative Research Method

- The aspects of research investigation may not be important to the participants.
- The distance between the researcher and the study population is comparatively wide.
- Participants may interpret questions differently from each other.

4.2.3 Qualitative Research Design

Qualitative design produces robust detailed data that leaves the observers opinions intact when providing a framework based on the participant behaviour (Yin, 2012). Nevertheless, the benefit of a qualitative method also has its disadvantage as the findings are usually not generalized across time and place. Results may vary greatly between researchers (Dudwick, Kuehnast, Jones, & Woolcock, 2006; Sekaran, 2003). The qualitative research method is mostly characterised by the small number and in-depth cases (O'leary, 2010).

The qualitative tradition demands inductive and deductive logic, embraces subjectivity, accepts multiple perspectives and realities on both participants and researchers. Qualitative researchers demonstrate a common belief that their approach provides a more in-depth understanding of phenomena than the quantitative approach (O'leary, 2010). According to O'leary (2010), the primary aim of undertaking qualitative study is to acquire an intimate understanding of people, environment, subject and culture through rigorous involvement in the

reality of the study. According to Henn el al. (2006) qualitative study adequately examines population attitudes, ideas, intentions and motives.

The strengths and weaknesses in qualitative research as presented by Flick (2011) and supported Kumar Kumar (2011).

4.2.4 Strength of Qualitative Research Method

- It allows for comprehensive and exact investigation of few cases where the participants have liberty to decide issues that are relevant in the context.
- The main strength is the ability to study phenomena in- depth.

4.2.5 Weaknesses of the Qualitative Research Method

- The analysis usually requires much time and results are not broadly generalizable.
- The design of qualitative research projects are less specific and do not have a consistent structural depth.

Nevertheless, this method becomes unsuccessful when the phenomenon under investigation is hard to measure. Hence, it is apparent that a purely quantitative or qualitative approach is not appropriate for this research.

4.3 Mixed Method

Creswell (2013) stated that utilising a mixed method of research provides a premise for understanding the research problems, provides a better understanding than either of the two approaches alone. A mixed research approach reduces the influence of personal bias and maximises validity in the research study (Henn et al., 2006). Researchers adopt a mixed methodological technique in the interests of combining both the quantitative and qualitative research pragmatically, purposely to compensate the paradigmatic shortcomings in the two approaches (Flick, 2011). The method allows collection of different types of data and interpretation of results using a variety of different analytic techniques.

Creswell (2013) stated that a mixed research techniques can be used for example when the researcher want to generalise the finding to a population in order to develop a full meaning of a phenomenon or individual concept. The study noted that the researcher can first explore generally in a qualitative manner to understand the study variable and subsequently study the variables with large sample of individuals quantitatively (Creswell, 2013). According to Creswell (2013), a pragmatic method is a technique that involves the mixed method and consists of "philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative approaches throughout the research process." O'leary (2010) identifies the strategies of a mixed method approach research that are basically designed in three ways:

- Using a quantitative perspective with acceptance of qualitative data: This method is used by researchers that accept more of the underlying assumptions of the quantitative approach, but also accept that the use of some qualitative data will be helpful in the validation of the study.
- Using a qualitative perspective with acceptance of quantitative data: This methodological approach is adopted by researchers that believe in quality rather than quantity, and subscribe more to the underlying assumptions of the qualitative traditions.
- Question- driven perspective: The motivation for selecting this approach is neither for qualitative nor quantitative interest areas but rather because it favours the adoption of an examination of research questions and selects the method that can best answer the research question, irrespective of paradigm.

The mixed-method approach may be more appropriate when using a quantitative perspective with acceptance of qualitative data. The reason that not only does the study provides an answer to what and how questions in the research concerning the problem identified, However, it also focuses on prediction and generalisation.

4.3.1 Justification for Adopting Mixed-Method

Choosing the right design should define how data for this research can be collected. However, quantitative and qualitative research methods share the similar basic principle of scientific investigation; they differ significantly in their design. When creating research strategies, apart from using a purely quantitative or qualitative approach, there are situations, as in this study of investigating the influence of on-site blockwork craft gangs learning in the optimisation of construction productivity, where a mixed-method approach might be more appropriate (Creswell, 2013; Yin, 2012).

4.4 Research Design for the Study

Saunders et al. (2012) described research design as a "composite strategy used for identification of research problem, the collection of data and analysis of data". Furthermore, Saunders et al. (2012) submitted that "a general plan and clear research strategy should contain clear objectives that direct the researcher in data collection including the time and location of the research and the ethical considerations relating to the project."

An investigation conducted by Sekaran (2003) noted that the development of a research design includes the following: "1. A series of rational decisions, 2. Identifying the purpose of the study, 3. Whether it is exploratory, descriptive or hypothesis-testing, 4. Identifying the type of investigation, 5. Deciding the extent of the researcher's intervention, 6. Identifying the setting of the study, 7. Deciding measurement and measures, 8. Deciding data analysis, 9. Deciding data collection methods, 10. Deciding time horizon, 11, Deciding sampling design; and finally Identifying the unit of analysis."

The majority of the previous study undertaken to improve construction industry labour productivity consider the perceptions survey of professionals on the factors affecting construction labour performance (Chigara & Mangore, 2012; Durdyev et al., 2013; Liberda et al., 2003; Nyakazeya, 2012). However, Jarkas (2010) and Granerud and Rocha (2011) recognised the necessity of observing the performance of construction craft workers in an effort to improve the construction

productivity. The aim of this study is to investigate how on-site blockwork craft gang's learning impacts productivity within a project-specific environment and how the craft gangs deal with the inevitable problems that arise on-site in order to optimise their productivity with the following objectives:

1. To identify the project-specific constraints blockwork craft gang's may need to respond to, in order to optimise their productivity.
2. To investigate the relationship between the responses of blockwork craft gang's to specific project-based factors.
3. To measure the impact and relative influence of on-site learning on the blockwork craft gang's productivity.

To achieve these objectives, considering the significant knowledge of construction blockwork craft gang's, site supervisors' and the project manager's supervisory experience in building production processes, the researcher employed a mixed method research approach outlined in Figure 4.1. According to Flick (2011), a mixed research approach combines qualitative and quantitative approaches where the shortcoming of one paradigm is compensated for by the strengths of the second. Specifically, the mixed methodological design for this study adopts quantitative perspectives with the acceptance of qualitative data, as recommended by O'leary (2010).

This research acknowledges the learning curve theory of construction craft gangs' optimisation. However, the project-specific constraints influencing on-site learning in the construction industry were explored in the study to devise mechanisms for resolving challenges in the construction industry. The selection of a particular approach significantly depends on the nature of the topic being studied, researcher experience, location of the study and the study participants (Kumar, 2011).

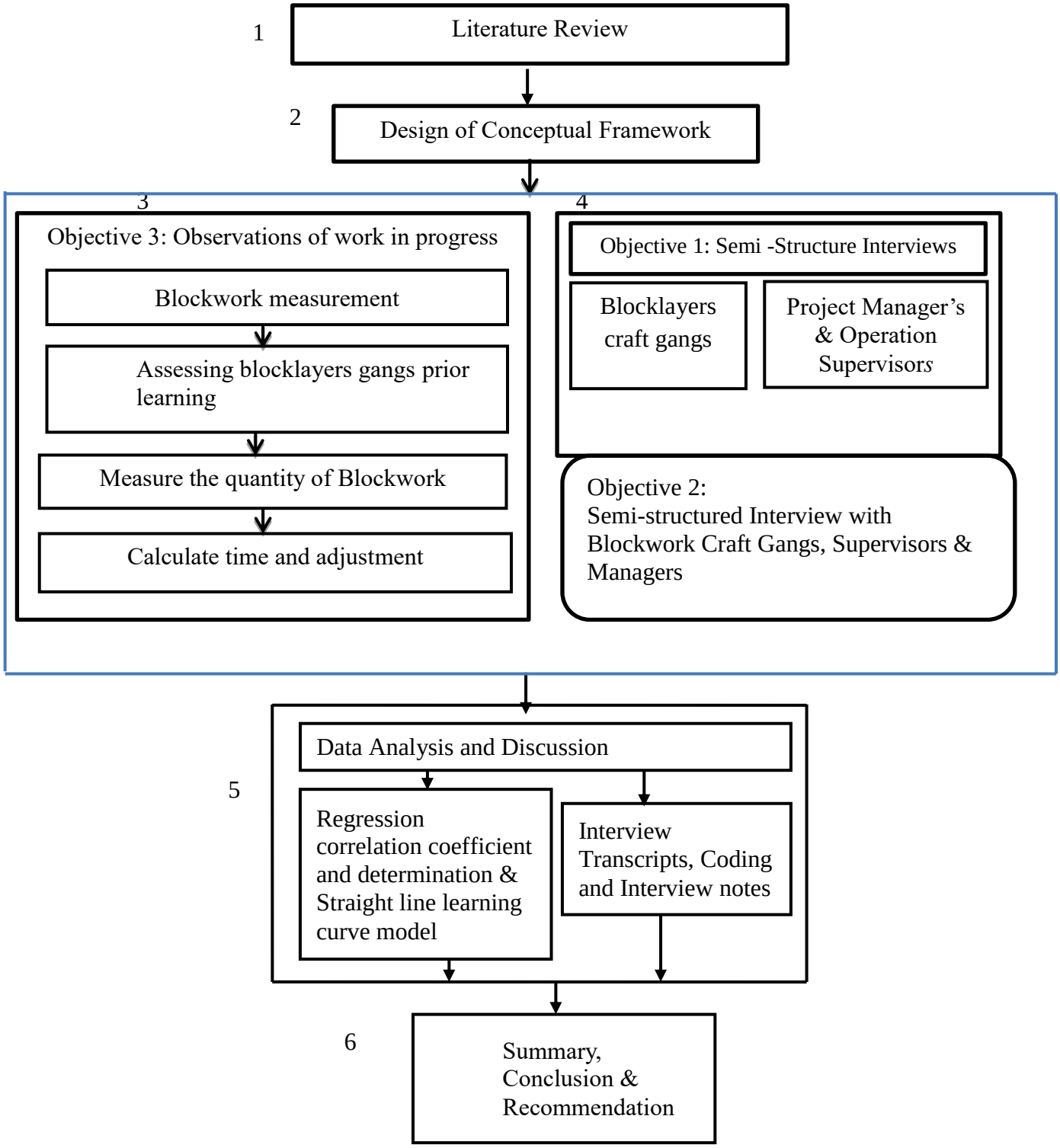

Figure 4.1: Research Design-Mixed Method Approach

4.5 Research Strategy of the Study

A research plan according to Creswell (2013) is intended to give direction and guidance to a researcher's effort, to enable a comprehensive and systematic study. The various data collection strategies used in this study are:

1. Observation
2. Interviews

4.5.1 Observation Methodology

A standard observation data collection form was used to record the craft gang's productivity input and output for the seven blockwork craft gang's observed in the on-going project sites. The form was designed to include the important information on the project such as the gang number, the starting date, confined space if any, normal gang's working hours and the management level of the site additionally, the description of the observed project method of wall type was included such as number of floor, weather condition and the characteristics of each craft gang's observed. The importance of such information is to facilitate in dividing the data according to the objectives of the. A typical observation sheet is presented in appendix B.

4.5.1.1 Sampling Method for Observation

The sampling method adopted for the observation study was a purposive sampling of seven (7) selected blockwork craft gang's working on the project and the firms executing the projects were also, sample based on their availability and enthusiasm to participate. The sample criteria were tenure on-site craft gangs of block layers with an opportunity of learning.

4.5.1.2 Description of Project Observed

The project observed was an office building presented in Figure 4.2. The project was located in the Federal Capital Territory (FCT), Abuja, Nigeria. The 17-Storey building was awarded for a cost of N39.2 Billion (Approximately $245 million). The office building is a tri-tower building and when completed, it will stand 86 meters high (excluding the height of its communications mast), one of the highest in Abuja and within the top 10 in Nigeria. It will have a basement and a 15-storey

parking structure. The proposed office complex has a gross area of about 81,000 sqm comprising of the following:

1. Car park block with a total of about 18,000 sqm (15 floors and Basement).
2. Administrative block consisting of 3 towers on a podium with an area of about 63,000 sqm (17 floors and a basement).
3. 700 Capacity Auditorium.
4. Welcome Centre, Fire Station, Security Station and other auxiliary facilities.
5. A total of 445 car parking spaces has been provided. This will be achieved through the provision of a multi-storey car park, basement parking as well as parking around the building as follows:
    - Multi-level car park accommodates 416 cars (12 floors).
    - Basement level parking accommodates 19 cars.
    - Parking around building accommodates 6 surface parking and 4 bus parks.



Figure 4.2: Project Front View Showing Operation

The focus on the project was on construction blockwork craft gangs who have common features as method of construction, tenure appointment and size and type of project. The productivity data was collected from the seventeen multi-storey on-going office project constructions over a total period of 12 weeks. In addition, selected craft gangs blockwork activities which are repetitive in nature within the observed project site were also monitored to complement the required productivity data. Activities observed included wall composition, quality test plan, and installation of wall stiffener, wall joints, block wall rebar, scaffold elements, u-block casting and housekeeping after each day.

4.5.1.3 Construction Methods

In the observed project, the craft gang's blockwork observed have similar sequence of blockwork activity. The super-structural blockwork methods comprises of the following seven stages:

Stage One:

- Blockwork laying area shall be clean and prepared for setting out.
- Land surveyors set out block wall position including openings.
- Quality test plan: for every 2000 blocks supplied, a set (3 blocks) shall undergo compressive crushing as represented in Figure 4.3.
- The attention of the site superintendent is to supervise activity and ensure that safety helmets, gloves, clear goggle, shoe and reflective must be worn at all stages.



Figure 4.3: Quality Test Plan: For Every 2000 Blocks Supplied

Stage Two:

- Specified and workable mortar mixing (1:4) with 10 mm mortar joint as represented in Figure 4.4.
- Course 1 arrangement full block, course 2 arrangement header/half block.
- Starter bar to be drilled 200 mm into slab first prior laying blocks
- Starter bar for columns 2Y12 @ 500 mm lapping drilled 200 mm in the slab and filled with mortar.



Figure 4.4: Mortar mixing (1:4) with 10 mm mortar joint on Blockwork

Stage Three:

- Erect blockwork to 1000 mm initial height as shown in Figure 4.5.
- Wall stiffener of 100 X 200 mm is introduced at every 3 course.
- Wall joints to be thoroughly rubbed on both sides after courses.
- Block wall Re-bar to be lapped with starters 600 mm for Dia. 12

- Wall columns steadily filled with concrete at each course.



Figure 4.5: Typical Block Wall Erection with Wall Stiffener

Stage Four:

- Erect scaffold as height progresses, put floor with access and ladder on the scaffold as represented in Figure 4.5 and 4.4.
- Safety personnel to confirm if scaffold are safe for use and place appropriate tags.
- Affix scaffold handrail at 500 mm and 1m high above worker's platform for guard.
- Mason to has 1m of block high in front of him when climbing up the climbing the scaffold as represented in Figure 4.5.

- Site Superintendent to supervise activity, and ensure that the Scaffold is not overloaded.

Stage Five:

- U-block casting, a good vibration of the concrete as shown in Figure 4.6.
- Maintain scaffold handrail 500 mm and 1 m high from worker platform.
- Scaffold elements MUST be confirmed fit by scaffold supervisor.
- Care must be taken not to overload scaffold.



Figure 4.6: U-block casting with good vibration of the Concrete

Stage 6:

- Employ the pulley system to transport blocks to height as shown in Figure 4.7.
- Maintain scaffold handrail 500 mm & 1 m high from worker's platform.



Figure 4.7: Transportation of Blocks via Crane to Height of Work

Stage 7:

- Removal of scaffolds after completion 24 hours later or after the rendering (if necessary) is done.
- Thorough cleaning after each day work.

In this study, the investigation on the influence of on-site learning in the optimisation of craft gangs' productivity was limited to the blockwork laying due to the availability and readiness of the craft gang's and the management level of corporation with the researcher.

4.5.1.4 Method of Site Observations

In order to successfully observe the influence of project-specific constraints on the blockwork craft gang's learning productivity in the observed project, seven (7) craft gangs were observed. Several amounts of data was collected to make sure that the findings are robust, reliable, valid and statistically important, and the craft gangs was selected carefully, in order to evaluate the effect of the project-specific constraints on the gang's productivity with lowest interruptions from other variables, due to the reason that some variables other than the constraints influencing the craft gang's productivity on sites, as far as possible, it is important to reduce the interruptions and influence of such variables. Therefore, only craft gangs with characteristics that common such as tenure appointment, methods of construction and site management level were selected for observation.

Due to the variability amongst craft gangs labour productivity which can arise from variability of management effectiveness or the workers skill. The workers skill differs between dissimilar craft gangs. However, it was very difficult to control these variables. Nevertheless, the rule adopted in this research study was to focus on comparing the average values obtained on the observed on-site project.

The step adopted was once the ongoing project was selected and approval was given for observation, the researcher approached the project manager with the approved introduction letter from the client stating the aim and objectives of the research. Immediately the permission to carry out observation study was granted by the project manager, a meeting was arranged with the project production manager to provide the researcher with the relevant copies of the architectural drawings of the project. The researcher started the observation study by meeting with the relevant blockwork craft gang's field supervisors and the gangs. The purpose of the data collection form was explained, stressing the fact that the observation is not related to management function and that all observed data information collected will be confidential and only used for the purpose of research as contained in the PIS in appendix G and I.

The researcher presented the participant information sheet (PIS) and explained the method to the blockwork craft gangs. During the observation, the observer used a wrist watch and stopwatch in recording the observed time for each of the craft gang block laying operation in a working day. The data were collected daily to determine the variation in output for the craft gang's blocks laying element in the selected project site. The work measurement procedure in Figure 2.2 and blockwork production process in Figure 3.2 was used for the observation. Each day, the observer would arrive on site as early as 7:00 am, note the progress of the blockwork under observation, and take time record of the blockwork and delays experienced during the workday on the observation sheet. As soon as the researcher has finished recording the start time, he would observe the various mechanisms the gangs are using to resolve the specific-project constraints from 7:00 am to 6:00 pm daily.

The researcher constantly reassured the craft gang's that the data information collected will be kept confidential and would sole used for the research purpose in order to maintain confidentiality. The researcher spent twelve weeks during the field observation of this study.

4.5.2 Qualitative Data collection

This research adopted a face-to-face semi-structured interview in the qualitative section of the study in order to explore in-depth and also to capture rich data from the interview participants. According to Liamputtong (2009), interviews are an effective qualitative technique for exploring in-depth information.

4.5.2.1 Interviews

The research study conducted by Saunders, et al., (2012) stated that an interview is a discussion focused among two or group of people for the purpose of collecting reliable and valid information regarding the research objectives and questions. In a related study, Collins and Hussey (2009) noted that an interview is a technique for collecting information where the participants are asked relevant questions on their profession, how they fell and how they carry out their work. In addition Bryman and Bell (2007) promoted interview as an efficient method of collecting data in qualitative research study. Interviews are predominantly used in

management and business research and social science research for data collection. It is a conversation of voice-to-voice directed by the interviewer (the researcher) to collect important information (data), expression, opinion and ideas of the respondents about the research questions. Interview when used for data collection is flexible and this is one of the advantages of the tool. The interviewer can rephrase questions to suit the situation under enquiry.

The flexibility in interview allows the interviewer to direct his interactions in such a manner that will yield a strong result. The interview also employs non-verbal communications such as the facial expressions, body languages and any other behaviour of the interviewer and this makes it easier for the participants to ask follow-up questions that are not obtainable in other techniques. However, interview method of data collection has its own demerits which may be very expensive and consumption of time, for instance in situation where there are several number of participants to be interviewed or in the case of access problem to direct relevant sample (Collis and Hussey, 2009).

Interviews can be divided into three categories: structured, unstructured and semi-structured interview. A structured interview is a kind of interview with predetermined list of questions which the researcher cannot influence the discussion which are not related to the research objectives while the unstructured interview can be described as a kind of conversation between a participant and the researcher without a predetermined list of questions relating to the research questions. The semi-structured and structured interviews are alike and have a list of pre-determined objectives questions directed to the respondent and the responses are tape recorded in a standard schedule. Creswell (2009) stated that interview data collection can be collected either by recording the conversation or by taking notes.

This research adopted a semi-structured interview utilising questionnaire as the research instrument to collect information data based on the research questions and the objectives. The reason is to allow good interaction between the participants and the researcher in order to have robust access to information as recommended by Creswell (2013).

4.5.2.2 Sampling Method for Semi-Structured Interviews

The semi-structured interview sampling was selected through purposive sampling of Fifteen (15) numbers population comprising of Eight (8) blockwork craft gang's, Three (3) project managers, Two (2) site managers and Two (2) site supervisors executing the projects based on their approachability and readiness to participate as supported by Lingayas (2012).

4.5.2.3 Interview Questions

Collis and Hussey, (2009) stated that questionnaires for an interview can comprise of open-ended or close questions to allow for flexibility response where the participant can make a choice of answers from the predetermined list of questions. Open and closed questions were used in this research study in order to allow participants express their views and insights on the specific questions arising from the research objectives and for the purpose of comparative data analysis. Cooper and Schindler (2010) noted that the factors that influence the use of open and closed questions comprise the requirement to categorise participants on some stated opinion.

The questions were arranged commencing with the demographic information, broad to more precise questions. The questions comprises of four sections. The first section is designed to gather information on the demography. The questions in the demographic comprise of the participant organisation whether is a multinational or national firm and the years of experience.

The second section concerned blockwork craft gang's prior learning and development. These questions included the participant thought about gang's learning importance and the types of prior learning of the various craft gang's in their firm. The third section asked questions on the production environment the craft gang's need to respond to in order to optimise productivity. The fourth section concerned the mechanism's the craft gangs used to respond to the project-specific constraints in order to optimise productivity.

The choice of words for the questionnaires should reflect the common language usage of the participants which was English Language. The questions length and

the time required for interview were all taken into consideration including the style and order of presentation of questions. Design, layout and wording of the questionnaire were all carefully considered.

4.5.2.4 Interview Procedures

The interview was conducted in the Federal Capital Territory Abuja Nigeria from April to June 2016. It was conducted at the convenience of the respondents. The respondents granted the permission to tape record the interview and notes was taken by the researcher as the interview progressed in order to check the transcription of the recorded interview. The interviews were conducted during break periods at the respondents' site offices with durations ranging from forty-five minutes to one hour.

The researcher explained the process to be followed at the beginning of the interview with much emphasis laid on confidentiality of the responses of the interviewee.

4.6 Data Analysis Methodology

This section presents the method of data analysis used in the collected data information on the research questions. The statistical techniques were carefully selected to suit the research questions and the objectives of the study.

4.6.1 Quantitative Statistical Methods

Horner et al. (1989) stated that there are several factors that make up productivity and one of which is the project-specific constraints. The key aim of this study is to investigate how on-site blockwork craft gang's learning impacts productivity within the production environment and how the craft gang's deal with the inevitable problems that arise on-site in order to optimise their productivity. In the observed activity within blockwork craft gang's, several relevant constraints impact the craft gangs' output concurrently. The gross influence on the gangs performance might be the sum of the total partial impact of the whole significant constraints. However, it is important to employ a suitable method of data analysis in order to evaluate the relative effect of each constraint on blockwork craft

gang's performance, the researcher employed the use of the least squares method which is also referred to as method of linear regression in the preliminary statistical analysis of the quantitative aspect of the study.

Research studies conducted by Jarkas (2005) has supported that the "ordinary least squares technique provides a linear model which yields the least average forecasting error, and therefore, provides the best fit to the data points."

In this study investigation, the observed times recorded for the labour productivity are the dependent variable while the cycle numbers are the independent variables. Previous studies have acknowledged that "when there is only one independent variable, the model is determined through simple linear regression and if there are two or more independent variables, the model is termed multiple linear regressions" (Jarkas, 2010; Sincich, Levine, & Stephan, 2002). The general form of the model is expressed thus:

$$Y = B_0 + b_1 \times_1 + b_2 \times_2 + b_3 \times_3 + \cdots + B_k \times_k + \in \ \ldots (4.1)$$

Y = is the variable that is dependent; Bo = the intercept; where bi represent the coefficients of regression, i = 1, 2, k; and $\in = error\ or\ residual\ term.$

The equation for the prediction model is presented as:

$$\hat{Y} = b_0 + b_1 b \times_1 + b_2 \times_2 + b_3 \times_3 + \cdots + b_k \times_k \quad \ldots (4.2)$$

Where "Y = the predicted value of Y, also referred to as Y that; bo = the value of Y ̂when all the Xi values are zero; bi = the measure of rate of change in Y per unit change in Xi or the regression coefficient, holding all other variables in the model constant, regression equations such as represented above, with no interaction terms between independent variables, are called main effects models" (Jarkas, 2005; Voujae, 1989).

4.6.1.1 Statistical Significance Tests

Significance tests are conducted in order to determine the reliability of regression relationships. Jarkas, (2005) defining statistical significance said that it signifies "the probability that a relationship found in the data is attributable to chance or

random errors, the chance of concluding that there is a relationship when there is none is referred to as type I error." Researchers control the probability of occurrence of such type of error. Jarkas (2005) stated that "probability of making type I error is called the level of significance and denoted by the symbol α." As the chances of the conclusions being reliable increases, the higher the probability of the significance level making type II error; conclusion being that there is no correlation when there is, thereby declining the power of the test.

Jarkas, (2005,2010) and Voujae, (1989) stated that in most research study subject to the significant of the objectives, the importance level varies from 0.01 to 0.10 established on numerous prior productivity researches. In this study 0.05, significance level was carefully chosen as a satisfactory degree of the inferences reliability and was used in the quantitative part of this study. Jarkas 2005 and Sincich et al. (2002) listed the following parameters that are used to measure the statistical significance in regression models: "Coefficient of correlation (R), Coefficient of determination (R^2), Standard error (SE), Degrees of freedom (OF), F-ratio, T-statistic, P-value and Variance inflation factor (VIF)"

Sincich et al. (2002) observed that the "strength of linear relationship between the dependent and independent variables in the regression model is measured by the correlation coefficient, the coefficient of determination indicates the percentage variance in the dependent variable which can be explained by the independent variables of the model." From the study, the correlation coefficient and determination are used to determine the experiments of goodness of fit, which defines the relationship between the data and the linear regression model. The higher the correlation coefficients in the regression model, the better the fit goodness (Sincich et al., 2002).

The investigation conducted by Jarkas (2005) stated that "generally, the standard error is a measure of the sampling error, in regression analysis and there are two estimates of standard error: the standard error of the regression model, and the standard error of the estimated coefficients." The research carried out by Sincich et al. (2002) noted that the degree of freedom mainly represents the value of number that are free to vary, it also described the available number of estimation

and it is very important in regression analysis. The F-ratio is a statistical test that is used to determine the regression model suitability and the suitability depends on the degree of freedom and the size of the sample. The research conducted by Sincich et al. (2002) observed that "the magnitude of the F-ratio determines whether any of the estimated regression coefficients are significantly different from zero, an F-ratio greater than 1 indicates that at least one regression coefficient in the model is significantly different from zero and that the overall regression model is useful for determining the dependent variable".

The p-value stands for the probability of calculating a t-statistic value that is greater than or equals to (in absolute value) the actually computed t-statistic. The lesser the p-value the better the degree of divergence among the data and it means the more significant the outcome becomes. Generally, if the p-value is lesser than the importance level α, we discard the theory (Jarkas, 2005; Sincich et al, 2002).

An investigation conducted by Jarkas (2005) noted that "the variance inflation factor (VIF), is used in regression analysis to assess the multicollinearity amongst the independent variables when the independent variables are highly correlated with one another, as mentioned previously, the standard error for the regression coefficients becomes inflated, thus undermining the reliability of the estimates." However, according to Sincich et al. (2002) "there has not been any agreement on a formal cut-off value to be used with VIF exceeding 10% are often regarded as indicating multicollinearity". Jarkas (2005) and Sincich et al. (2002) are in agreement, stating that "if strongly correlated independent variables are redundant, an effective procedure to minimise multicollinearity in regression is to drop the strongly correlated independent variables in the model."

4.6.1.2 Standardized Coefficients of Regression

In evaluating and determining the statistical importance of the coefficients of regression, Jarkas (2005) noted that "it is important to examine the comparative significance and effect of the independent variables on the dependent variable. The study also, stated that a multiple regression model may include numerous independent variables having dissimilar units of measurement and therefore,

direct association of the size of various coefficients is an important reason that assessing their relative influence on the dependent variable could be spurious."

Sincich et al. (2002) stated that "the standardised regression coefficients are measured on the same scale, with a mean of zero and a standard deviation of one, and therefore are directly comparable to one another with the largest coefficient in absolute value indicating the greatest influence on the dependent variable." The formula normally used in standardised regression coefficient is as follow:

$$b_k * = \binom{Sk}{Sy} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.3)$$

In equation 4.3: "bk• = standardised regression coefficient of the kth independent variable; bk = regression coefficient of the kth independent variable; Sk = standard deviation of the kth independent variable; and Sy = standard deviation of the dependent variable. Commonly, standardised regression coefficients are referred to as beta weights" (Sincich et al., 2002).

The predictive regression models in this research investigation for the observed blockwork craft gang's activities were developed using the dependent variable as the craft gangs blockwork recorded time labour productivity. PHStat software (Microsoft Excel statistics add-in) was used in all analyses of the regression conducted. The steps used in the analyses are as follows: firstly, the parameters of the regression model were quantified in order to determine that the basic assumptions of the regression model were not violated. Secondly, the researcher conducted statistical tests to evaluate the main importance of the models and also to determine the usefulness of the results. In reporting the result, the standardised regression correlation coefficients and coefficient of determination of the independent variables determined in order to evaluate their relationship with the effect on the dependent variable and lastly, the learning curve for each of the blockwork craft gang productivity was determined.

4.6.1.3 Quantitative Data Coding System

Each blockwork craft gang investigated was allocated with a set of unique number. The aim of this code was to determine the on-site craft gang observed in

the study project for the purpose of the analyses of the research data. The code begins with the year the observation was conducted represented with the last two digits and next is assigning the project numbers. For instance, if an on-site craft gang has 1601 as the number, it means that on-site craft gang was observed in the year 2016 and was allocated number 1. This explains the year in that the study investigation was carried out and its number it's automatically determine. Arising from this simple principle, if an on-site craft gang project has the number 1606, it means that this on-site craft gang observed in the project was investigated in the year 2016 and was allocated unique number 06.

4.6.2 Qualitative Data Analysis

Saunders et al. (2012) stated that "qualitative data depend on the research questions and are subjective in the analysis." Their study noted that "there are many analytical techniques, however, the method involves disaggregating the numerous information data into important portions or categories and this permits reorganisation and analysis of the data in a systematic and rigorous manner". In the qualitative analysis of this research, the collected data from notes and transcripts were reread in order to determine the similarity and drawing conclusions.

Immediately each interview was completed, the analysis will commence in order to preserve the participants' opinions and perceptions fresh and with the focus on the problem of the research. The audio recorded interviews were transliterated and notes are written in the English language for analysis. Additionally, research diary and summaries were used to support in appreciating the flow of the data.

According to Easterby-Smith et al. (2012) "interviews should be placed to allow sufficient time for administration and to think about the data, analyses and explore some issues." In the conversation, each participant spent between forty-five minutes to one hour per working day over the period of the months, there was enough time to reason about each interview transcription in detail.

The interview transcripts were read again in order to have a meaning on the result collected during the interview stage and was analysed via content analysis, an

objective and systematic form of data analysis applicable to analysing data such as semi-structured interviews (Creswell, 2013). Computer-assisted content analysis via NVivo computer software was also used to aid the analysis. Content analysis is a systematic data analysis technique that collates valid inferences from texts into fewer content groups based on explicit guidelines of coding and themes (Hasbollah, 2014). Saunders et al. (2003) stated that "qualitative data can be assessed quantitatively using frequency of given events to display a large amount of themed data." This method of description and presentations in the qualitative data provided a suitable method for analysing the project-specific constraints in the research question.

4.6.2.1 Interview Data Coding System

The participant interviewed was allocated a distinctive set of numbers. The reason for this numbers was to determine the participant interviewed in the project in the analysis phase of this research. The number begins with the participant given as P, followed by the participant assigned number. For instance, if a participant is allocated with number P01, it means that P is the participant interviewed and was given the number 01. That way, the participant and its number are automatically determined. From this explanation, if a participant is allocated with the number P20, it can be concluded that this participant interviewed was given the number 20.

4.7 Unit of Analysis

The unit of analysis explained the case under investigation, which could be individuals, functional groups, organisations, institutions, communities, relationships, movements and countries (Neuman, 2006; Yin, 2012). The study unit of analysis is the productivity and learning effect of gangs of block layers. These gangs were selected from the on-going FCDA project in Abuja, Nigeria.

4.8 Validity

Dudwick et al. (2006) observed that in qualitative and quantitative research, "objectivity and accuracy forms the central themes in producing a reliable study,

therefore, poorly designed and executed research procedure is likely going to compromise the validity and findings of a study." Bearing this in mind, different components of the interview questions and observation sheet in this research were presented and analysed with clarity and logic. In addition, Dudwick et al. (2006) stated that "the ability to replicate a study is considered pertinent in a research: however, they argue further that replicating the study conducted faces challenges because aspects of the field interaction, social contexts and research-participant exchanges can hardly be replicated."

In agreement with the above argument, Creswell (2013) listed the following methods that can improve research validity as triangulation, evidence disconfirming, and reflexivity of research, checking Member, collaborating, and trail audit, description of thick and rich and debriefing of Peer.

Validity threats were abated by triangulation of data collected from various multiple sources from the interview and observation study. In this study participant's information were triangulated by searching for various sources of data in order to evaluate points of convergence through a systematic process.

4.9 Reliability

This research adopted a standard observation sheet for work measurement and reflexive approach in the interviewee by assessing the project-specific constraints the blockwork craft gangs may need to respond to, in order to optimise their productivity. The opinions of the participants' were likened with the researcher's notes in order to maintain accuracy. According to Neuman (2006) "reliability depends on a researcher's insight, awareness, suspicion and questions". In order to uphold accuracy and fairness, the transliterated data from the interview was reread and participants' straight quotations were contained within the analysis and the report discussion section. The reason is to emphasise on the exact words of the participants and this was also, integrated into the analytical texts.

4.10 Confidentiality

In order to attain confidentiality, the participants were continuously reassured that the collected information in the research investigation will not be made available to a third party. The state of affairs in the FCDA projects, Nigeria demands privacy as the Agency is complex. In view of this, the information data collected were protected with different codes for the purpose of anonymity of participants' confidentiality of data. It is significant to note that the number connection to the codes does not represent any form of data collection procedures.

4.11 Generalizability

The constraints related to how on-site blockwork gang's prior learning impacts productivity within a project-specific production environment and how the gang's deal with constraints and inevitable problems that arise on a site is specific and it concentrates on a particular selected craft gang's operations in Nigeria. The mechanism for resolving these constraints can also be generalized as was established in the review of the literature. However, the complication of the constraints calls for a multidimensional solution. Consequently, the methodological techniques and the method used, was intended for providing non-generalizable result.

4.12 Bias

Leedy and Ormrod (2013) defined bias as "any impact, condition or set of conditions that singly or together distort the data from what may have been obtained under the conditions of pure chance". The descriptive research is predominantly subject to bias. Every effort was made to eliminate the likelihood of biased data, although the possibilities of bias data are acknowledged. The aspects that contributed to bias include the following:

1. Variation in sample population- the ratio of project managers, supervisors and the craft gangs on the construction site.
2. Poor attitude towards learning and research on the part of some participants.

3. The possibility that participants may not divulge information, and
4. Non-response.

To reduce bias in the study, seven blockwork craft gang's on a single construction project sites were selected for multiple observations as supported by Yin (2012) in order to obtain at least 95% participants.

4.13 Ethical considerations

In this study, the researcher maintained equilibrium ethics values of non-interference between the lives of the investigation and the progressing knowledge Neuman (2006) stated that "the ethical issues are the concerns, dilemmas, and conflicts about the proper way to conduct social research". Researchers often explore the private spaces of their research subjects. As noted by Newman (2006) "without a careful research design, any research methods have the potential to cause physical harm, discomfort, pain, embarrassment, or loss of privacy to the research subjects". Since the aim of this research is to investigate the influence of on-site craft gang's prior learning in the optimisation of construction productivity, the following ethical issues were considered:

- All research was done according to the Human Research Ethics policy of the University of Witwatersrand ethics clearance protocol number: H16/02/34 attached in appendix E.
- All participants were given the consent letter and participant information sheet, participation was voluntary and anonymous as contained in the attached observation and interview consent form and participant information sheet in appendix F, G, H and I.
- Data was kept confidentially and was only accessible to the researcher and the supervisor.
- The interviews were tape recorded and interviewers can withdraw at any time.
- In reporting, all project and team were made anonymous.

4.14 Summary of Chapter

This section presents the research methodology, the paradigm and the techniques used in data collection for the study. The study aim is to investigate how on-site blockwork craft gang's learning impacts productivity within a project-specific environment and how the craft gang's deal with the inevitable problems that arise on-site in order to optimise the productivity. The study adopted a mixed method research. A mixed research approach minimises the influence of personal bias and maximises the research validity (Henn et al., 2006). This technique allowed a methodological process in the interests of combining quantitative and qualitative research pragmatically, purposely to compensate the paradigmatic shortcomings in the two approaches (Flick, 2011).

The various data collection strategies used in this study included interviews and observation work study. The interview method of collection of data comprised of semi-structured interviews in order to collect rich information from variables which are required to be discovered in depth. A purposeful sampling method was adopted to select the projects, managers, supervisors and the blockwork craft gangs executing the projects based on their convenience and readiness to contribute for the semi-structured interview. A standard observation form was used in all craft gang's blockwork observed within the project sites. The aim of the form was for essential and regularly recording of the productivity time output and the related inputs for the various observed blockwork craft gangs, and to ascertain the actual site conditions during the observation. The forms were designed carefully to include various relevant information relating to the research questions. A purposeful sampling method was adopted to select the craft gangs working on the projects. The sample criteria were tenure blockwork craft gangs.

Since a project site with multiple blockwork gangs was observed simultaneously, the project comprises of an office buildings headquarter located in the Federal Capital Territory (FCT), Abuja, Nigeria. The 17-Storey building was awarded for a cost of N39.2 Billion (Approximately $245 million). The office building is a tri-tower building and when completed, it will stand 86 meters high (excluding the height of its communications mast), it will have a basement and a 15-storey

parking structure. The method of construction of blockwork regardless of the type of craft gangs' blockwork observed were similar design and system exists at all the blockwork construction operations. The building of foundation and super-structural blockwork element involves seven stages. The next chapter discussed the data presentation and analysis method.

CHAPTER 5

5.0 DATA PRESENTATION AND ANALYSIS

5.1 Interview Data Analysis

The data analysis section presents the findings from the analysis of the data in relation to the research questions. 15 interviews were conducted with Project Managers, Site Managers, Engineers, Supervisors, and the blockwork Craft Gangs laying the blocks from Multinational and National Construction Firms handling the Federal Capital Development Authority (FCDA) Projects in Nigeria. The interviews were designed to identify the project-specific constraints blockwork craft gangs may need to respond to, in order to optimise their productivity and the relationship between the responses of blockwork craft gangs to specific project-based factors.

In the first section of the analysis, the information regarding participants demographic and details of the organisations block layers craft gang's prior learning and the participants' views on the project specific constraints that influence the craft gangs learning outcomes and also, their views on the successful mechanism used in resolving the project specific issues were discussed. The findings from the interviews were presented using a descriptive analysis and frequency distribution and where applicable, quotes from the interviewees were incorporated to demonstrate relevant views.

5.1.1 Participants

This section explained each of the research participant organisations and collected demographic data on the research study participants as presented in Table 5.1 profile of participants and their years of experience.

Table 5.1: Profile of Participant

Participant	Position	Years of Experience
P1	Project Manager	7
P2	Site Engineer	13
P3	Project Manager	29
P4	Blockwork Craft gang members	8
P5	Project Manager	4
P6	Blockwork Craft gang members	5
P7	Blockwork Craft gang members	3
P8	Blockwork Craft gang members	6
P9	Blockwork Craft gang members	8
P10	Assistant Manager	6
P11	Blockwork Craft gang members	10
P12	Supervisor	2
P13	Blockwork Craft gang members	4
P14	Blockwork Craft gang members	5
P15	Supervisor	25

Demographic information was collected on the participant years of experience and position as represented in Table 5.2 and 3

Table 5.2: Participant Demographic

Years of Experience	Number	Percentage (%)
0-5	6	40
6-10	6	40
11-15	1	6.66
16-20	0	0
21-25	1	6.66
26 and above	1	6.66
Total	**15**	**100**

Table 5.3: Participant Demographic position

Position	Number	Percentage (%)
Project Managers	3	20
Site Managers	1	7
Site Engineers	1	7
Supervisors	2	13
Craft gang members	8	53
Total	**15**	**100**

The context of this research study participants reveals that the construction firms they represent are diverse, representative of various construction companies. The firms were medium and large, ranging up from 60 to 750 employees. The interviewees were responsible for their firms' on-site craft gangs blockwork and their years of experience, in general, indicated considerable knowledge in their occupation and understanding of the project specific constraints influencing the learning of on-site craft gangs productivity in the construction industry.

5.1.2 Constraints Influencing Blockwork Craft Gangs Productivity

Using qualitative analysis techniques, the project-specific factors were identified and organised into a tabular format, as shown in Table 5.4. The interview transcriptions were re-read to reinterpret the result collected during the interview stage and was analysed via content analysis. Computer-assisted content analysis via NVivo computer software was also used to aid this analysis.

Table 5.4 illustrates the craft gangs' interview opinion on the project-specific constraints they need to respond to, in order to optimise their productivity. The transcripts were analysed via content analysis with a computer-assisted content analysis via NVivo computer software and the results are tabulated below:

Table 5.4: Blockwork Craft Gangs Project Specific Constraints

NODES /CLASSIFICATION	P4	P6	P7	P8	P9	P11	P12	P13	P14	Frequency
Motivation related Factors										
Promotions	✓			✓	✓	✓	✓		✓	6
Staff Housing				✓			✓		✓	3
Job Security					✓		✓		✓	3
Lunch and Breaks		✓		✓						2
Payment delay		✓	✓	✓	✓			✓	✓	6
Bonus motivation	✓			✓		✓			✓	4
Workers recognition programs				✓				✓	✓	3
Non-provision of transport	✓			✓	✓	✓			✓	5
Places for eating		✓			✓	✓		✓	✓	5
Workers related Factors										
Lack of skilled/ experience		✓	✓	✓	✓	✓				5
Level of Education	✓			✓		✓				3
Rework	✓			✓		✓				3
Workers' dissatisfaction				✓					✓	2
Misunderstanding among labour				✓		✓		✓	✓	4
Competition among workers				✓	✓					2
Increase in workers' age		✓		✓	✓	✓		✓	✓	6
Craft workers personal problems		✓				✓		✓	✓	4

NODES /CLASSIFICATION	P4	P6	P7	P8	P9	P11	P12	P13	P14	Frequency
Alcoholism and drug abuse					✓					1
Workers disputes (e.g. industrial action)				✓	✓					2
Attendance to social functions				✓	✓	✓	✓	✓		5
Workers' pride in their work						✓				1
Lack of tools and equipment training			✓	✓		✓		✓		4
Project related factors										
Working in a confined space				✓		✓	✓	✓		4
Interference from supervisors				✓	✓					2
Construction method	✓		✓		✓	✓	✓			5
Delay in material availability	✓	✓	✓			✓	✓		✓	6
Poor material quality					✓					1
Drawing errors	✓							✓		2
Non availability of drawings					✓					1
Drawing illegibility	✓									1
Stoppages due to disputes with owners/consultants	✓			✓				✓		3
High quality works										

NODES /CLASSIFICATION	P4	P6	P7	P8	P9	P11	P12	P13	P14	Frequency
Inspections delay					✓	✓				2
Specification and standardisation	✓				✓			✓	✓	4
Working overtime				✓			✓	✓	✓	4
Environmental factors										
Different languages spoken		✓	✓		✓					3
Youth interference	✓							✓		2
Cultural differences	✓	✓		✓						3
Disruption of power/water	✓		✓							2
Health & Safety Factors										
Accidents at work sites						✓		✓		2
Health and safety resources	✓	✓	✓	✓	✓				✓	6
Poor health condition	✓	✓		✓		✓	✓	✓	✓	7

Table 5.4 represents the management interviews personal views on the project-specific constraints the craft gangs needed to respond to, in order to optimise their productivity. The transcripts were analysed via content analysis with a computer-assisted content analysis via NVivo computer software and the results are tabulated above (Table 5.4).

Table 5.5: Management Project-Specific Constraints

NODES /CLASSIFICATION	P1	P2	P3	P5	P10	P12	P15	Frequency
Motivation related Factors								
Promotions	✓	✓	✓	✓	✓	✓	✓	7
Staff Housing	✓		✓			✓		3
Job Security	✓	✓	✓		✓	✓	✓	6
Lunch and Breaks	✓							1
Payment delay	✓		✓		✓		✓	4
Bonus motivation	✓	✓	✓	✓	✓			5
Workers recognition programs		✓	✓					2
Non-provision of transport		✓			✓		✓	3
Places for eating	✓	✓	✓	✓	✓		✓	6
Workers related Factors								
Lack of skilled/ experience	✓						✓	2
Level of Education	✓	✓	✓	✓	✓			5
Rework		✓	✓	✓	✓			4
Workers dissatisfaction with their work		✓						1
Misunderstanding among labour	✓	✓		✓	✓			4
Competition among workers	✓	✓		✓	✓		✓	5
Increase in workers age	✓	✓		✓	✓		✓	5
workers personal problems		✓	✓	✓	✓			4
Alcoholism and drug abuse	✓		✓	✓			✓	4
Workers disputes (e.g. industrial action)			✓	✓	✓		✓	4

NODES /CLASSIFICATION	P1	P2	P3	P5	P10	P12	P15	Frequency
Attendance to social functions	✓		✓	✓	✓	✓	✓	6
Craft workers' pride in their work	✓		✓	✓	✓			4
Lack of tools and equipment training	✓	✓		✓				3
Project Management factors								
Working in a confined space	✓	✓		✓	✓	✓		5
Interference from supervisors			✓				✓	2
Construction method	✓	✓	✓	✓		✓	✓	6
Delay in material availability	✓	✓	✓		✓	✓	✓	6
Poor material quality	✓						✓	2
Drawing errors	✓		✓		✓			3
Non availability of drawings	✓						✓	2
Drawing illegibility					✓			1
Stoppages due to disputes with owners/consultants	✓	✓			✓			3
Design complexity	✓		✓		✓			3
Inspections delay	✓	✓	✓		✓		✓	5
Specification and standardisation		✓	✓		✓		✓	4
Working overtime	✓		✓		✓	✓		4
Environmental factors								
Different languages spoken	✓				✓		✓	3

NODES /CLASSIFICATION	P1	P2	P3	P5	P10	P12	P15	Frequency
Political insecurity (e.g. insurgency)	✓		✓					2
Youth interference	✓							1
Cultural differences	✓							1
Disruption of power/water	✓		✓					2
Health & Safety Factors								
Accidents at work sites	✓	✓	✓		✓			4
Health and safety resources	✓						✓	2
Poor health condition of workers'	✓	✓	✓	✓	✓	✓		6
Hot weather conditions			✓					1

The combined interview opinion of the blockwork craft gangs and the management on the project-specific constraints the craft gangs needed to respond to, in order to optimise their productivity was transcribed. The transcripts were analysed via content analysis with a computer-assisted content analysis via NVivo computer software and the results are presented in a tabular form. The combined opinions of all the project-specific constraints, clearly show the constraints with the highest frequency that the craft gangs (block layers) needed to respond to, in order to optimise their productivity as presented in Table 5.6 below.

Table 5.6: Combine (Craft Gangs & Management) Project Specific Constraints

NODES /CLASSIFICATION	INTERVIEWS SOURCE P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	Frequency	Rank
Promotions	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓		✓	✓	12	1
Poor health condition of workers	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓		12	1
Delay in material availability	✓	✓	✓	✓		✓	✓			✓	✓	✓		✓	✓	11	3
Places for eating	✓	✓	✓		✓	✓			✓	✓	✓		✓	✓	✓	11	3
Increase in workers' age	✓	✓			✓	✓		✓	✓	✓	✓		✓	✓	✓	11	3
Payment delay	✓		✓			✓	✓	✓	✓	✓			✓	✓	✓	10	6
Attendance to social functions	✓		✓		✓			✓	✓	✓	✓	✓	✓		✓	10	6
Construction method	✓	✓	✓	✓	✓		✓		✓		✓	✓			✓	10	6
Bonus motivation	✓	✓	✓	✓	✓			✓		✓	✓			✓		9	9
Non provision of transport		✓		✓				✓	✓	✓	✓			✓	✓	8	10
Misunderstanding among labour	✓	✓			✓			✓		✓	✓		✓	✓		8	10
Workers' personal problems		✓	✓		✓	✓				✓	✓		✓	✓		8	10
Confined space	✓	✓			✓			✓		✓	✓	✓	✓			8	10

NODES /CLASSIFICATION	INTERVIEWS SOURCE P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	Frequency	Rank
Health and safety resources	✓			✓		✓	✓	✓	✓					✓	✓	8	10
Specification and standardisation		✓	✓	✓					✓	✓			✓	✓	✓	8	10
Job Security	✓	✓	✓						✓	✓		✓		✓	✓	8	10
Level of education	✓	✓	✓	✓	✓			✓		✓	✓					8	10
Lack of skilled/ experience	✓					✓	✓	✓	✓		✓				✓	7	18
Rework		✓	✓	✓	✓			✓		✓	✓					7	18
Competition among workers	✓	✓			✓			✓	✓	✓					✓	7	18

The interviews of the craft gangs and the management on the project-specific constraints the craft gangs needed to respond to, in order to optimise their productivity were transcribed. The transcripts was analysed via content analysis with a computer-assisted content analysis via NVivo computer software and the results are presented in Table 5.6. The combined opinions of all the project-specific constraints clearly show the level of constraints with the highest frequency and rank that the craft gangs (block layers) needed to respond to, in order to optimise their productivity as listed below:

1. Promotions
2. Poor health condition of workers
3. Delay in material availability
4. Places for eating
5. Increase in workers age
6. Payment delay
7. Attendance to social functions
8. Construction method
9. Bonus motivation
10. Non-provision of transport
11. Misunderstanding among labourers
12. Workers personal problems
13. Working in confined space
14. Health and safety resources
15. Specification and standardisation
16. Job security
17. Level of education
18. Lack of skilled/ experience
19. Rework
20. Competition among workers

5.2 Responses Mechanisms to the Project-Specific Constraints

Using the interview analysis techniques outlined earlier in chapter 4, the interview transcripts were re-read to reinterpret the results collected during the interview stage and were analysed via content analysis. Computer-assisted content analysis via NVivo computer software was also used to aid the analysis and the relationship between the response of the blockwork craft gangs and the key project- specific based constraints are detailed below.

The participants were asked to identify the mechanisms which their craft gangs use to resolve the various skill issues such as unskilled/inexperienced workers, the level of education, rework, and competition among workers, increase in age, alcoholism, workers pride and labourers' disputes in order to optimise productivity in their work. Table 5.7 represents the blockwork craft gangs skill issues and the response mechanisms.

Table 5.7: Blockwork Skill Challenges and Response Mechanisms

Participant	Issues	Responses Mechanisms
P01	Inexperienced Workers	*We have experience people that work marvellously and the ones that are not experienced, what we do is to mix them up so that the new workers we learn from the experienced once, the method of our construction.*
P10	Inexperienced Workers	*About 98% of the blockwork gangs are below average when it concerns their skilled knowledge about our company's method statement, so when they are employed, they have to learn afresh. So it requires constant supervision especially during the early week's commencement of work.*
P11	Inexperienced Workers	*Most times when we see that a worker is not skilled, in the new job, we train him by pairing him with a gang that is mixed with old skilled workers in order for them to learn as a gang and this method has been helping us to meet our goals.*
P12	Inexperienced Worker	*We always advise our workers during inductions to follow up construction method instruction, it is very helpful.*
P02	Inexperienced Worker	*When we have issue of inexperience worker we resolve this, by reshuffling the craft gangs by including at least one experienced worker among the gangs.*
P03	Inexperienced Worker	*On the issue of experience of workers, it's a mix of experienced people and we can guess that experienced people are younger.*

Participant	Issues	Responses Mechanisms
P05	Inexperienced Worker	*Most times when we see a worker is not skilled, to resolve this, we reshuffle the gangs by putting at least one experienced worker among a gang.*
P09	Inexperienced Worker	*At the beginning of every project, we have craft gangs that are inexperienced, however, they learn from other experienced workers and they have improved their skills.*
P10	Inability to Read and Understand the Method Statement	*The mechanism we adopt to resolve the issue when some craftsmen are not literate to read understand or not being able to interpret the method statements, we train them. When training them, the trainer has to come down to their level of understanding and avoid using ambiguous terms.*
P03	Inability to Read and Understand the Method Statement	*For workers generally, we make sure that they receive education for the practice of crafts gang on site. There is a specific school here for Masonry and others. But generally, for projects we find educated people with experience to handle the work together with inexperienced people. It's always a mix.*
P03	Rework	*Reworking has to do with quality and we have a quality plan. Our quality plan presents the full work and how is to be done and if not done according to plan, it might need reworking. Also, on this issue of rework, sometimes yes but we comply with such issues. In our firm, we have procedures and quality system that says whether what you are doing is right or wrong; so everyone has to follow the system policy.*

Participant	Issues	Responses Mechanisms
P05	Rework	*On the issue of rework, if the rework is arising from site instruction from the consultants, the client bears the cost.*
P03	Alcohols and Drugs	*Alcohols and drugs are fully forbidden on site and in the office. If we observe odd behaviour, we have policies that address that issue.*
P09	Alcohols and Drugs	*Some workers take alcohol and drugs, and there are suspended if noticed and penalty goes without pay.*
P11	Misunderstanding Between Blockwork gangs	*In the event of misunderstanding between these labourers, it is the duty of the foreman, to resolve their differences. However, the company has rules that address such issues.*
P13	Misunderstanding between blockwork gangs	*When there is a misunderstanding between these labourers, the supervisor calls them to order and instruct them on what to do.*
P14	Blockwork gangs Personal Problem	*If there is labourer's personal problem, the worker is expected to go to their sectional heads, who advises on the best action to avoid workers having injuries due to over thinking.*
P15	Blockwork gangs Disloyalty	*In the event of workers being disloyal due to them not being happy with their jobs, they would have to meet their sectional heads to resolves it.*
P03	Labour Disputes	*On the issue of labour disputes, we just observed national warning strike but it was not caused by our project, it was a national issue and we have a union in our company. The union representatives, represent the workers and the issues are resolved.*

Participant	Issues	Responses Mechanisms
P09	Misunderstanding Among blockwork gangs	*When there is a misunderstanding among gangs, the foreman resolves the issue.*
P15	Blockwork gangs Disputes	*We've not experienced total stoppage apart from the National industrial action when we were asked to stop work and it was resolved at the National level.*
P10	Workers Personal Problem	*Every worker is entitled to a 5 days casual leave which is not part of their annual leave, so this would cover for such days where a worker wants to attend a social function and personal issues.*
P11	Workers' Personal Problem	*In the event of labourer's personal problem, if the workers apply for personal loans it can be granted for example: In the event of workers wanting to attend social functions, the worker can apply for casual leave and if consider it will be granted.*
P13	Workers' Personal Problem	*In the case of workers wanting to attend social functions, there are advised to apply for casual leave and it will be approved.*
P14	Workers Personal Problem	*Workers wanting to attend social functions are advised to apply for casual leave.*
P15	Workers Personal Problem	*There are issues of workers personal problems, the worker is permitted to address such issue by applying for casual leave if the workers want to attend social functions.*
P02	Workers Personal Problem	*In the case of workers' personal problem, the worker can take a casual leave but there is no financial attachment except he applies for advanced payment.*

Participant	Issues	Responses Mechanisms
P05	Workers Personal Problem	*When a worker is having a personal problem, the worker can apply for casual leave.*
P09	Workers Personal Problem	*A worker wanting to attend personal functions is accommodated here but it's not regular due to deceit from some of the craft gangs.*
P10	Craft Workers Pride	*We observed issue of craft workers pride because errors could arise due to refusal to obey instructions. If such errors are seen, pictures are taken and such a worker is cautioned by his supervisor, and if such continues, disciplinary measures are taken. Three verbal warnings are given to such a worker before a warning letter which goes into their files and sometimes could come with 2 days suspension without pay.*

5.2.1 Project Management Challenges and Response Mechanisms

The participants were asked on how they deal with project management issues such as confined space, drawing errors or unavailability of drawings/eligibility of the drawings complexity, specifications and standards, working overtime and disputes with owners or consultants. Table 5.8 illustrates the various ways of resolving project management related issues that were identified in the interviews.

Table 5.8: Project Management Challenges and Response Mechanisms.

Participant	Issues	Responses Mechanisms
P03	Working in Confined Space	*On this site, will deal with the issue of confined space because it causes a delay in the execution of work, we cannot bring much equipment and this is causing a tussle between consultants and contractor on the use of equipment. But we address this issue by planning a program for carrying out of certain works.*
P15	Working in Confined Space	*We arrange the site according to the way the site is, to address the issue of confined space.*
P02	Working in Confined Space	*This site is confined and there are no places to store materials coming into the site. We resolve this by engaging in extra time, where some workers would work during the break.*
P01	Problem of interpretation of drawings	*The company has few people with technical education. However, it's the responsibility of the engineer to interpret the drawings for the workers.*
P03	Issues of Drawing Errors and Eligibility of Drawings	*There are problems of drawing errors and also unavailability of drawings but because we are contractors we have to timely request for these drawings on time so that we can remedy the situation, in the case of eligibility of drawings, we have a printer plotter if the drawings are not eligible, we use the printer to enlarge the drawings.*
P10	Design Complexity	*We also experience design complexity most especially in the beams, the way with which they connect to the columns, the entrance canopy connection was not linked to the beams. We resolved it by having an interface meeting with the consultant.*

Participant	Issues	Responses Mechanisms
P10	Eligibility of the Drawings	*On the issue of eligibility of the drawings, we have a technical room where we can enlarge and print copies of the drawings. In the case of non-availability of drawings, we resolve it by calling for an interface meeting with the consultant and the client.*
P04	Eligibility of the Drawings	*Due to the large nature of this project, all the drawings cannot be compiled together at once, so when we get to a particular stage, we request for the detail drawings.*
P11	Issue of Construction Method	*We resolve the issue of construction method by ensuring that the workers follow up the method instruction as specified.*
P15	Issue of Construction Method	*The method of construction is not easy but we adhere to the work method statement.*
P03	Issue of Construction Method	*We have a method team or supervisors who visit the sites to make sure that the methods of construction are being implemented. If there is a problem, we have to make corrections if necessary specifically, the design is not done by us, it's done by consultants.*
P03	Issue of Construction Method	*When there are issues with method statement, we check with our method statement to know if it's there. The planning manager combines the programs and discusses the progress and there is a weekly, monthly and yearly review. If there is any specific condition we comply with it. The method statement affects the way the workers are working because if they want to exceed 3.5m and the work says 3.0m, they have to comply. It guides the operation and not the quality.*

Participant	Issues	Responses Mechanisms
P04	Issue of Construction Method	*Every construction company has its method of executing a job. Here, we identified the equipment's we are going to need and we acquired them to make the work easier. This building is divided into panels and at every section when we are ready to commence work we would seek for clarification and approvals.*
P01	Problem of Specification & Standards	*In order to minimise this problem of standards, I have realized that getting the correct pairing of craft gangs can help a lot and grouping the right people because the issue of compatibility is very important*
P02	Problem of Specification & Standards	*To ensure that we comply with the specification and quality standard, the supervisors have to carry out one or two training, but this sometimes slows down production.*
P01	Problem of Overtime	*When there is a demand to work overtime, we have a few people that work overtime. Especially, on weekends and the company pay overtime and also give them some incentive like off days.* Also, *for the staffs that work overtime on Saturdays and Sundays, they work a half day from 8-12 pm. The reason is to reduce stress and avoid diminishing returns.*
P03	Problem of Overtime	*Currently, we are set up now to work overtime due to the previous stoppage of work arising from the consultant before the installation of the lift. However, the workers will get remuneration for each hour they work overtime.*
P15	Problem of Overtime	*We have issues of overtime; however, we are also paid overtime according to the number of hours we put in.*

Participant	Issues	Responses Mechanisms
P03	Issue of Stoppage of Work Due to Disputes With Client/ Consultants	*In the event of stoppage of work due to disputes with owners or consultants which we experienced in the area of the lift installation because the consultants wanted the lift shop drawings in order to know the kind of material that was used in its construction. We had to speedily prepare the drawing and it was approved.*
P02	Disputes Between Owners and Consultant	*In the case of disputes between owners and consultant, we have to stop work and continued when it has been resolved.*
P08	Interference from Consultant	*Interference by supervising consultants affects the craft workers. These will resolve through induction learning by telling the workers to always take instruction from their supervisor.*

5.2.2 Environmental Challenges and Response Mechanisms

Participants acknowledged that they deal with issues such as language, religious, youth and community interference, power and water problems: According to the participants, these issues could affect the project if not managed accordingly. Table 5.9 outlines the environmental issues and the responses given.

Table 5.9: Environmental Challenges and Response Mechanisms

Participant	Issues	Response Mechanisms
P01	Language Issues	*We experienced language issues on a daily basis and it's very difficult to resolve. We make sure that the gangs understand each other when setting up a gang. Grouping them into like groups and gangs are helping to address this issue.*
P06	Language and religious Issues	*There are language and religious problem; however we group the gangs according to their language and we allow each other to observe their prayers time, like our Muslims workers.*
P08	Religious Issues	*We have cultural differences. The mechanism is by allowing like Muslim workers to always observe their prayers, especially during their fasting.*
P13	community and youth Interference	*We had issues with community and youth interference in our project because there was some economic tree on the land. This was resolved by adequate compensation from the client and also, the contractor compensated the youth.*
P04	community Interference and Religious Issues	*We experienced community interference at the beginning of the project when the indigenes of the community came asking for compensation. This was resolved by duly compensating the community. We also have religious issues with our Muslims workers. However, we maintain a harmonious way of organizing work such that we take into consideration issues like prayer time to accommodate the Muslims workers.*
P03	Problem of Water and Power	*During the inception stage, what we did was to drill a borehole and procure a 500 KVA generator and currently, the problem is resolved.*

5.2.3 Health and Safety Challenges and Response Mechanisms

The participants were asked what mechanisms they use to resolve workers health and safety related issues in order to optimise their productivity. The participants responded that they held strong opinions that they deal with these issues through gangs learning in their workplace. Tables 5.10 represent the health and safety issues and the responses mechanisms.

Table 5.10: Health and Safety Challenges and Response Mechanisms

Participant	Issues	Response Mechanisms
P10	Poor Health Condition of Workers	*There are issues of the health condition of workers and accidental issues: the company has certified nurses who are on-site to administer drugs on minor health cases, and on very serious cases the worker is referred to a hospital.*
P11	Poor Health Condition of Workers	*We resolve workers health problem with our health professionals in the clinic, they are the professionals that takes care of those issues.*
P12	Accidental Issues	*We have health professionals that treat the workers in the event of an accident and are given safety equipment's as preventive measures.*
P13	Accidental Issues	*If there is an accident on site; the engineers help to take the worker to the hospital. We have site clinic where minor health issues are been taken care off.*
P14	Health Condition of Workers	*There is a site Nurse and in the event, if the health case is severe, the worker is taken to a hospital for proper treatment. It is also a safety rule that any worker without PPE's won't be allowed to work on site.*
P03	Health Condition of Workers	*We run a site clinic that administers treatment and we also take statistics on a weekly or monthly basis, usually to make a possible correction if the effect is due to site condition. There is a lot of equipment deployed to the site that complies with both local and international standards. On this site, we have recorded two accidents; we have a policy on safeties that is to first investigate the cause and explain why it arises.*

Participant	Issues	Response Mechanisms
P04	Health Condition of Workers	*We've safety measures including safety boots, helmets to ensure that every person is safe. The Company has a first aid section, but if any person is sick beyond the site clinic treatment the person will be directed to the company recommended the hospital.*
P05	Safety Issues	*We give all workers induction on health issues every morning before the start of work in order to minimise the risk of an accident.*
P09	Health Condition of Workers	*There is a situation when there is poor health condition of workers. However, if observed by the HSO, The worker is first sent to the site clinic for first aid before sending the worker home for bed rest. The company gives the worker money for treatment. Also, the company provides training on safety measures every week although it is good it slows down the work productivity.*
P10	Accidental Issues	*We've one recorded accident, but we try to inform the workers on safety measures every week, we also have health and safety department responsible in ensuring for fumigation and disposal of waste are done without affecting the health of workers.*

5.2.4 Material Challenges and Response Mechanisms

The participants were asked what mechanism their craft gangs use to resolve materials issues such as materials delay, unavailability of materials and quality standard of materials in order to optimise productivity in their work. Tables 5.11 represent the materials issues and the responses mechanisms.

Table 5.11: Material Challenges and Response Mechanisms

Participant	Issues	Response Mechanisms
P01	Material delay	*The issue of delay in the material due to confined space on this site is to look at the site and know the quantity of materials needed and how long it takes to get the materials. If possible, you can increase the ordering time and let your expected productivity match the provided materials.*
P10	Material delay and quality of standard	*On this site, we resolve an issue of lack of materials, by requesting in bulk from the suppliers and daily supplies are made when needed. We also carry out testing of these materials in order to ensure the quality; we have a quality assurance department with a functional laboratory to test all the materials supplied.*
P11	Quality standard of materials	*Materials, when supplied, are always tested to meet the quality standard.*
P03	Quality standard of materials	*When we order for materials, we conduct a test on them to ensure that it meets the required quality standard before sending them to site.*
P04	Material delay	*In order to resolve our materials problems, we pay for the materials in bulk, however, we order for them when we need them on site.*
P07	Material delay	*We have issues of material delay because it slows down our work. This was resolved by planning through the production manager to supply us materials on time and currently, the crane first delivers our material before any other trade.*

5.3 Summary

The analysis of the chapter was presented in line with the research interviews. The interviews were designed to examine the project-specific constraints the blockwork craft gangs need to respond to, in order to optimise their productivity. This also included the mechanism used to resolve the project specific constraints influencing successful optimisation of construction productivity. The first section of the research analysis includes the following:

- Data on the participating organisation.
- Information on the participants demographic.
- Information of the firms blocklayers craft gangs prior learning and
- Participants' views on the project specific constraints that influence the craft gangs learning outcomes and also, their views on the successful mechanism used in resolving the project specific issues.

Using qualitative analysis techniques, the project-specific factors were identified and organised into a tabular format. The interview records were re-read to reinterpret the result collected during the interview stage and was analysed via content analysis. The findings were presented with descriptive analysis and frequency distribution and where applicable; quotes from the interviewees are incorporated to illustrate important viewpoints. The combined opinions of all the project-specific constraints clearly show the level of constraints with the highest frequency and rank that the craft gangs (block layers) needed to respond to, in order to optimise their productivity.

This chapter also discussed the response mechanisms which the craft gangs employed to resolve the project constraints such as skill issues, project management issues, environmental issues, health and safety related issues and materials issues in order to optimise productivity in their craft gangs work. The various issues and their response mechanisms were highlighted and discussed.

The next chapter discusses the observation data and includes its presentation and analysis.

CHAPTER 6

6.0 PRESENTATION AND ANALYSIS OF OBSERVED DATA

This chapter presents and analyses the observation data. The purpose is to examine the influence prior and on-site learning has in the optimisation of blockwork craft gangs' production optimisation. The linear regression method that is also referred to as the ordinary least squares method was used in the quantitative statistical analysis in this research.

6.1 Influence of On-site-Learning on the Blockwork Craft Gang's

In order to measure how prior and on-site learning assists blockwork craft gang's to deal with project specific constraints and optimise productivity, the participants were first asked about the types of prior learning/training their craft (block layers) gang's need in order to cope with the production environment on-site and maintain productivity and there were substantial comments on this theme as shown in Table 6.1.

Table 6.1: Blockwork Craft Gang's Prior Learning Observed

Craft Gang's No	No of Craft in a Gang			Prior Learning
	Skilled	Unskilled	Total	
1601	1	2	3	NABTECH (National Board of Technical Education), Induction and tool box
1602	1	2	3	Apprenticeship, Induction and Tool Box
1603	2	3	5	Apprenticeship, on the job learning, Induction and tool box
1604	2	2	4	Apprenticeship, Induction and tool box
1605	2	2	4	Trade test, Apprenticeship, Induction, tool box and on the job learning
1606	2	1	3	On the job learning, Induction and tool box
1607	2	2	4	On the job learning, Induction and tool box
Total	**12**	**14**	**26**	

6.2 Data presentation and Analysis of Blockwork Gang Productivity

This section presents the quantitative data and regression analysis for the blockwork craft gangs measurement of the impact and relative influence of on-site learning on the blockwork craft gang's productivity in the observed project site. Appendix J represents the details of the observed data.

The predictive regression model in the research observed activities in the blockwork craft gangs was developed using the observed recorded time craft gangs' productivity to represent the dependent variable. All the analysis conducted

on the regressions was calculated using the PHStat software, add-in statistics software that is normally used for Microsoft Excel. In the first step involves the quantification of the correlations of determination and coefficients models. The aim is to verify that all the basic assumptions of regression model were not violated with the regression method. Thereafter, a statistical test was conducted to examined and to the overall usefulness of the regression predictive models, and also, to assess the importance of the results. In addition, the aim of the result was to quantify the standardised regression model in order to calculate their relative impact on the dependent variable and finally, the productivity of the observed craft gang's rate of learning.

Appendix K1 to K14 represents the overall regression coefficients for the various blockwork craft gangs in the observed project. The simple linear regression technique was used to investigate the relationship between the cycle numbers of the repetitive work and the productive input.

The correlation coefficient is the relationship between the average difference in craft gangs blockwork productivity between first and repeated cycle numbers of blockwork. The negative sign represents that, the average, labour productivity of the first cycle is less than the labour productivity of the repeated cycles as presented in appendix K. It determines the strength of linear correlation relationship between the independent and dependent variables in the regression analysis.

Appendix K represents observed blockwork craft gangs correlation determination coefficient. It described the percentage of variance in the independent and the dependent variables of the analysis. The two coefficients (coefficients of correlation and determination) are tests used to determine the fit of goodness, this fit explains how well the relationship between the linear regression model and the data. The higher the relationship between the coefficients of determination and correlation the more significance fit of goodness.

In order to obtain reliable estimates, significant relevant interaction terms are expressed and presented in the regression analysis in all observed craft gangs'

analysis. For all models, the dependent variable is craft gangs recorded observed time productivity. A significant level of 5% was used to determine the relationship between blockwork inputs and cycle numbers by substituting the recorded observed time into the linear regression model equation:

$$Y = \alpha + \beta X \qquad (6.1)$$

From the regression equation, α, and β indicate the intercept and the slope of the linear regression model. The slope and the intercept are estimated thus;

$$\beta = (n\sum xy - \sum x \sum y) / (n\sum x2 - (\sum x)\ 2) \qquad (6.2)$$

$$\alpha = \bar{Y} - \beta \dot{X} \qquad (6.3)$$

Where Y, is the Man-hours and X, are the Cycle Numbers.

The regression equation above α and β was used to calculate the regression model for the blockwork craft gangs as presented in Table 6.2 to 6.9 below.

Table 6.2: Regression Model for Blockwork Craft Gang 1601

S/N	LN Man-hours Y	LN Cycle No X	C XY	D X^2	E Y^2	F $n\sum XY$	G $\sum X\sum Y$	H $n\sum X^2$	I $(\sum x)^2$	J H-I	K F-G	M $\beta=K/J$	N $B\dot{x}$	O $\alpha=\bar{Y}-\beta\dot{X}$
1	6.10	-	0	-	37.2100							-0.0271		6.08464
2	6.04	0.6931	4.186324	0.4804	36.4816									
3	6.03	1.1098	6.692094	1.2317	36.3609									
4	6.01	1.3862	8.331062	1.9216	36.1201									
5	6.01	1.6094	9.672494	2.5902	36.1201									
6	6.03	1.7917	10.80395	3.2102	36.3609									
7	6.12	1.9459	11.90891	3.7865	37.4544									
8	6.04	2.0794	12.55958	4.3239	36.4816									
9	6.05	2.1972	13.29306	4.8277	36.6025									
10	6.02	2.3025	13.86105	5.3015	36.2404									
11	6.04	2.3978	14.48271	5.7494	36.4816									
12	6.03	2.4849	14.98395	6.1747	36.3609	9579.295908	9591.644112	4209.966516	3754.35602	455.6104957	-12.348204		-0.063871109	
13	6.04	2.5649	15.492	6.5787	36.4816									
14	6.04	2.6390	15.93956	6.9643	36.4816									
15	6.00	2.7080	16.248	7.3333	36.0000									
16	6.01	2.7725	16.66273	7.6868	36.1201									
17	6.04	2.8332	17.11253	8.0270	36.4816									
18	5.98	2.8903	17.28399	8.3538	35.7604									
19	6.01	2.9444	17.69584	8.6695	36.1201									
20	5.98	2.9957	17.91429	8.9742	35.7604									
21	5.98	3.0445	18.20611	9.2690	35.7604									
22	5.99	3.0918	18.51988	9.5592	35.8801									
23	5.98	3.1355	18.75029	9.8314	35.7604									
24	5.98	3.1781	19.00504	10.1003	35.7604									
25	6.01	3.2189	19.34559	10.3613	36.1201									
26	5.98	3.2581	19.48344	10.6152	35.7604									
∑	**156.54**	**61.2728**	**368.4345**	**161.9218**	**942.5226**									

As depicted in Table 6.2 regression model for blockwork craft gang 1601, the regression equation, α and β indicate the intercept and the slope of the linear regression model. The slope and the intercept were estimated thus:

$\beta = (n\sum xy - \sum x \sum y)/ (n\sum x2 - (\sum x)\ 2)$, and $\alpha = \bar{Y} - \beta\dot{X}$.

Where y is the man-hours and x are the cycle numbers.

From the table above, α = 6.08, β= -0.03, ϒ= -0.64 as presented in Appendix K1. Where α is given as the intercept of the linear standard equation, β is given as the slope of the linear curve, ϒ is the correlation coefficient of the observed gangs. Hence, the general regression model for the observed blockwork craft gangs 1601 is as given below:

Y = 6.08 - 0.03X

Where Y is Man-hours = 6.08 - 0.03 cycle numbers

The slope of the relationship is negative. This means that as the cycle numbers increases, the man-hour inputs decreases and vice versa.

Table 6.3: Regression Model for Blockwork Craft Gang 1602

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	L	O			
S/N	Y	X	XY	X^2	Y^2	$n\sum XY$	$\sum X\sum Y$	$n\sum X^2$	$(\sum x)^2$	H-I	F-G	β=O/L	Bẋ	α=Ȳ-βẊ
1	6.09	-	0	-	37.0881							-0.05761		6.112368
2	6.05	0.6931	4.193255	0.4804	36.6025									
3	6.02	1.1098	6.680996	1.2317	36.2404									
4	6.01	1.3862	8.331062	1.9216	36.1201									
5	6.03	1.6094	9.704682	2.5902	36.3609									
6	6.05	1.7917	10.83979	3.2102	36.6025									
7	6.03	1.9459	11.73378	3.7865	36.3609									
8	6.05	2.0794	12.58037	4.3239	36.6025									
9	6.00	2.1972	13.1832	4.8277	36.0000									
10	6.02	2.3025	13.86105	5.3015	36.2404									
11	6.00	2.3978	14.3868	5.7494	36.0000	7843.49088	7865.39	3382.69	3002.58	380.11	-21.90		-0.131534669	
12	5.99	2.4849	14.88455	6.1747	35.8801									
13	5.93	2.5649	15.20986	6.5787	35.1649									
14	5.93	2.6390	15.64927	6.9643	35.1649									
15	5.97	2.7080	16.16676	7.3333	35.6409									
16	5.92	2.7725	16.4132	7.6868	35.0464									
17	5.98	2.8332	16.94254	8.0270	35.7604									
18	5.98	2.8903	17.28399	8.3538	35.7604									
19	5.97	2.9444	17.57807	8.6695	35.6409									
20	5.92	2.9957	17.73454	8.9742	35.0464									
21	5.91	3.0445	17.993	9.2690	34.9281									
22	5.89	3.0918	18.2107	9.5592	34.6921									
23	5.89	3.1355	18.4681	9.8314	34.6921									
24	5.91	3.1781	18.78257	10.1003	34.9281									
∑	**143.54**	**54.7958**	**326.8121**	**140.9453**	**858.5640**									

Table 6.3 represents the regression model for blockwork craft gang 1602, the regression equations are α and β which indicate the intercept and the slope of the linear regression model. The slope and the intercept were estimated with the regression model below:

$\beta = (n\sum xy - \sum x \sum y)/ (n\sum x2 - (\sum x)\ 2)$, and $\alpha = \bar{Y} - \beta\dot{X}$.

Where y, is the man-hours and X, is the cycle numbers.

From the table above, α = 6.11, β= -0.06, y= -0.84 as presented in Appendix K3. Where α is given as the intercept of the linear standard equation, β is given as the slope of the linear curve, y is the correlation coefficient of the observed gangs. Hence, the general regression model for the observed blockwork craft gangs is given below as:

Y = 6.11- 0.06X

That is, man hours = 6.11 - 0.06 cycle numbers

The slope of the relationship is negative. This means that as the cycle numbers increases, man hour inputs decreases and vice versa.

Table 6.4: Regression Model for Blockwork Craft Gang 1603

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	L	O			
S/N	Y	X	XY	X^2	Y^2	$n\sum XY$	$\sum X\sum Y$	$n\sum X^2$	$(\sum x)^2$	H-I	F-G	β=O/L	Bẋ	α=Ȳ-βẊ
1	6.11	-	0	-	37.3321							-0.07933		6.145627
2	6.09	0.6931	4.220979	0.4804	37.0881									
3	6.07	1.1098	6.736486	1.2317	36.8449									
4	6.06	1.3862	8.400372	1.9216	36.7236									
5	6.02	1.6094	9.688588	2.5902	36.2404									
6	6.02	1.7917	10.78603	3.2102	36.2404									
7	6.02	1.9459	11.71432	3.7865	36.2404	2930.476192	2942.309841	1090.57	941.40	149.17	-11.83		-0.152127288	
8	5.99	2.0794	12.45561	4.3239	35.8801									
9	5.98	2.1972	13.13926	4.8277	35.7604									
10	5.94	2.3025	13.67685	5.3015	35.2836									
11	5.91	2.3978	14.171	5.7494	34.9281									
12	6.00	2.4849	14.9094	6.1747	36.0000									
13	5.94	2.5649	15.23551	6.5787	35.2836									
14	6.01	2.6390	15.84983	6.9643	36.0720									
15	5.87	2.7080	15.89596	7.3333	34.4569									
16	5.87	2.7725	16.27458	7.6868	34.4569									
∑	**95.896**	**30.6823**	**183.1548**	**68.1608**	**574.8315**									

As depicted in Table 6.4 represent the regression model for blockwork craft gang 1603, the regression equation; α and β indicate the intercept and the slope of the linear regression model. The slope and the intercept were estimated thus;

$\beta = (n\sum xy - \sum x \sum y)/ (n\sum x2 - (\sum x)\ 2)$, and $\alpha = \bar{Y} - \beta\dot{X}$.

Where $\curlyvee$, is the Man-hours and X are the cycle numbers

From the table above, $\alpha = 6.15$, $\beta = -0.08$, $y = -0.86$ as presented in appendix K5. Where α is given as the intercept of the linear standard equation, β is given as the slope of the linear curve, y is the correlation coefficient of the observed gangs. Hence, the general regression model for the observed blockwork craft gangs is given below as:

$Y = 6.15 - 0.08X$

Where y is the Man-hours = 6.15 - 0.08 cycle numbers

The slope of the relationship is negative. This means that as the cycle numbers increases, man hour inputs decreases and vice versa.

Table 6.5: Regression Model for Blockwork Craft Gang 1604

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	L	O			
S/N	Y	X	XY	X^2	Y^2	$n\sum XY$	$\sum X\sum Y$	$n\sum X^2$	$(\sum x)^2$	H-I	F-G	β=O/L	Bẋ	α=Ȳ-βẊ
1	6.23	-	0	-	38.8129							-0.09289		6.168428
2	6.04	0.6931	4.186324	0.4804	36.4816									
3	6.04	1.1098	6.703192	1.2317	36.4816									
4	6.03	1.3862	8.358786	1.9216	36.3609									
5	5.99	1.6094	9.640306	2.5902	35.8801									
6	6.00	1.7917	10.7502	3.2102	36.0000									
7	6.01	1.9459	11.69486	3.7865	36.1201									
8	6.02	2.0794	12.51799	4.3239	36.2404	3394.233821	3410.20	1295.19	1123.29	171.90	-15.97		-0.183133955	
9	5.96	2.1972	13.09531	4.8277	35.5216									
10	5.99	2.3025	13.79198	5.3015	35.8801									
11	5.95	2.3978	14.26691	5.7494	35.4025									
12	5.91	2.4849	14.68576	6.1747	34.9281									
13	5.90	2.5649	15.13291	6.5787	34.8100									
14	5.99	2.6390	15.80761	6.9643	35.8801									
15	5.87	2.7080	15.89596	7.3333	34.4569									
16	5.86	2.7725	16.24685	7.6868	34.3396									
17	5.96	2.8332	16.88587	8.0270	35.5216									
∑	**101.75**	**33.5155**	**199.6608**	**76.1878**	**609.1181**									

As depicted in Table 6.5 represents the regression model for blockwork craft gang 1604, the regression equation, α and β indicate the intercept and the slope of the linear regression model. The slope and the intercept were estimated thus;

$\beta = (n\sum xy - \sum x \sum y)/ (n\sum x2 - (\sum x)\ 2)$, and $\alpha = \bar{Y} - \beta\dot{X}$.

Where y is the man-hours and x are the cycle numbers.

From the table above, α = 6.17, β= -0.09, y= -0.87 as presented in Appendix K7. Where α is given as the intercept of the linear standard equation, β is given as the slope of the linear curve, y is the correlation coefficient of the observed gangs. Hence, the general regression model for the observed blockwork craft gangs is given below as:

Y = 6.17- 0.09X

Where y is man-hours = 6.17 - 0.09 cycle numbers

The slope of the relationship is negative. This means that as the cycle numbers increases, man hour inputs decreases and vice versa.

Table 6.6: Regression Model for Blockwork Craft Gang 1605

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	L	O			
S/N	Y	X	XY	X^2	Y^2	$n\sum XY$	$\sum X\sum Y$	$n\sum X^2$	$(\sum x)^2$	H-I	F-G	β=O/L	Bẋ	α=Ȳ-βẊ
1	6.26	-	0	-	39.2252							-0.13683		6.269175
2	6.21	0.6931	4.306923	0.4804	38.6138									
3	6.05	1.1098	6.71651	1.2317	36.6267									
4	6.05	1.3862	8.38651	1.9216	36.6025									
5	6.03	1.6094	9.704682	2.5902	36.3609									
6	6.03	1.7917	10.80395	3.2102	36.3609									
7	6.01	1.9459	11.69486	3.7865	36.1201									
8	6.00	2.0794	12.48472	4.3239	36.0480	3394.727773	3418.25	1295.19	1123.29	171.90	-23.52		-0.269757593	
9	5.99	2.1972	13.16123	4.8277	35.8801									
10	5.99	2.3025	13.79198	5.3015	35.8801									
11	6.02	2.3978	14.43476	5.7494	36.2404									
12	5.95	2.4849	14.78516	6.1747	35.4025									
13	5.96	2.5649	15.2868	6.5787	35.5216									
14	5.99	2.6390	15.79837	6.9643	35.8382									
15	5.92	2.7080	16.03136	7.3333	35.0464									
16	5.57	2.7725	15.44283	7.6868	31.0249									
17	5.95	2.8332	16.85924	8.0270	35.4096									
∑	**101.9901**	**33.5155**	**199.6899**	**76.1878**	**612.2019**									

Table 6.6 represents the regression model for blockwork craft gang 1605, the regression equation, α and β indicate the intercept and the slope of the linear regression model. The slope and the intercept were estimated thus:

$\beta = (n\sum xy - \sum x \sum y)/ (n\sum x2 - (\sum x)\ 2)$, and $\alpha = \bar{Y} - \beta\dot{X}$.

Where y, is the man-hours and X, are the cycle numbers.

From the table above, α = 6.27, β= -0.14, y = -0.77 as presented in Appendix K9. Where α is given as the intercept of the linear standard equation, β is given as the slope of the linear curve, y is the correlation coefficient of the observed gangs. Hence, the general regression model for the observed blockwork craft gangs is as given below:

Y = 6.27-0.14X

Where y is man-hours = 6.27 - 0.14 cycle numbers.

The slope of the relationship is negative. This means that as the cycle numbers increases, man hour inputs decreases and vice versa.

Table 6.7: Regression Model for Blockwork Craft Gang 1606

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	L	O			
S/N	Y	X	XY	X^2	Y^2	n∑XY	∑X∑Y	n∑X^2	$(\sum x)^2$	H-I	F-G	β=O/L	Bẋ	α=Ȳ-βẊ
1	6.18	-	0	-	38.1924							-0.11459		6.200769
2	6.17	0.6931	4.276427	0.4804	38.0689									
3	6.05	1.1098	6.71429	1.2317	36.6025									
4	6.04	1.3862	8.372648	1.9216	36.4816									
5	6.02	1.6094	9.688588	2.5902	36.2404									
6	6.00	1.7917	10.7502	3.2102	36.0000									
7	5.99	1.9459	11.65594	3.7865	35.8801									
8	5.96	2.0794	12.39322	4.3239	35.5216	3384.558276	3404.26	1295.19	1123.29	171.90	-19.70		-0.225910603	
9	5.94	2.1972	13.05137	4.8277	35.2836									
10	5.93	2.3025	13.65383	5.3015	35.1649									
11	5.90	2.3978	14.15325	5.7494	34.8407									
12	5.93	2.4849	14.73546	6.1747	35.1649									
13	5.89	2.5649	15.10726	6.5787	34.6921									
14	5.87	2.6390	15.49093	6.9643	34.4569									
15	5.94	2.7080	16.08552	7.3333	35.2836									
16	5.86	2.7725	16.24685	7.6868	34.3396									
17	5.90	2.8332	16.71588	8.0270	34.8100									
∑	**101.5726**	**33.5155**	**199.0917**	**76.1878**	**607.0238**									

As presented in Table 6.7 regression model for blockwork craft gang 1606, the regression equation, α and β indicate the intercept and the slope of the linear regression model. The slope and the intercept were estimated thus;

$\beta = (n\sum xy - \sum x \sum y)/ (n\sum x2 - (\sum x)\ 2)$, and $\alpha = \bar{Y} - \beta\dot{X}$.

Where y, is the Man-hours and X, is the cycle numbers.

From the table above, $\alpha = 6.20$, $\beta = -0.11$, $y = -0.97$ as presented in Appendix K11. Where α is given as the intercept of the linear standard equation, β is given as the slope of the linear curve, y is the correlation coefficient of the observed gangs. Hence, the general regression model for the observed blockwork craft gangs is as given below:

$Y = 6.20 - 0.11X$

Where y is the man-hours = 6.20 - 0.11 cycle numbers.

The slope of the relationship is negative. This means that as the cycle numbers increases, man hour inputs decreases and vice versa.

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Table 6.8: Regression Model for Blockwork Craft Gang 1607

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	L	O			
S/N	Y	X	XY	X^2	Y^2	$n\sum XY$	$\sum X \sum Y$	$n\sum X^2$	$(\sum x)^2$	H-I	F-G	β=O/L	Bẋ	α=Ȳ-βẊ
1	6.26	-	0	-	39.1876							-0.0963		6.210335
2	6.23	0.6931	4.318013	0.4804	38.8129									
3	6.01	1.1098	6.669898	1.2317	36.1201									
4	5.96	1.3862	8.261752	1.9216	35.5216									
5	6.05	1.6094	9.73687	2.5902	36.6025									
6	6.03	1.7917	10.80395	3.2102	36.3609									
7	6.03	1.9459	11.73378	3.7865	36.3609									
8	6.01	2.0794	12.49719	4.3239	36.1201	3923.108982	3942.02	1521.75	1325.38	196.37	-18.91		-0.194779714	
9	6.05	2.1972	13.29306	4.8277	36.6025									
10	5.92	2.3025	13.6308	5.3015	35.0464									
11	5.99	2.3978	14.36282	5.7494	35.8801									
12	5.99	2.4849	14.88455	6.1747	35.8801									
13	5.95	2.5649	15.26116	6.5787	35.4025									
14	6.00	2.6390	15.834	6.9643	36.0000									
15	5.96	2.7080	16.13968	7.3333	35.5216									
16	5.92	2.7725	16.4132	7.6868	35.0464									
17	6.00	2.8332	16.9992	8.0270	36.0000									
18	5.92	2.8903	17.11058	8.3538	35.0464									
∑	**108.28**	**36.4058**	**217.9505**	**84.5417**	**651.5126**									

Table 6.8 represents the regression model for blockwork craft gang 1607, the regression equation, α and β indicates the intercept and the slope of the linear regression model. The slope and the intercept were estimated thus:

$\beta = (n\sum xy - \sum x \sum y)/ (n\sum x2 - (\sum x)\ 2)$, and $\alpha = \bar{Y} - \beta\dot{X}$

Where y is the Man-hours and x are the cycle numbers.

From the table above, α = 6.21, β= -0.10, y = -0.83 as presented in Appendix K13. Where α is given as the intercept of the linear standard equation, β is given as the slope of the linear curve, y is the correlation coefficient of the observed gangs. Hence, the general regression model for the observed blockwork craft gangs is as given below:

Y = 6.21 - 0.10X

Man- hours = 6.21 - 0.10 cycle numbers

The slope of the relationship is negative. This means that as the cycle numbers increases, man hour inputs decreases and vice versa.

Table 6.9: Overall Blockwork Craft Gangs Regression Model

	GANG 1601	GANG 1602	GANG 1603	GANG 1604	GANG 1605	GANG 1606	GANG 1607	AVERAGE
α	6.08	6.11	6.15	6.17	6.27	6.20	6.21	**6.17**
β	-0.03	-0.06	-0.08	-0.09	-0.14	-0.11	-0.10	**-0.09**
Y	-0.64	-0.84	-0.86	-0.87	-0.77	-0.97	-0.83	**-0.82**

The unit straight-line learning curve model was calculated by using simple linear regression coefficients. A significant level of 5% was used to determine the correlation between blockwork craft gang's recorded time inputs and the number of the repetitive cycles by substituting the corresponding parameters into the linear regression model equation:

$Y = \alpha + \beta X$

From the regression equation, α, and β indicate the intercept and the slope of the linear regression model. The slope and the intercept are estimated with the regression model:

$\beta = (n\sum xy - \sum x \sum y)/ (n\sum x2 - (\sum x)\ 2)$, and $\alpha = \bar{Y} - \beta \dot{X}$.

Where Y, is the Man-hours and X, is the Cycle Numbers.

From the overall regression in Table 6.9, α=6.17, β= -0.09, y = -0.82. Where α is given as the intercept of the linear standard equation, β is given as the slope of the linear curve, y is the correlation coefficient of the observed gangs. Hence, the general regression model for the overall observed blockwork craft gangs is given below as:

$Y = 6.17 - 0.09X$

That is Man hours = 6.17-0.09 cycle numbers.

The slope of the relationship from the overall blockwork craft gangs is negative.

The learning curve theory states that whenever the production quantity of product doubles, the unit or cumulative average cost required for production, i.e., man-hours, cost, or time, declines by a certain percentage of the previous unit or cumulative average rate. This percentage is referred to as the "learning rate," which identifies the learning effect achieved in the process. Moreover, it establishes the slope of the learning curve. The lower the learning rate, the greater the learning achieved. A learning rate of 100% indicates that no learning takes place (Jarkas, 2010).

From the overall blockwork regression model in Table 6.9, the craft gang's regression model shows a negative relationship between the blockwork gang inputs and the cycle numbers. These indicate that there is a relationship with the learning curve model. This means that as the cycle numbers increases, man hour inputs decreases and vice versa.

6.3 The Influence of Learning on Blockwork Gangs Productivity

The unit straight-line learning curve model was selected to form the basis for investigating the role the prior and on-site-learning play in assisting craft gang's to deal with project-specific constraints and optimise their productivity. In the application of the learning curve theory to repetitive blockwork activities, the straight-line unit model is expressed as a power function (Couto & Teixeira, 2005; Jarkas, 2010; Thomas et al., 1986). The mathematical expressions underlying the logarithmic straight-line learning curve are:

$$Y = TI\times (\times) b \qquad (6.4)$$

Where Y = cost, man-hours, or time required to perform the repeated unit; T1=cost, man-hours, or time necessary to perform the first unit; x = cycle number of the unit; and b represents the slope of the logarithmic curve, which is calculated as: $b=InS/ln2$ (6.5)

Where S= learning rate, which is defined as the percentage reduction in the unit input, i.e., cost, man-hours, or time, as a result of doubling the number of units completed. Equation 6.5 can be rewritten as:

$$S= (2\text{^}b)*100 \qquad (6.6)$$

In the observed craft gangs' blockwork, the regression coefficients were used to assess the significance of the estimated slope in the linear regression equation as presented in Table 6.2 to 6.9. The learning rate of each observed repetitive work activity was quantified, and the unit straight-line model equations in the standard linear and power function formats were determined for each observed craft gang in the project. This procedure was repeated for each craft gang on the project and the applicability of learning curve theory to each blockwork craft gang involved in the repetitive work activities was determined as presented in Figure 6.1 to 6.8: respectively.

Table 6.10, represents the learning rate table used to plot the learning curve for craft gang 1601 blockwork observed.

Table 6.10: Learning Rate for Blockwork Craft Gang 1601

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	J	K	L	M	O	P	Q
S/N	Y	X	XY	X2	n∑XY	∑X∑Y	n∑X2	(∑x)2	E-F	G-H	β=I/J	Ẏ	Ẋ	Bẋ	α=Ẏ-Bẋ	S=2b*100
1	6.1000	-	-	-							**-0.0271**					**98.1389**
2	6.0400	0.6931	4.1863	0.4804												
3	6.0300	1.1098	6.6921	1.2317												
4	6.0100	1.3862	8.3311	1.9216												
5	6.0100	1.6094	9.6725	2.5902												
6	6.0300	1.7917	10.8040	3.2102	9,579.2959	9,591.6441	4,209.9665	3,754.3560	-12.3482	455.6105		6.0208	2.3566	-0.0639	**6.0846**	
7	6.1200	1.9459	11.9089	3.7865												
8	6.0400	2.0794	12.5596	4.3239												
9	6.0500	2.1972	13.2931	4.8277												
10	6.0200	2.3025	13.8611	5.3015												
11	6.0400	2.3978	14.4827	5.7494												

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	J	K	L	M	O	P	Q
S/N	Y	X	XY	X2	n∑XY	∑X∑Y	n∑X2	(∑x)2	E-F	G-H	β=I/J	Ẏ	Ẋ	Bẋ	α=Ẏ-Bẋ	S=2b*100
12	6.0300	2.4849	14.9839	6.1747												
13	6.0400	2.5649	15.4920	6.5787												
14	6.0400	2.6390	15.9396	6.9643												
15	6.0000	2.7080	16.2480	7.3333												
16	6.0100	2.7725	16.6627	7.6868												
17	6.0400	2.8332	17.1125	8.0270												
18	5.9800	2.8903	17.2840	8.3538												
19	6.0100	2.9444	17.6958	8.6695												
20	5.9800	2.9957	17.9143	8.9742												
21	5.9800	3.0445	18.2061	9.2690												
22	5.9900	3.0918	18.5199	9.5592												
23	5.9800	3.1355	18.7503	9.8314												
24	5.9800	3.1781	19.0050	10.1003												

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	J	K	L	M	O	P	Q
S/N	Y	X	XY	X2	n∑XY	∑X∑Y	n∑X2	(∑x)2	E-F	G-H	β=I/J	Ẏ	Ẋ	Bẋ	α=Ẏ-Bẋ	S=2b*100
25	6.0100	3.2189	19.3456	10.3613												
26	5.9800	3.2581	19.4834	10.6152												
∑	156.5400	61.2728	368.4345	161.9218												

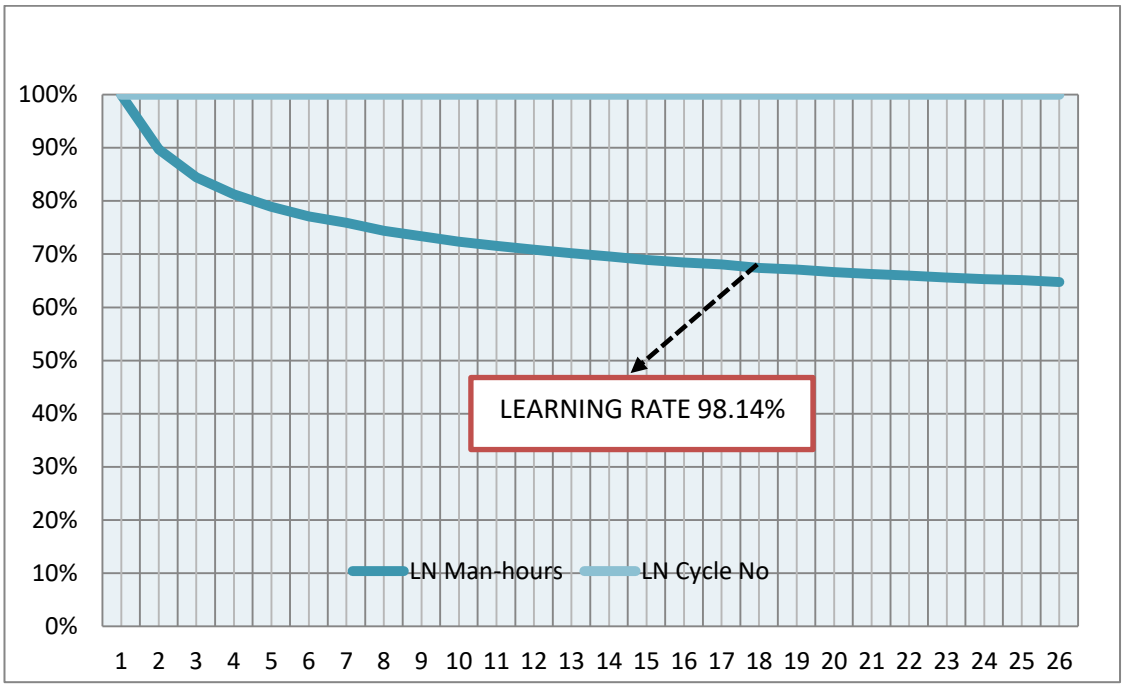

Figure 6.1: Relationship of Blockwork Gang No 1601 and Cycle Number

Figure 6.1, represent Craft gang no: 1601 learning rate. The unit straight-line learning curve shown above is derived using simple linear regression. The overall regression model statistics are presented in Tables 6.2.

The learning rate (S), expressed as a percentage, is quantified by substituting the slope (b) shown in equation 6.6 above, that is -0.03, into the learning rate equation as follows;

S = (2-0.03) x 100 = 98.14%, this is approximately 98% as indicated in Table 6.10 above, showing that the average learning rate is insignificant for the blockwork craft gangs observed.

The relationship between the man hours and the cycle numbers was derived using the straight line unit equation in 6.2. The learning rate reveals 98.14% which is insignificant (p-value $\geq$ 0.05). The result indicates that the slope is insignificantly different from zero. The unit straight-line learning curve for the repetitive observed blockwork craft gang represented in figure 6.1 and Table 6.10 shows an insignificant effect in the blockwork craft gang with 98.14%. Thus, we can state

that in this gang that no significant learning has occurred. The observed productivity determinant indicated insignificant rates of learning in the project were attributed to the craft gang low familiarity with the details of construction method and method statement as follows:

- Variation in block course arrangement: The arrangement, of course, is made up of a full block, course 2 arrangement header/half block.
- Variability in wall stiffener: wall stiffener of 100 x 200 mm is introduced at every third course).
- Variation in Block wall Re-bar to be lapped with starters 600 mm for Dia. 12
- Variability of wall columns to be steadily filled with concrete at each course.

A portion of the gang problem was also attributed to inadequate skills in the gang or a lack of prior learning in relation to the construction method.

Table 6.11, represents the learning rate data used to plot the learning curve for craft gang 1602 blockwork activities which were observed.

Table 6.11: Learning Rate for Blockwork Craft Gang 1602

S/N	LN Man-hours Y	LN Cycle No X	C XY	D X2	E n∑XY	F ∑X∑Y	G n∑X2	H (∑x)2	I E-F	J G-H	K β=I/J	L Ẏ	M Ẋ	O Bẋ	P α=Ẏ-Bẋ	Q S=2b*100
1	6.0900	-	-	-												
2	6.0500	0.6931	4.1933	0.4804												
3	6.0200	1.1098	6.6810	1.2317												
4	6.0100	1.3862	8.3311	1.9216												
5	6.0300	1.6094	9.7047	2.5902												
6	6.0500	1.7917	10.8398	3.2102												
7	6.0300	1.9459	11.7338	3.7865												
8	6.0500	2.0794	12.5804	4.3239												
9	6.0000	2.1972	13.1832	4.8277												
10	6.0200	2.3025	13.8611	5.3015												
11	6.0000	2.3978	14.3868	5.7494												
12	5.9900	2.4849	14.8846	6.1747												
13	5.9300	2.5649	15.2099	6.5787												
14	5.9300	2.6390	15.6493	6.9643	7,843.4909	7,865.3891	3,382.6861	3,002.5797	-21.8983	380.1065	**-0.0576**	5.9808	2.2832	-0.1315	**6.1124**	**96.0854**
15	5.9700	2.7080	16.1668	7.3333												
16	5.9200	2.7725	16.4132	7.6868												
17	5.9800	2.8332	16.9425	8.0270												
18	5.9800	2.8903	17.2840	8.3538												
19	5.9700	2.9444	17.5781	8.6695												
20	5.9200	2.9957	17.7345	8.9742												
21	5.9100	3.0445	17.9930	9.2690												
22	5.8900	3.0918	18.2107	9.5592												
23	5.8900	3.1355	18.4681	9.8314												
24	5.9100	3.1781	18.7826	10.1003												
∑	143.5400	54.7958	326.8121	140.9453												

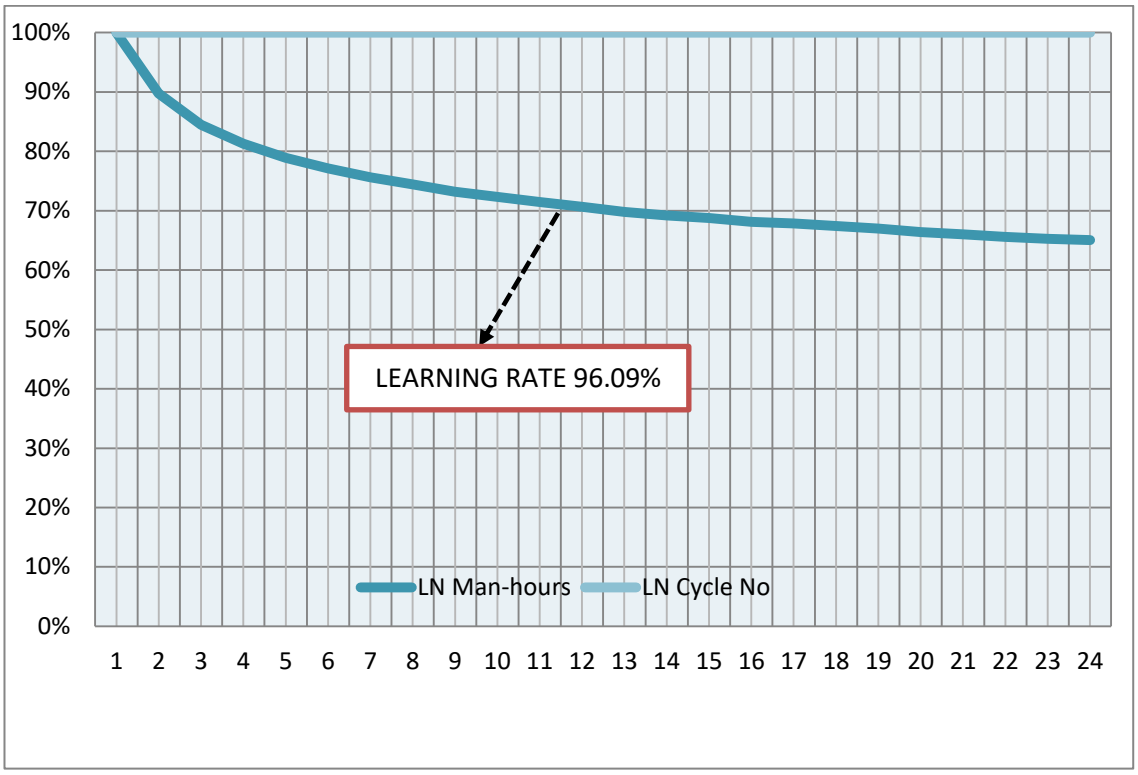

Figure 6.2: Relationship of Blockwork Gang No 1602 and Cycle Number

Figure 6.2, shows the relationship between craft gang 1602 blockwork laying and the cycle numbers, the unit straight-line learning curve shown above is derived using simple linear regression presented in Table 6.3.

The learning rate (S), expressed as a percentage, is quantified by substituting the slope (b) shown in the equation 6.6 above, that is -0.06, into the learning rate equation as follows:

S = (2-0.06) x 100 = 96.09%, this is approximately 96% as indicated in Table 6.11 above, showing that the average learning rate is insignificant for the blockwork craft gang observed.

The overall regression model and coefficients' statistics are presented in Tables 6.3 and Appendix K3 respectively. The learning effect reveals an insignificant learning rate of 96.09% from the observed craft gang, which was attributed to the craft gang low familiarity with the details of construction method and method the

statement, the existing construction methods were not optimised to utilise the learning curve and maximise the efficiency of workers. The craft gang has prior learning including apprenticeships, induction and tool box. The gang has a composition of one skilled worker and two unskilled workers crew for block wall laying. It was also, observed that as a result of combining two unskilled workers and one skilled, the learning rate for the gang was not created to optimise efficiency.

Table 6.12, represents the learning rate table used to plot the learning curve for craft gang 1603 block work that was observed.

Table 6.12: Learning Rate for Craft Gang 1603 Block Work (S)

S/N	LN Man-hours Y	LN Cycle No X	C XY	D X2	E n∑XY	F ∑X∑Y	G n∑X2	H (∑x)2	I E-F	J G-H	K β=I/J	L Ẏ	M Ẍ	O Bẋ	P α=Ẏ-Bẋ	Q S=2b*100
1	6.1100	-	-	-							**-0.0793**					**94.6497**
2	6.0900	0.6931	4.2210	0.4804												
3	6.0700	1.1098	6.7365	1.2317												
4	6.0600	1.3862	8.4004	1.9216												
5	6.0200	1.6094	9.6886	2.5902												
6	6.0200	1.7917	10.7860	3.2102												
7	6.0200	1.9459	11.7143	3.7865	2,930.4762	2,942.3098	1,090.5728	941.4035	-11.8336	149.1693		5.9935	1.9176	-0.1521	**6.1456**	
8	5.9900	2.0794	12.4556	4.3239												
9	5.9800	2.1972	13.1393	4.8277												
10	5.9400	2.3025	13.6769	5.3015												
11	5.9100	2.3978	14.1710	5.7494												
12	6.0000	2.4849	14.9094	6.1747												
13	5.9400	2.5649	15.2355	6.5787												
14	6.0060	2.6390	15.8498	6.9643												
15	5.8700	2.7080	15.8960	7.3333												
16	5.8700	2.7725	16.2746	7.6868												
∑	95.8960	30.6823	183.1548	68.1608												

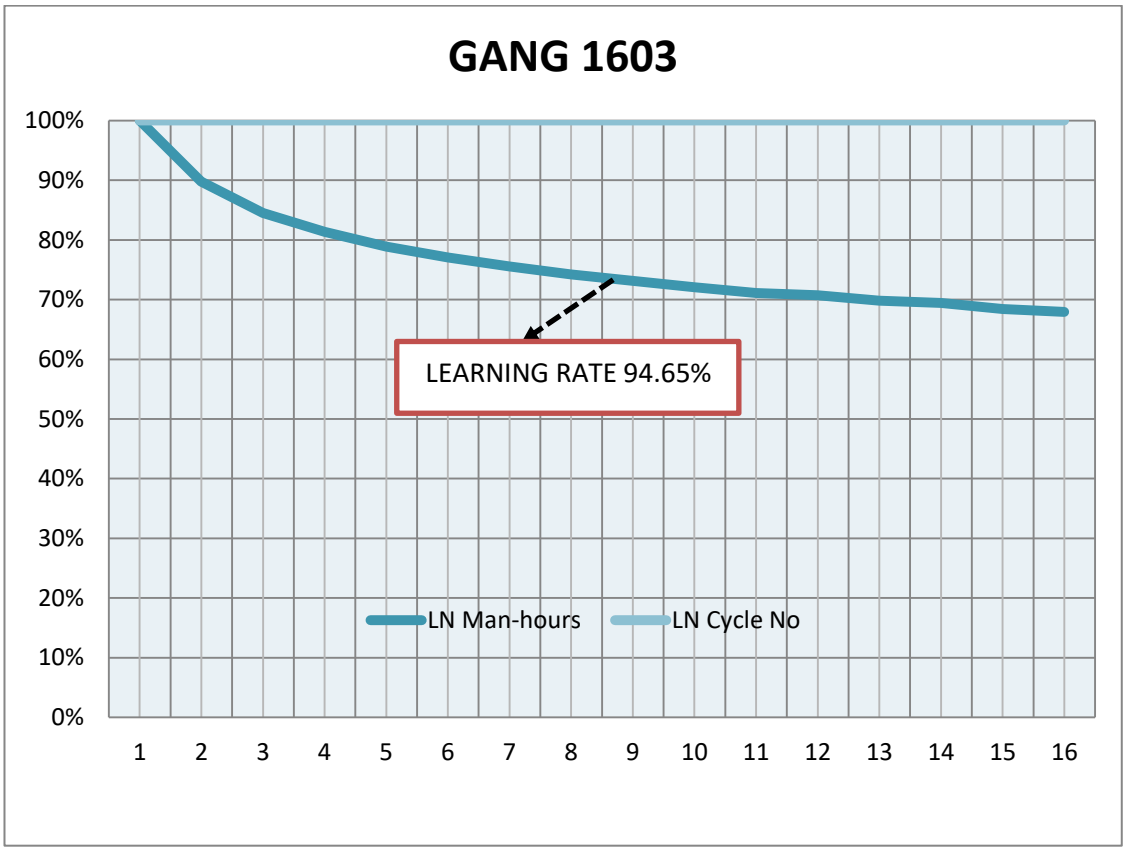

Figure 6.3: Relationship of Blockwork Craft Gang No 1603 and Cycle Number

Figure 6.3, represents the relationship between craft gang No: 1603 blockwork and the cycle numbers observed productivity, the unit straight-line learning curve shown above is derived using simple linear regression presented in equation 6.2.

The learning rate (S), expressed as a percentage, is quantified by substituting the slope (b) shown in the equation 6.6 above, that is -0.08, into the learning rate equation as follows:

S = (2-0.08) x 100 = 94.65%, this is approximately 95% as indicated in Table 6.12 above, showing that the average learning rate is significant for the blockwork craft gang observed.

The overall regression model and coefficients' statistics are presented in Tables 6.4 and Appendix K5 respectively. The learning rate reveals a significant learning of 94.65% as presented in figure 6.3. The craft gang block layers had some level of familiarity with the details of the construction method of the block wall. However, one of the craft gang members did not seem to have a clear understanding of the safety culture of the project. The new craft worker did not utilise the safety protection materials (despite the availability of this equipment on site).

Table 6.13 represents the learning rate table used to plot the learning curve for craft gang 1604 block work observed.

Table 6.13: Learning Rate for Blockwork Craft Gang 1604

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	J	K	L	M	O	P	Q
S/N	Y	X	XY	X2	n∑XY	∑X∑Y	n∑X2	(∑x)2	E-F	G-H	β=I/J	Ẏ	Ẋ	Bẋ	α=Ẏ-Bẋ	S=2b*100
1	6.2300	-	-	-							**-0.0929**					**93.7642**
2	6.0400	0.6931	4.1863	0.4804												
3	6.0400	1.1098	6.7032	1.2317												
4	6.0300	1.3862	8.3588	1.9216												
5	5.9900	1.6094	9.6403	2.5902												
6	6.0000	1.7917	10.7502	3.2102												
7	6.0100	1.9459	11.6949	3.7865												
8	6.0200	2.0794	12.5180	4.3239												
9	5.9600	2.1972	13.0953	4.8277												
10	5.9900	2.3025	13.7920	5.3015												
11	5.9500	2.3978	14.2669	5.7494	3,394.2338	3,410.2021	1,295.1930	1,123.2887	-15.9683	171.9043		5.9853	1.9715	-0.1831	**6.1684**	
12	5.9100	2.4849	14.6858	6.1747												
13	5.9000	2.5649	15.1329	6.5787												
14	5.9900	2.6390	15.8076	6.9643												
15	5.8700	2.7080	15.8960	7.3333												
16	5.8600	2.7725	16.2469	7.6868												
17	5.9600	2.8332	16.8859	8.0270												
∑	101.7500	33.5155	199.6608	76.1878												

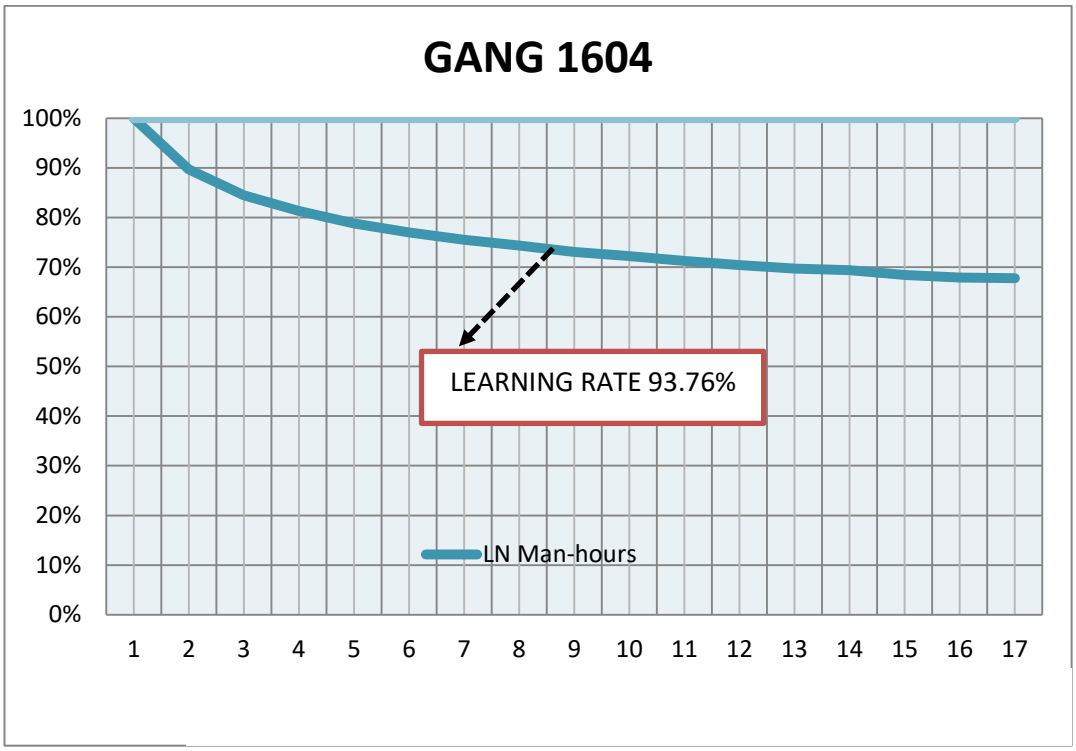

Figure 6.4: Relationship of Blockwork Gang No 1604 and Cycle Number

Figure 6.4, represent craft gang No: 1604 observed learning rate for the blockwork construction productivity. The unit straight-line learning curve shown above is derived using simple linear regression in equation 6.2.

The learning rate (S), expressed as a percentage, is quantified by substituting the slope (b) shown in the equation 6.6 above, that is -0.09, into the learning rate equation as follows:

S = (2-0.09) x 100 = 93.76%, this is approximately 94% as indicated in Table 6.13 above, showing that the average learning rate is significant for the blockwork craft gang observed.

The overall regression model and coefficients' statistics are presented in Tables 6.5 and Appendix K7 respectively. The learning rate reveals 94% which is significant for improvement of craft gang productivity in the construction industry. The productivity evaluation determinant indicated the significant rate of learning in this project could be attributed to motivation, skills and good

behaviour of the craft gang workers. The craft gang workers had familiarity with the details of the construction method of the block wall.

Table 6.14, represents the learning rate table used to plot the learning curve for craft gang 1605 blockwork observed.

Table 6.14: Learning Rate for Blockwork Craft Gang 1605

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	J	K	L	M	O	P	Q
S/N	Y	X	XY	X2	n∑XY	∑X∑Y	n∑X2	(∑x)2	E-F	G-H	β=I/J	Ẏ	Ẋ	Bẋ	α=Ẏ-Bẋ	S=2b*100
1	6.2630	-	-	-							**-0.1368**					**90.9516**
2	6.2140	0.6931	4.3069	0.4804												
3	6.0520	1.1098	6.7165	1.2317												
4	6.0500	1.3862	8.3865	1.9216												
5	6.0300	1.6094	9.7047	2.5902												
6	6.0300	1.7917	10.8040	3.2102												
7	6.0100	1.9459	11.6949	3.7865												
8	6.0040	2.0794	12.4847	4.3239												
9	5.9900	2.1972	13.1612	4.8277												
10	5.9900	2.3025	13.7920	5.3015												
11	6.0200	2.3978	14.4348	5.7494	3,394.7278	3,418.2492	1,295.1930	1,123.2887	-23.5214	171.9043		5.9994	1.9715	-0.2698	**6.2692**	
12	5.9500	2.4849	14.7852	6.1747												
13	5.9600	2.5649	15.2868	6.5787												
14	5.9865	2.6390	15.7984	6.9643												
15	5.9200	2.7080	16.0314	7.3333												
16	5.5700	2.7725	15.4428	7.6868												
17	5.9506	2.8332	16.8592	8.0270												
∑	101.9901	33.5155	199.6899	76.1878												

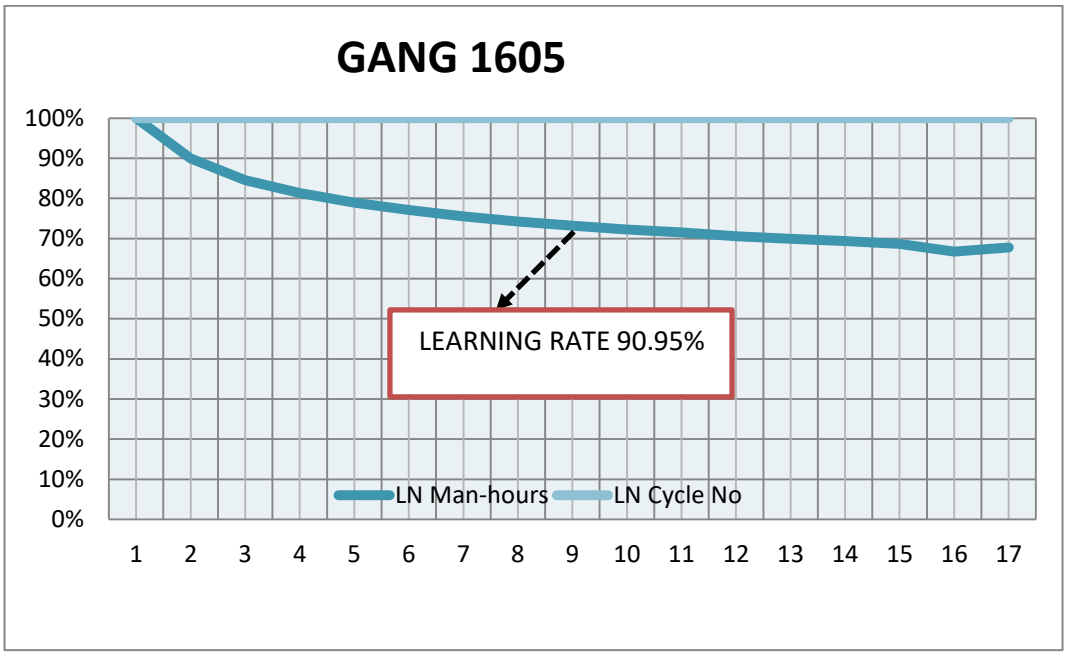

Figure 6.5: Relationship of Blockwork Craft Gang No 1605 and Cycle Number

Figure 6.5, represents the relationship between craft gang No: 1605. The unit straight-line learning curve shown above is derived using simple linear regression. The learning rate (S), expressed as a percentage, is quantified by substituting the slope (b) shown in the equation 6.6 above, that is -0.14, into the learning rate equation as follows:

S = (2-0.14) x 100 = 90.95%, this is approximately 91% as indicated in Table 6.14 above, showing that the average learning rate is significant for the blockwork craft gang observed.

The overall regression model and coefficients' statistics are presented in Tables 6.16 and Appendix K9 respectively. The learning rate represented shows a significant learning rate of 9.05% rate turnover. The learning rate reveals 90.95% which was significant (p-value $\geq$ 0.05). The result indicates that the slope is significantly different from zero. The unit straight-line learning curve for the repetitive observed blockwork craft gang represented in Figure 6.5 and Table 6.14 shows a significantly learning rate optimisation in the blockwork craft gang. Thus, we can state that a learning rate of 90.95% has occurred. The productivity

observed indicated a significant rate of learning in this project, could be attributed to the observed following indicators:

- Workers had greater familiarity with the details of construction method
- Familiarity with the safety resources and equipment.

The significant learning rate achieved in this gang could also, be attributed to motivation and skills of the workers as observed. The collaboration among the craft gang in the work areas was good and this attributed to the gang increasing their knowledge about block laying over a period of time. Finally, the craft gang had better coordination compared to craft gangs 1601 and 1602.

Table 6.15, represents the learning rate table used to plot the learning curve for craft gang 1606 blockwork observed.

Table 6.15: Learning Rate for Blockwork Craft Gang 1606

S/N	LN Man-hours Y	LN Cycle No X	C XY	D X2	E n∑XY	F ∑X∑Y	G n∑X2	H (∑x)2	I E-F	J G-H	K β=I/J	L Ẏ	M Ẋ	O Bẋ	P α=Ẏ-Bẋ	Q S=2b*100
1	6.1800	-	-	-							**-0.1146**					**92.3646**
2	6.1700	0.6931	4.2764	0.4804												
3	6.0500	1.1098	6.7143	1.2317												
4	6.0400	1.3862	8.3726	1.9216												
5	6.0200	1.6094	9.6886	2.5902												
6	6.0000	1.7917	10.7502	3.2102												
7	5.9900	1.9459	11.6559	3.7865												
8	5.9600	2.0794	12.3932	4.3239	3,384.5583	3,404.2565	1,295.1930	1,123.2887	-19.6982	171.9043		5.9749	1.9715	-0.2259	**6.2008**	
9	5.9400	2.1972	13.0514	4.8277												
10	5.9300	2.3025	13.6538	5.3015												
11	5.9026	2.3978	14.1533	5.7494												
12	5.9300	2.4849	14.7355	6.1747												
13	5.8900	2.5649	15.1073	6.5787												
14	5.8700	2.6390	15.4909	6.9643												
15	5.9400	2.7080	16.0855	7.3333												
16	5.8600	2.7725	16.2469	7.6868												
17	5.9000	2.8332	16.7159	8.0270												
∑	101.5726	33.5155	199.0917	76.1878												

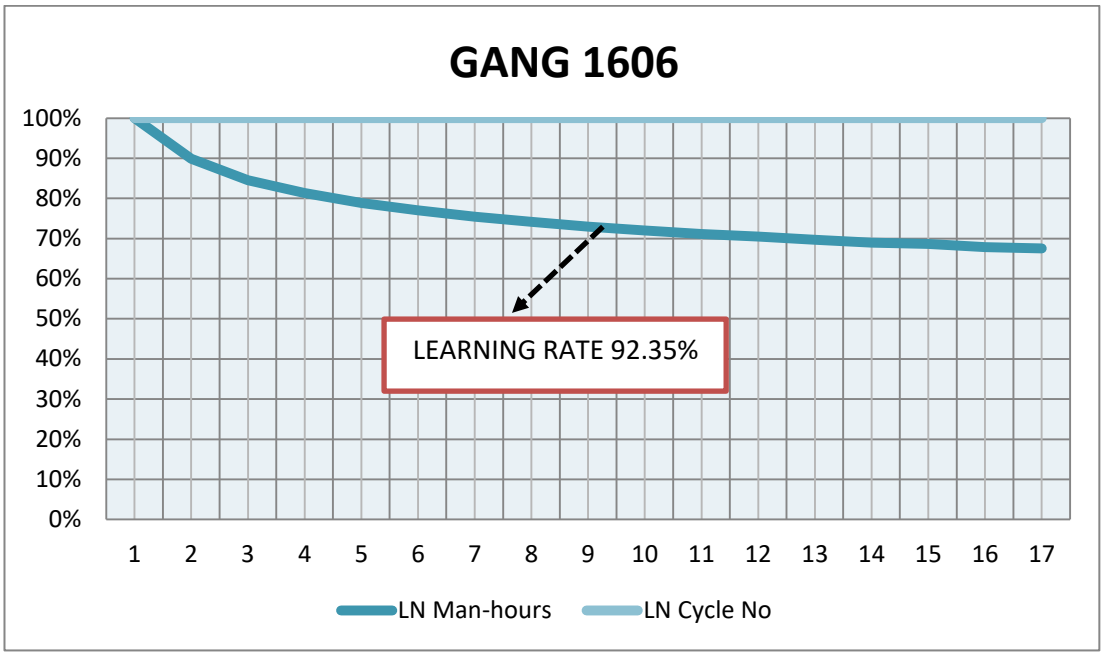

Figure 6.6: Relationship of Blockwork Gang Number 1606 and Cycle Number

Figure 6.6; represent the relationship of craft gang no: 1606 block wall and cycle number. The unit straight-line learning curve shown above is derived using simple linear regression in equation 6.2 above.

The learning rate (S), expressed as a percentage, is quantified by substituting the slope (b) shown in the equation 6.6 above, that is -0.11, into the learning rate equation as follows:

S = (2-0.11) x 100 = 92.37%, this is approximately 92% as indicated in Table 6.15 above, showing that the average learning rate is significant for the blockwork craft gang observed.

The overall regression model and coefficients' statistics are presented in Tables 6.7 and Appendix K11 respectively. The learning rate reveals 92.35% which is significant (p-value ≥ 0.050). This result indicates that the slope is significantly different from zero. The unit straight-line learning curve for the repetitive observed blockwork craft gang represented in figure 6.6 and Table 6.15, shows a significant productivity of craft gang with 92.36%. This result indicates that a learning rate of approximately 92% occurred. The productivity observed

determinant indicated a significant rate of learning in this gang could be attributed to familiarity with the details of construction in block course arrangement: The craft gang has a prior learning on the arrangement of block wall course, which is made up of 1 full block, course 2 arrangement header/half block. Also, the gang had familiarity with the wall stiffener and the wall joints as represented in Table 6.15 learning rate used to plot the learning curve for craft gang No: 1606 block work observed.

Table 6.16: Learning Rate for Blockwork Craft Gang 1607

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	J	K	L	M	O	P	Q
S/N	Y	X	XY	X2	n∑XY	∑X∑Y	n∑X2	(∑x)2	E-F	G-H	β=I/J	Ẏ	Ẋ	Bẋ	α=Ẏ-Bẋ	S=2b*100
1	6.2600	-	-	-							**-0.0963**					**93.5426**
2	6.2300	0.6931	4.3180	0.4804												
3	6.0100	1.1098	6.6699	1.2317												
4	5.9600	1.3862	8.2618	1.9216												
5	6.0500	1.6094	9.7369	2.5902												
6	6.0300	1.7917	10.8040	3.2102												
7	6.0300	1.9459	11.7338	3.7865												
8	6.0100	2.0794	12.4972	4.3239	3,923.1090	3,942.0200	1,521.7499	1,325.3823	-18.9110	196.3676		6.0156	2.0225	-0.1948	**6.2103**	
9	6.0500	2.1972	13.2931	4.8277												
10	5.9200	2.3025	13.6308	5.3015												
11	5.9900	2.3978	14.3628	5.7494												
12	5.9900	2.4849	14.8846	6.1747												
13	5.9500	2.5649	15.2612	6.5787												
14	6.0000	2.6390	15.8340	6.9643												
15	5.9600	2.7080	16.1397	7.3333												
16	5.9200	2.7725	16.4132	7.6868												
17	6.0000	2.8332	16.9992	8.0270												
18	5.9200	2.8903	17.1106	8.3538												
∑	108.2800	36.4058	217.9505	84.5417												

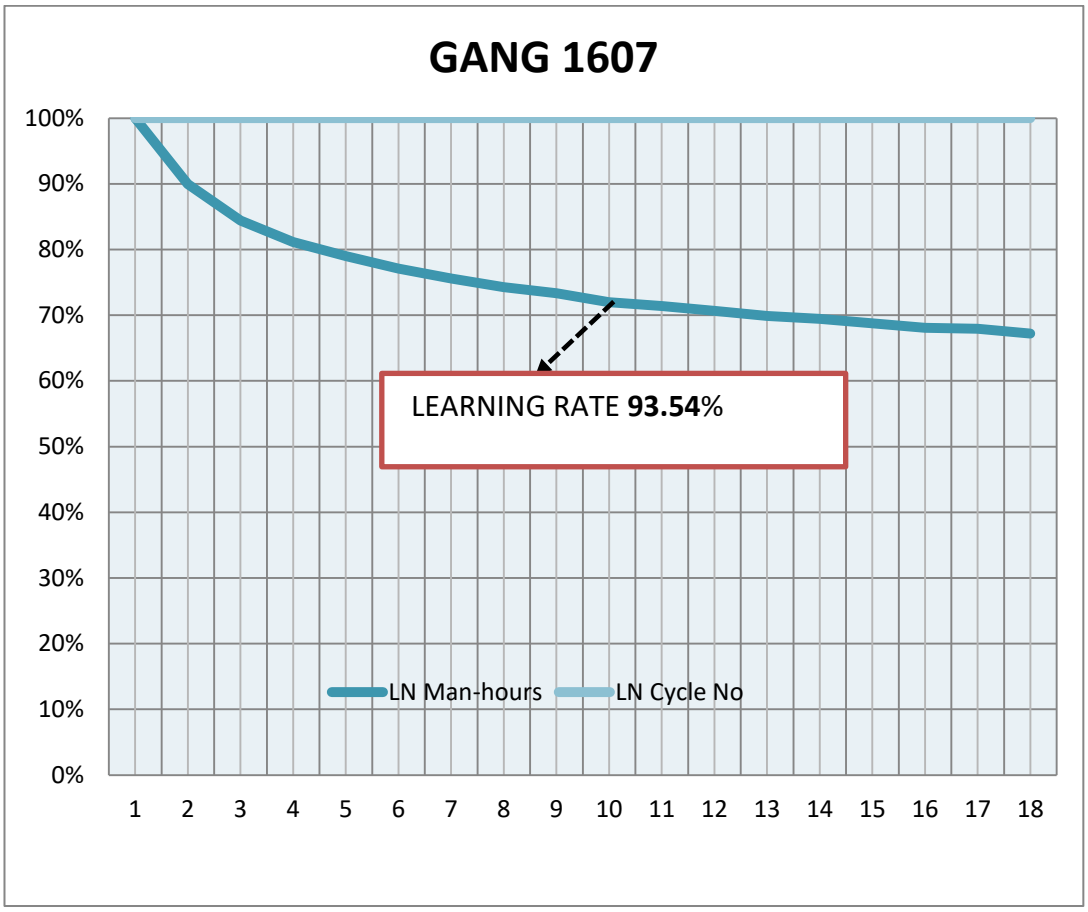

Figure 6.7: Relationship of Blockwork Gang Number 1607 &Cycle Number

Figure 6.7 represents the relationship of craft gang No: 1607 blockwork and cycle number observed productivity. The unit straight-line learning curve shown above is derived using simple linear regression in equation 6.2.

The learning rate (S), expressed as a percentage, is quantified by substituting the slope (b) shown in the equation 6.6 above, that is -0.10, into the learning rate equation as follows:

S = (2-0.10) x 100 = 93.54%, this is approximately 94% as indicated in Table 6.16 above, showing that the average learning rate is significant for the blockwork craft gang observed.

The overall regression model and coefficients' statistics are presented in Tables 6.8 and Appendix K13 respectively. The learning rate reveals a significant

learning of 93.54% as presented in figure 6.7. The learning is attributed to the craft gang familiarity with the details of the construction method of the block wall. In addition, the observed determinant could be attributed to motivation, skills and good behaviour of the craft gang workers.

Table 6.17: Summary of the Blockwork Crafts Gang's Learning Rate

PROJECT ID	TOTAL CYCLE NUMBER	AVERAGE MAN-HOURS	COEFFICIENT OF CORRELATION $\mathcal{R}$	LEARNING RATE ($\mathcal{S}$)	% GAIN	INFLUENCE OF LEARNING ON BLOCKWORK PRODUCTIVITY
G1601	26.00	6.02	-64.04	98.14		INSIGNIFICANT
					1.86	
G1602	24.00	5.98	-83.62	96.09		INSIGNIFICANT
					3.91	
G1603	16.00	5.99	-86.26	94.65		SIGNIFICANT
					5.35	
G1604	17.00	5.99	-87.32	93.76		SIGNIFICANT
					6.24	
G1605	17.00	6.00	-76.83	90.95		SIGNIFICANT
					9.05	
G1606	17.00	5.97	-96.75	92.36		SIGNIFICANT
					7.64	
G1607	18.00	6.02	-82.61	93.54		SIGNIFICANT
					6.46	
	AVERAGE		**-82.49**	**94.21**	**5.79**	SIGNIFICANT

Tables 6.17, summarise the quantitative observed results obtained from the craft gangs learning curves, using the straight line curve as a result of observing the craft gangs blockwork for the seven gangs' in the observed project, having identical wall configurations and composition. As shown in Table 6.17, the summary of the crafts gangs learning rate patterns on the influence of the craft gangs blockwork productivity.

The learning rate (S), expressed as a percentage, is quantified by substituting the slope (b) shown in equation 6.6 as presented in Table 6.9, that is -0.09, into the learning rate equation as follows;

S = (2-0.09) x 100 = 94.21%, as indicated in Table 6.9 above, showing that the overall average summary of the learning rate is significant for the blockwork craft gangs observed.

The influence of learning rate from the summary in Table 6.17 shows an average of 94.21% significant learning from the craft gangs blockwork observed. Craft gang number G1601 & number G1602, showed an insignificant reduction in the cycle number as blockwork increases, while gangs number G1603 to G1607 shows a significant learning rate (p-value ≥ 0.05). From the result summary, the average learning rate shows significant productivity improvement as presented in Figure 6.8.

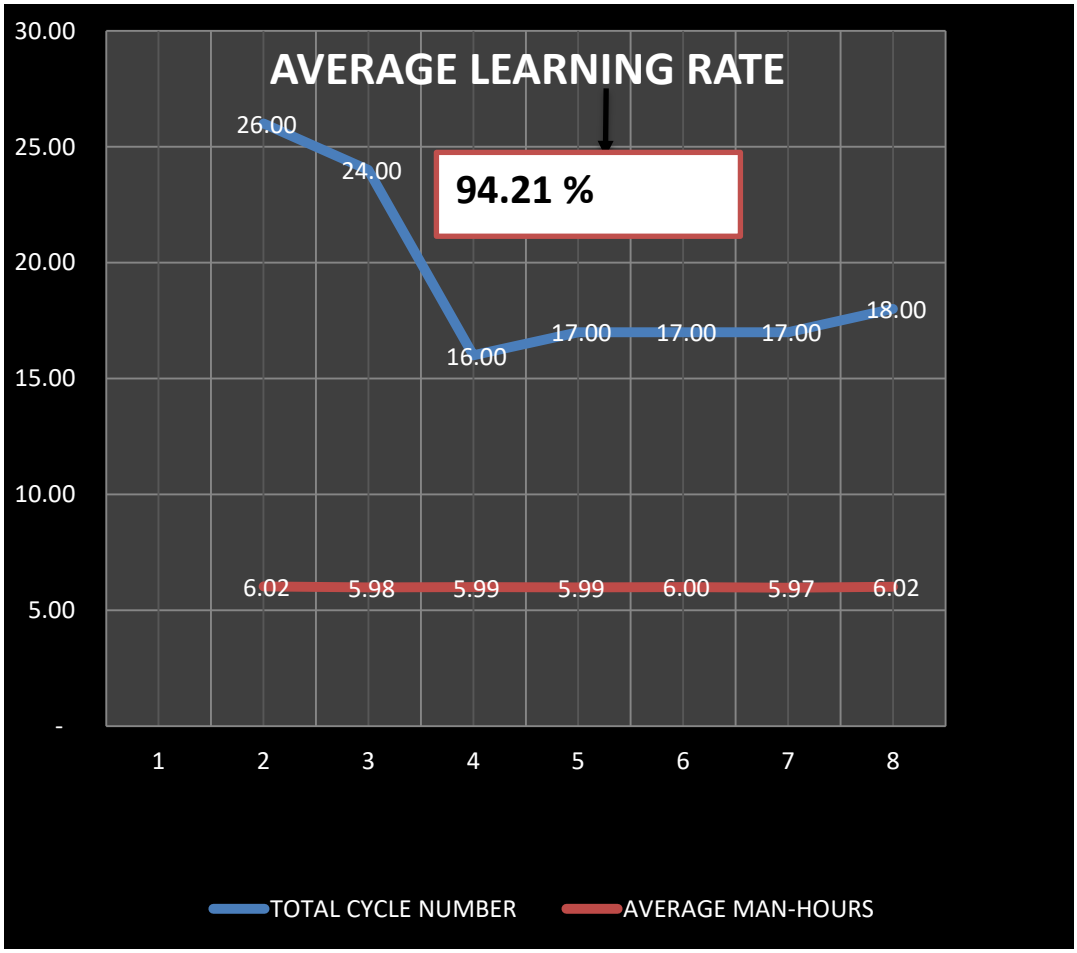

Figure 6.8: Summary of Average Learning Rate

It is important to further note that in all craft gangs observed, the craft gangs learning rates determined fell within the range of 98.14% and 90.95%. A learning rate value of 100% indicates that no learning has taken place, a value lower than 100% indicates the justification of the learning curve theory. A negative

relationship between man-hours and cycle numbers is determined, that is, man-hours decreases as the cycle numbers increases. In both cases, the learning theory is applicable to the blockwork craft gang observed. An insignificant impact of learning on blockwork craft gang as in gang G1601 and G1602 indicates that although a negative relationship between cycle numbers and man-hours of the blockwork gangs is determined, that is man-hours decreases as cycle numbers increases, its impact has no statistical significance.

The learning rate results in Table 6.17 summary are in agreement and also in disagreement with the outcomes of previous researchers in this field (Couto & Teixeira, 2005; Jarkas, 2005, 2010; Long et al., 2013; Thomas et al., 1986). This finding shows some evidence of the learning curve theory applicability to blockwork craft gang's productivity in the observed project. The patterns depicted may be attributed to the mechanism used to resolve the project-specific constraints.

Research had shown that the expected range of learning rate for most construction activities falls between 90 and 70% (Parker & Oglesby, 1972). What this means in simple terms is that if a certain hypothetical activity follows the 70% learning curve and if the cost to construct the first unit, for instance, is 1000 man-hours, then the cost to construct the next two units would be 90% 900 man-hours, and the cost to construct the next units would be 70% 700 man-hours, etc. However, as the number of units' increases, the production rate stabilises since operatives become completely familiar with the produced task or activity, the learning rate remains constant during the whole activity cycles.

6.4 Chapter summary

This chapter presented an analysis of the data collected through the work measurement observations. The observation sheets were designed to examine the influence on-site learning has in the optimisation of craft gang's blockwork construction productivity. The ordinary least squares method, commonly referred to as linear regression, was selected to form the basis for the statistical analysis in this research project. A significance level of 0.05 was selected as an acceptable measure of the reliability of inferences and was used in the quantitative part of this research study. The statistical significance in regression models was measured by the following parameters; coefficient correlation (R); coefficient of determination (R2) and p-value as supported by previous researchers (Jarkas, 2005; Sincich et al., 2002).

The next section of the chapter discussed the data coding system. Each craft gang observed and participant interviewed was given a unique set of numbers. The main purpose of this code was to identify the observed craft gang in the project in the analysis phase of this research. The code starts with the year number rounded to the last two digits, followed by the assigned number of the project. For example, if a certain craft gang bears the number 1601, we can conclude that this project craft gang was observed in the year 2016 and was given the number 01. Further, issues of reliability and validity, and data analysis were also discussed.

In the observed blockwork craft gangs, the dependent variable was the total productive input used to complete the activity of the monitored independent cycle. The repetitive blockwork activities were transformed into logarithmic values and the dependent variable, i.e. man-hours were plotted against the independent variable; the cycle number. Since the data were transformed into logarithmic values, a straight line plot should result as discussed. The next chapter moves the narrative from the presentation and analysis of observed data to discussion of the findings and interpretations for future practice of the research.

CHAPTER 7

7.0 DISCUSSION OF FINDINGS

The literature and empirical evidence has demonstrated that on-site learning provides the solution for improving the skills of prospective craftsmen and accordingly contributes to a craft gang's optimisation of productivity. This result derived from the analysis are discussed in this chapter from craft gangs' interview responses, supervisors and project managers and the observation data collections on the influence of prior and on-site learning in the optimisation of craft gangs' productivity. The research aim is to investigate how on-site blockwork craft gangs learning impacts productivity within the production environment and how the craft gangs deal with the inevitable problems that arise on-site in order to optimise their productivity.

The study questions that frame the argument are:

1. What are the project-specific constraints blockwork craft gangs may need to respond to, in order to optimise their productivity?
2. What is the relationship between the response mechanisms of blockwork craft gangs to specific project-based factors?
3. How can the impact and relative influence of on-site learning be measured on blockwork craft gang's productivity?

This chapter is structured on these lines: the project-specific constraints blockwork craft gangs may need to respond to, in order to optimise their productivity; the relationship between the response mechanisms; and, the craft gangs prior and on-site learning influence in the optimisation of craft gangs construction productivity.

7.1 Research Question 1 Findings

''What are the project-specific constraints blockwork craft gangs may need to respond to, in order to optimise their productivity''?

The first research question was discussed in this section, the project-specific constraints blockwork craft gangs may need to respond to in order to optimise their productivity. The interviewees discussed their project-specific constraints and their various opinions that the craft gangs needed to respond to, in order to optimise their productivity.

7.1.1 Human/Motivation Top Constraints

This refers to all constraints affecting construction craftsmen productivity which are attributable to the human/motivation factors where the project is being executed and as a result are location dependent. Table 7.1 outlines the top responds for human/motivation constraints which were extracted from Table 5.5 Combine (Craft Gangs & Management) Project – constraints.

Table 7.1: Human/Motivation Top Constraints

Project-specific Factors	Responses	%	Non Responses	%	Total
Lack of Promotion	12	80	3	20	15
Lack of Place of eating/Lunch break	11	73	4	27	15
Increase in Age of craft worker	11	73	4	27	15
Delay Payment	10	73	4	27	15
Attendance to social functions	10	67	5	33	15

Table 7.1 reveals that the top 5 human/motivation constraints influencing on-site learning are as follows: promotions, place of eating, and increase in workers age, payment delay, and attendance to social functions. There are the most significant

human/motivation related factors influencing craft gangs learning in the construction productivity.

7.1.1.1 Lack of Promotion

The result in Table 7.1 shows that promotions represent a responses rate of 80% of people questioned. This means that the possibility of promotion influences the productivity of the workers. This finding is similar to the research conducted by Adedokun et al. (2013), identified non-financial motivation and financial schemes and noted that the non-financial motivation schemes are more important in improving productivity. In addition, Adedokun et al. (2013) noted that all motivation schemes should be used constantly to monitored and ensure that there are no conflicts arising on the site. These findings are related to the study of Monese and Thwala (2014) who stated that job enrichment scheme is a technique for improving productivity which site management should consider.

7.1.1.2 Lack of Place of Eating

Lack of place of eating has the 2nd response rate of 73% in Table 7.1. Theory Z of Ouchi (1981) considered the emphasis on working conditions as a way of increasing productivity and optimisation of the company and self-esteem for its employees. Elton Mayo's observations from his study were partially different from Taylor's views that workers are motivated through economic self-interest. Mayo's findings demonstrated a basic concept: 'workplaces are social environments and within them, people are motivated by much more than economic self-interest.' A study conducted by Rucklidge and Farrell (2005) supported Mayo's findings stating that "understanding of the workplace as a social environment and that people are motivated by their role within this social environment,' these findings clearly shows that this is potentially transferable to the construction industry. In addition, these finding is related to the result of previous researchers (Enshassi et al., 2007; Ouchi, 1981; Rucklidge & Farrell, 2005). Therefore, provision of places for eating for workers could as well be a motivating factor to improve productivity.

7.1.1.3 Increase in Age of Worker

In Table 7.1 increase in age was selected by 73% of participants. A significant cause of the decline in productivity can be related to the age of workers cognitive abilities (Prskawetz, 2006). A research conducted by Prskawetz (2006) noted that there are large numbers of evidence that supports the opinion which states that in some stage of adulthood, cognitive abilities decline. From this evidence, it can be stated that the age of the workers influences job on-site productivity. In another related study, Verhaegen and Salthouse (1997) investigated a metadata of 91 studies that explained that mental abilities develop over the life span. These findings from these studies reveal that significant cognitive abilities, like speed and episodic memory, reasoning, decline significantly at the age of 50. The result of this study is similar to the findings of previous researchers (Enshassi et al., 2007; Prskawetz, 2006; Verhaegen & Salthouse, 1997) on increase in age factors affecting construction labour productivity.

7.1.1.4 Delay in Payment

In Table 7.1, delay in payment was selected in 73% response. Delay in payment of workers' wages could lead to dissatisfaction and reduced morale. This, in turn, will affect productivity, hence such factor is a de-motivating one. It has been generally believed by builders that workers' wages is an important motivational factor and incentive compensation has a direct and beneficial effect on productivity; more pay results in more productive work (Mojaheed, 2005; Monese & Thwala, 2014). These findings extend the findings of previous researchers (Enshassi et al., 2007; Monese & Thwala, 2014) on motivation factors affecting productivity.

7.1.1.5 Attendance to Social Functions

Attendance to social functions represents 67% response rate in Table 7.1. It is a common occurrence in Africa, particularly in the Nigerian South-South Geo-political Zone where people pay attention to social functions. This attitude promotes absenteeism which has been reported to have an effect on the productivity of construction workers. This result is related to the finding of

Alinaitwe et al. (2007), who noted that one of the constraints influencing labour productivity in the construction industry is attendance to social functions.

The findings in Table 7.1, human/motivation constraints clearly shows that these project constraints (promotions, place of eating, increase in workers age, payment delay, and attendance to social functions) influence craft gangs on-site productivity.

7.1.2 Project Management Constraints

This refers to the constraints influencing the productivity in the construction industry that is related to the on-site project and as a result, can be described as the on-site project specific constraints. In other words, these constraints could be peculiar to a particular on-site project and may therefore not be generalised for all construction projects. The top 5 management project-specific constraints affecting construction craft gang's productivity are represented in Table 7.2 below. These constraints are extracted from Table 5.5.

Table 7.2: Project Management Top Constraints

Project-specific Factors	Responses	%	No Responses	%	Total
Delay in material availability	11	73	4	27	15
Construction method	10	67	5	33	15
Confined Space	8	53	7	47	15
Specification and standards	8	53	7	47	15
Inspection delay	7	47	8	53	15

Table 7.2 represent response indices of 73%, 67%, and 53%, 53% and 47% respectively. From the interview responses, delay in material, construction method, confined space, specification and standards and inspection delay are the top project management constraints influencing craft gang's on-site learning in the construction productivity as extracted from Table 5.5.

7.1.2.1 Delay in Material Availability

Delay in material availability represents 73% responses rate in Table 7.2. Thomas et al. (2005) defined material management as the storage, allocation of delivery and handling spaces and resources for the primary aim of assisting the workers in order to minimise inefficiencies arising from congestion and surplus of material movement. The problems associated with adverse material management in the construction industry include supplying and shipping and this influence the labour productive time (Nyakazeya, 2012).

A research study conducted by Kazaz et al. (2008) noted that the problems that can appear in relation with the application of material management are: 1)running out of materials; 2) extensive multiple-handling of materials; 3) improperly sorted or marked materials, which makes identifying them difficult; 4) wrong or damaged materials that exceed acceptable specification tolerances, or production errors pointing to poor quality and 5) unsystematic flow of materials and production rates of materials in plant incongruous with those on site. These findings are in relation to previous research studies that supported that non-availability of material is one of the constraints that are frequently occurring as a productivity constraint facing building construction sites (Kazaz et al., 2008; Thomas et al., 2005).

7.1.2.2 Construction Method

In Table 7.2, construction method has a response rate of 67% influence on the craft gang's productivity. In a similar study, Enshassi et al. (2007) identified construction methods among 45 factors affecting construction labour productivity. These findings are in relationship with the recent researchers conducted by Tabassi et al. (2012) on the influence of construction methods and performance in a high rise construction of a public housing in Hong Kong and found out that the application of new technology in the construction industry and effective construction techniques have various influence on time, requirements of labour and costs.

7.1.2.3 Working within a Confined Space

In Table 7.2, working space has a responses rate of 53%. This refers to the working environmental conditions or the physical environment where work is been conducted. It also describes the particular characteristics of the work physical environment. This can be included as such features as amount of space and ambient levels of light and noise. Such constraints have been shown to have a significant influence on the labour and threaten the mental health, physical and on the other. The result extends to the findings of previous researchers (Enshassi et al., 2007) on the effect of working within a confined space on labour productivity.

7.1.2.4 Specification and Standardisation

In Table 7.2, specification and standardisation represent a responses rate of 53%. The response on specification and standardisation shows the need for standardisation in order to meet up with the requirement for the use of prefabrication as constraints that could affect labour productivity. This finding is consistent with the result of previous research conducted in Thailand on the critical factors affecting construction productivity and observed and ranked standardisation and specification 14th position among the 23 critical factors (Makulsawatudom et al., 2004).

7.1.2.5 Inspection Delay

In Table 7.2, inspection delay shows a response rate of 47% from the interview transcript. In the construction industry, all works which an approval is needed are subjected to an inspection as provided by the law in Code Enforcement Division/Section/Unit and in addition, some special types of construction shall also, have an approval by special inspectors for every procedure in the construction as specified in Section 3.7 of the code, however, delay in such inspection is capable of affecting labour productivity. This result is comparable to the findings of the study carried out by Alinaitwe et al. (2007) on inspection delay as one of the factors affecting construction labour productivity.

7.1.3 Environmental, Health and Safety Constraints

This refers to all constraints influencing the productivity of labour in the construction industry which can be related to the environment, health and safety

where the project is being executed and as a result are location dependent. Table 7.3, depicts environmental health and safety top five constraints extracted from Table 5.5 interview responses considered relevant to the study.

Table 7.3: Environmental, Health and Safety Top Constraints

Project-specific Factors	Responses	%	No Responses	%	Total
Poor health condition of workers	12	80	3	20	15
Healthy and safety condition.	8	53	7	47	15
Differences in language	6	40	9	60	15
Accident at work sites	6	40	9	60	15

7.1.3.1 Poor Health Condition of Workers

Table 7.3, shows that poor health condition of workers has a significant influence on the craft gangs with a responses rate of 80%. Many deaths are recorded through bad condition on sites, operational accidents and accumulated diseases (Agwu & Olele, 2014; Mustapha et al., 2015; Zakaria et al., 2010). Poor health of workers can undoubtedly affect productivity since health is related to the functionality of the individual. This result is similar to the findings of previous research investigated by Alinaitwe et al. (2007) on the poor health of workers as one of the factors identified to affect the productivity of construction workers.

7.1.3.2 Conditions of Health and Safety

Conditions of health and safety in Table 7.3 represent a responses rate of 53%. Safety performance relates to the Occupational Health and Safety (OHS) condition of construction sites. Idoro (2011) observed that the measures used by researchers for health and safety performance in the construction industry can be grouped into two categories as 1) objective measurements which are related to accident and injury and 2) subjective measurements which are based on perception of stakeholders' of environmental health and safety status of work. The

health and safety of workers have a significant effect on the productivity of workers. This result is in relation with the study carried out by previous researchers (Idoro, 2011; Kazaz et al., 2008).

7.1.3.3 Different Languages Spoken

Different languages spoken on a project has a responses rate of 40% in Table 7.3. According to Library of Congress –Federal Research Division, Nigeria is made up of over 250 ethnic groups and languages, the predominant groups are Hausa and Fulani with a record of 29%, Yoruba 21%, Igbo or Ibo 18%, and Ijaw 10%. In the northern part of Nigeria, is dominated traditionally by the Hausa and Fulani, in the southwest, the Yoruba's while the southeast is dominated by the Igbo's and in the Niger Delta region that is also called the south-south is dominated by the Ijaw's (Nigeria, 2009). It is not an uncommon scene with countries having such ethnic diversities for communication to be made in the local languages in order to be properly understood especially by illiterate workers. Hence, such practices could result in different languages spoken on the project which was observed as one of the constraints influencing the productivity of labour in the construction industry from the opinion of the interview responses.

These findings from this result are in relationship with the previous result of Dai et al. (2009), who noted from their study that one of the labour productivity constraints is related to different language that is spoken on site. Additionally, this result is associated with the previous research findings conducted by Victor (1992) stating that problem of language on a site is one among the top factors confronting the project managers on the smooth integration of both national and foreign migrants into a workforce (Victor, 1992). This finding is also in relation to the previous research result conducted by Mills (1972) in the USA and warned seriously concerning the problems of language amongst the different ethnic groups in the USA construction industry. Furthermore, the findings from this result are also in correlation with the previous research findings of Lim and Alum (1995) observed and ranked communication with foreign workers as the 5th most important factor affecting productivity improvement in Singaporean construction industry.

7.1.3.4 Accidents at Work Sites

Accident at work sites was identified by 40% of participants. Accidents are usually an unpleasant event which happens unexpectedly and causes injury or damage. According to Zakaria et al. (2010), the nature of accidents in the construction industry are multi-causal in nature, these accidents in most cases do not happen on site but however, it happens with a combination of causes and factors. Their findings noted that some of the reasons are related to the following: 1) workers' attitudes towards safety, 2) their knowledge and skill, and 3) their alertness and health. These factors and reasons are related to 1) pressure arising from peers, 2) education and training, 3) working hours, 4) payment schemes and 4) previous injuries or ill-health. These results are comparable with the study of previous researchers (Agwu & Olele, 2014; Mustapha et al., 2015) who identified accidents at work sites as top constraints influencing labour productivity in the construction industry.

The findings in Table 7.3, clearly shows that environmental health and safety remains a serious concern to construction stakeholders across the nation, these results are consistent with previous researchers (Agwu & Olele, 2014; Annan et al., 2015; Dodo, 2014; Mustapha et al., 2015).

7.2 Research Question 2 Findings

''What is the relationship between the response mechanisms of blockwork craft gangs to specific project-based factors''?

This section provides answers to the second research questions on the relationship between the response mechanisms of craft gangs to the project-specific constraints. The interviewees discussed their project-constraints and the various mechanisms used to resolve the project constraints in order to optimise their productivity.

7.2.1 Relationship between Gangs Skill Issues and the Mechanisms

The transcribed interview responses mechanisms on the project-constraints were analysed and inferences were drawn on the responses. The participants largely cohere in their agreement and in their mechanism used for resolving the project constraints recognising the need for on-site learning, by paring experience and inexperienced craft workers in the construction industry, especially in relation to issues such as: unskilled/inexperienced workers rework, misunderstanding among labourers and labourers' personal problem as demonstrated in the response mechanism in Table 5.6.

7.2.1.1 Inexperienced Workers

Inexperienced workers can be described as inadequate trained skilled construction productive workforce; it can also be related to a mismatch between skills available and skill required despite the adequate number of operatives. Skill being an ability to do something well could undoubtedly affect productivity, skills and competencies are inseparable. From the responses mechanisms in Table 5.6, Inexperience workforce is one of the constraints affecting productivity in the construction industry, this constraint can seriously impact the project duration time to complete the work and these can have a negative influence on the labour cost and the quality of the work. Similarly, from the interview responses mechanism, paring or a mixture of the inexperience craft gang member with the experience gang members where they can learn as a gang on-site can assist in

reducing the inefficiency of the craft worker. On-site learning will also, enhance the craft gang member competent in order to optimise productivity.

7.2.1.2 Rework

Rework can occur as a result of inexperience craft gang member, rework is the process of redoing a work that was not properly done and implemented the first time. A research conducted by the Construction Industry Institute (1990) acknowledge field rework as a process of activities that remove work that was previously done in a project, it is also regarded as activities that remove work that are previously installed in a construction project. Fayek et al. (2006) stated that rework that is caused as a result of the change of scope and order variations arising from clients is not related to the field rework. Similarly, the interview responses mechanism on rework in Table 5.6 reveals the importance of establishing a clear channel of communication between workers and the supervisors, so that the craft gangs' workers know where to expect instruction from in order to avoid interference with supervisors that may lead to rework. Also, there is the need to establish a quality plan, the quality plan presents the full work and how it should be done according to work plan, and this method can assist in reducing the issues of rework in order to improve craft gangs productivity.

7.2.1.3 Misunderstanding among Workers

More often than not disputes or conflicts arise between labourers and superintendents or supervisors on construction sites mainly because they are the closest in terms of working relationship and also in the line of authority; labourers are the direct subordinate of the foremen and supervisors. The magnitude of the effect of misunderstanding between craft gangs and supervisors on productivity was underscored in the interview responses on Table 5.4. Misunderstanding among workers can cause a disagreement between the operatives and the work bounds of each gang member; this can generate some mistakes that can result to rework, and consequently influence the productivity of craft gangs.

Similarly, Table 5.6 mechanisms show that this can be resolved by informing the craft gang's workers at the induction stage that there is no room for violence and

to forward their grievance to their foremen and supervisors. Essentially, this mechanism neutralises the negative effects of misunderstanding among workers.

7.2.1.4 Craft gangs personal problems/ Poor condition of workers

Craft gangs personal issues can result in mental distraction for labourers and this distraction can have a negative effect on the craft gang's safety more than the productivity of labour. Such craft gangs issues have the potential of disturbing the mind and emotion of a person thereby affecting the ability of the individual to concentrate on his or her work and this can result to rework or accident, labour personal problem was identified in the interview responses in Table 5.5, as a factor capable of affecting productivity. Similarly, the interview responses mechanism in Table 5.6 shows the need of the craft gangs to report their personal problem to their foremen/supervisors in order to receive adequate attention. This mechanism can assist in reducing the issues of craft gang's personal problem and improve productivity.

7.2.2 Relationship between Management Issues and the Mechanisms

Challenges in the smooth management of a project significantly influence craft gangs commitment in the optimisation of construction project improvement. As shown in Table 7.2, delay in material availability, construction method and working in a confined space are the major challenges influencing the productivity of the observed craft gangs workers.

7.2.2.1 Delay in Material Availability

The application of material management method is one of the problems that can be associated with improperly marked or sorted or shortage of required materials, multiple-handling of materials which can result in difficulty in identification of the materials, damaged or wrong materials that did not meet the standard of specification, or errors arising from production leading to low quality, inaccurate distribution of materials and the rate of materials production on site in relation to plant.

In connection with the delay in materials, this can cause low productivity of the craft gangs. Similarly, the material responses mechanism in Table 7.2 shows that

this can be resolved by knowing the quantities of materials needed and requesting in bulk from the suppliers and daily supplies are made when needed. This mechanism can assist in reducing the issues of materials delay and improve craft gangs productivity.

7.2.2.2 Construction Method

The uses of new construction technology can affect construction methods that may have an impact on time, labour requirements and costs. Construction methods are one among other constraints affecting craft gangs construction productivity. The nature of construction project might necessitate high quality of the materials and workmanship and meet the required construction method may affect the productivity of craft gangs. The method of construction can affect the way the workers work, for example, if the workers want to lay blocks exceeding a 3M height of the wall and the method statement says 3M, they have to comply. It guides the operation and not the quality.

Similarly, the responses mechanism in Table 5.7 reveals that this issue can be resolved by ensuring that the workers follow up the method instruction as specified and with the assistance of the method team or supervisors who visit the sites to make sure that the methods of construction are being implemented. Similarly, following the method instruction as specified and with the assistance of the method team or supervisors will help to minimise the challenges of construction method.

7.2.2.3 Working within a Confined Space

Working within confine space in a project is a condition that focuses on characteristic a particular physical environment in a project site. This can be related to the amount of ambient space, levels of noise and light. These constraints have been observed to have an influence on the craft gang's productivity and subsequently threaten the mental and physical health of the craft gang's workers. Similarly, the effect of working within a confined space on labour productivity causes a delay in the execution of work. Similarly, this issue is resolved through planning a program of works as expressed in Table 5.7 responses mechanism.

Essentially, this mechanism neutralises the negative effects of the working in a confined space.

7.2.3 Relationship between Environmental, Health and Safety Issues and the Mechanisms

Challenges relating to environmental issues of the project significantly influence the craft gangs' commitment in the project. As shown in Table 5.7 and 5.8, different Languages Spoken, poor health of workers and accidents at work sites are the major challenges influencing the productivity of craft gangs.

7.2.3.1 Different Languages Spoken

Nigeria has 250 ethnic groups (Nigeria, 2009) and different nationalities are mostly seen on the Nigerian construction project sites. These construction sites are predominated by French, Germans, Lebanese and Italians making the highest number of the multinational firms. However, these firms are faced with issues arising from many different languages spoken on site; the use of English is confined to a small proportion of the population and cannot be confined as the main medium of communication because the only little proportion of the construction workers can speak English fluently. These little proportions are usually the supervisors and managers, who are highly task-orientated and do not have enough time or the opportunity to enhance their multi-lingual abilities.

Most of the supervisors stated that it is not unusual to communicating with different groups of 10 languages on a project site and that in most cases non-speaking English group are more reluctant to communicate with supervisors compared to English speaking workers. However, there is a perception of supervisors who believed that absent of a common language in the construction industry might have a significant influence that can lead to frustration and this can affect the efficiency of the workers. However, this relationship was weak for multi-lingual workers. In addition, participants did not agree that none-English workers suffer the high risk of accident on site, furthermore, some issues of concern were express by some workers stating that these workers passed through the safety induction test by the unions without the full understanding of the health and safety procedure on the site. Some supervisors and managers have

acknowledged the likely danger such group may face and has accordingly adjusted their managerial strategy.

Similarly, the 250 ethnic groups in Nigeria could result in different languages spoken on the project site which was identified as a constraint that can affect the productivity of the craft gangs' from the observation and the interview response. Similarly, Table 5.8 environmental issues and responses mechanism reveals that these challenges are resolved by grouping the on-site craft gangs into like group according to their language and religion. This will enable closer supervision and the constant given out of instructions in various mediums, the techniques is acceptable to the supervisors as it is regarded as an unavoidable consequence of dealing with a multi-cultural workforce. Relatedly, the grouping of craft gangs into like group will help to minimise the challenges of different languages spoken on the construction site.

7.2.3.2 Poor Health Condition of Workers

Poor health of workers can undoubtedly affect productivity since health is related to the functionality of the individual. Poor health of workers is one of the constraints identified to affect the productivity of construction craft gangs. Poor health of workers can result from any of the following: bad condition on sites, operational accidents and accumulated diseases. Similarly, the poor health condition of worker affects the productivity of the craft gangs. Table 5.9 health and safety response and mechanism show that these issues can be resolved through the provision of site clinic with certified nurses who are on-site to administer medication on minor health cases, and on very serious cases the worker is referred to a hospital. Also, is the need to investigate and record the health condition of the workers on site on a weekly or monthly basis, the need is to evaluate the cause and to make possible the correction if the effect is due to poor site condition. Similarly, the implementation of these mechanisms will help to minimise the challenges of the poor health of workers on the construction site.

7.2.3.3 Accidents at Work Sites

Table 5.9, health and safety issues and responses mechanisms show that accidental issues are resolved in the site clinic for minor injuries, but if the case is

beyond the site clinic, the worker is referred to the company approved hospital. In addition, there is the need for induction of all the workers on safety measures every week by the health and safety department. Also, is the need to provide all the safety resources including safety boots, helmets and other safety measures in order to minimise accidental cases. Similarly, the implementation of the above mechanisms will assist in minimising accidents at work sites.

7.3 Research Question 3 Findings

''How can the impact and relative influence of on-site learning be measured on blockwork craft gang's productivity''?

This section discusses the answers to the third research question, "How can the impact and relative influence of on-site learning be measured on blockwork craft gang's productivity?" The observation analysis from the regression coefficients which was used to determine the learning rate table and curve reveals the significant impact and influence of how prior and on-site-learning assist craft gang's to deal with project constraints in order to optimise productivity.

The learning curve theory according to Jarkas (2010) "states that whenever the quantities of production doubles, the unit or total average cost requirement for the production, i.e., cost, man-hours, or time, reduces with a proportion of the percentage of the first unit or the cumulative average rate". This percentage can be described as the rate of learning; it explained the rate of learning achieved during the process. However, it determines the slop of learning curve. The lesser the rate of learning, the better the achieved learning and if the rate of learning is 100% it means that no learning has been achieved.

7.3.1 Craft Gang's Number: 1601 & 1602 Learning Significance

Figure 6.1 and 6.2 in Chapter 6.3, represent Craft gang's number: 1601 & 1602 learning rate. The association between the man-hours and the cycle numbers was derived using the straight line unit equation in 6.2. The learning rate reveals an insignificant learning rate of 98.14% and 96.09% respectively, which is insignificant with reference to the 0.05% level of the significance level of acceptance. The finding shows that the slope is unimportantly different from zero.

From the observed block craft gangs represented in Figure 6.1 and 6.2 in Chapter 6 shows a weak optimisation in the block layers craft gangs. From the findings on the above learning rates, the influence of experience and learning are insignificant in the craft gang's blockwork in the observed project site. Additionally, optimisation of the craft gangs' productivity did not decrease significantly as the

cycle number increased as stated in the learning curve theory. The craft gang numbers 1601 and 1602 observed productivity determinant indicate insignificant rates of learning which were attributed to the craft gang inability to deal with the following details of construction method and method statement as:

- Variation in blockwork course arrangement: The arrangement, of course, is made up of the full block, course 2 arrangement header/half block.
- Variability in wall stiffener: wall stiffener of 100 x 200 mm is introduced at every third course).
- Variability in wall joints: Wall joints to be thoroughly rubbed on both sides after each course.
- Variation in Block wall Re-bar to be lapped with starters 600 mm for Dia. 12 and
- Variability of wall columns to be steadily filled with concrete at each course.

These findings in Figure 6.1 and 6.2 are conflicting to the findings in the literature that number of cycles that learning occurs varies from one activity to another. Thomas el al. (1986) stated that the levels of complexity about operation between activities are different. The rates of learning are different as a result; craft gang's productivity in the observed gangs reduced in the last two weeks which was not adequately evident in the blockwork laying activities in this project of study. This result is also, conflicting with the findings of Wideman (1994) who conducted a research on the tub bath effect in high-rise repetitive construction and noted that the bath tub reflects the shape of the profile of man-hours per floor plotted against floor numbers. Their findings show that the tub bath learning effect shows a progressive increase in labour productivity in the first floors and gradually reduced in the last floors. Productivity may increase in many more number of floors than claimed in previous studies.

The findings in Figure 6.1 and 6.2 are in relation to the findings of Jarkas (2010) and Jarkas and Radosavljevic (2013). These researchers investigated the

application of the learning curve model to reinforcement bar and formwork labour productivity of building floors and found little evidence in the productivity. Their study further mentioned four reasons to support their findings: 1) the nature of the formwork/rebar operations; 2) distinction between productivity improvement due to “trade learning” and “site acquaintance”; 3) psychological effect; and 4) the influence of learning may have been overshadowed by other project-related and/or human factors (e.g. change in working methods).

7.3.2 Craft Gang Number: 1603 Learning Significance

Figure 6.3 in Chapter 6.3, represent craft gang No: 1603 observed blockwork productivity. The learning rate reveals a significant learning of 94.65% as presented in Figure 6.3. With the learning rates above, the effect of learning and experience is significant for the craft gang blockwork laying activity in the observed project study. In addition, productivity improvement of the block work activity increased in cycle number 8-16 in the observed man hours as shown in Figure 6.3. This can be explained that the craft gang block layers were able to deal with the challenges concerning the details of the construction method of the block wall.

However, one of the craft gang members from the observation seemed not to have a clear understanding of the safety culture of the project. The new craft gang member did not utilise the safety protection materials (despite the availability of this equipment on site) when laying the blocks due to lack of prior learning on the safety requirement. These results extend the findings in the literature, that number of cycles that learning occurs is different from activity to another. (Jarkas, 2005; Thomas et al., 1986; Wideman, 1994) Productivity may increase in more number of weeks than claimed in previous studies. (Couto & Teixeira, 2005) The learning rate of this craft gang blockwork activity in the project study improved as the cycle no increased (cycle 8, 9, 10, 11, 13 and 15). From the result, the learning in craft gang number 1603 blockwork observed has an effect on productivity.

7.3.3 Gang Numbers: 1604 and 1607 Learning Significance

Figure 6.4 and 6.7 in Chapter 6.3 pages 138 and 143 respectively, represent craft gang numbers: 1604 & 1607 observed learning rate for the blockwork layers

productivity. The learning rate reveals 93.76% and 93.54% respectively; this rate was significant for optimisation of the craft gangs in the in the observed project. In addition, productivity improvement of the blockwork activity increased in cycle number 9-17 for craft gang number 1604 and also, improved in cycle number 9, 10 and 12-17 for craft gang number 1607 in the observation man-hours as shown in Figure 6.4 and 6.7.

The productivity evaluation determinant indicated the significant rate of learning in this craft gang's blockwork laying which could be attributed to the gangs ability to deal with challenges such as motivation, inadequate skills and construction method. The gangs have detail familiarity with the details of the construction method of the block wall. These findings contradict the recent findings of Jarkas (2010). These authors found that there was ''little evidence in the applicability of the learning curve theory to rebar and formwork labour productivity of building floors''. The learning rates found in the craft gang's blockwork is in a relationship with the findings of Couto and Teixeira (2005) who observed a significant rate of learning which not less than 85% was.

7.3.4 Craft Gangs Numbers: 1605 and 1606 Learning Significance

The learning rate represented in Figure 6.5 and 6.6 shows a significant learning rate of 90.95% and 92.36% respectively, compared to the learning rate of gangs numbers 1601 and 1602 within a similar method of construction in the observed project. The association among the man-hours and the cycle numbers was derived using the unit straight line equation in 6.2. The learning rate reveals an improvement of 90.95% and 92.37% respectively, which is significant (p-value $\geq$ 0.05%). The result indicates a significant optimisation in the craft gang's blocks laying work activity. Thus, we can state that a significant learning rate has occurred in the observed craft gangs. In addition, productivity improvement of the craft gang's blockwork activity improved in cycle numbers 9-10, 12-17 for Gang 1605, and cycle numbers 7-17 for Gang 1606, in the observation man hours as shown in Figure 6.5 and 6.6.

The craft gang productivity optimisation in this project could be attributed to the ability of the craft gang to deal with the following challenges: the details of

construction method, health and safety management and understanding among craft gang members. These findings extend the learning curve theory according to Thomas et al. (1986) who stated that labour inputs are expected to decrease by a certain percentage as the cycle number increases. This finding is in conformity with the basic principle underlying the learning curve theory. However, these findings contradict the recent findings of Jarkas (2010), stating that majority of buildings observed exhibited either an increase or a negligible reduction in labour inputs as the cycle number of recurring floors increased (Jarkas, 2010). These finding also relates to the recent study of Long et al. (2013) on form work labour productivity and noted increases in the first five floors of construction.

7.3.5 Summary of Blockwork Craft Gangs Average Learning

Tables 6.17, summarise the quantitative observed results obtained from the craft gangs learning rate, using the straight line curve as a result of observing the craft gangs blockwork laying for the seven craft gangs in the observed project, having identical wall configurations and composition. As shown in Table 6.17, the summary of the craft gangs learning rate patterns on the influence of the craft gangs blockwork productivity. The influence of learning rate from the summary in Table 6.17 shows an average of 94.21% learning rate from the craft gangs blockwork observed. From the result summary, the average learning rate shows significant productivity improvement as presented in Figure 6.8. These findings extend the recent study of Long et al. (2013), on the labour productivity of formwork activity and observed increases in the first five floors of construction.

7.4 Chapter Summary

This chapter discussed the research findings. The empirical evidence has demonstrated that on-site learning provides the platform for improving the abilities of the craft gang's through the development of their skills and accordingly contributes to craft gangs' optimisation in the building construction industry. The results derived from the analysis of the interview responses from the craft gangs, supervisors and project managers in the observation data

collections on the influence on prior and on-site learning in the optimisation of craft gang's productivity are in a relationship with previous research study.

The result of the influence of the model of learning to craft gang's blockwork optimisation in the observed construction project seems to support the findings of other researchers. The project-specific based constraints were investigated with the relationship to the mechanism employ by the craft gangs. This study revealed a strong relationship between the project specific constraints, i.e. labour challenges, project management issues, environmental challenges, health and safety and material challenges, and the mechanisms employ to resolve the challenges.

The implementation of these research findings was presented in the form of suggestions to be implemented during the construction phase. It is important to note, however, that the unique influences of the project-specific constraints presented in this study are to be interpreted only within related context. The recommendations for the craft gangs' labour productivity improvements are summarised and presented.

CHAPTER 8

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusion

This thesis explored the problem of the deficiency in craftsmen knowledge, adoption of basic hand tools and equipment, delay in supply of materials and variation in the process of construction that reduces the productivity approaches of contractors craftsmen on site that has led to low levels of productivity in the construction industry (Alinaitwe et al., 2007; Odusami & Unoma, 2011). This low productivity means project objectives are not met with the consequence of time and cost overruns (Ameh & Odusami, 2002; Association of Senior Civil Servants of Nigeria, 2001; Couto & Teixeira, 2005; Jarkas, 2010).

Previous studies on craft gangs' productivity in construction have been limited to identifying the factors affecting labour productivity and determining their performance. These studies have mainly utilised perception surveys and interviews focusing on the key constraints and investigation to quantify craftsman's performance. One would expect that on-site gang learning impacts on the productivity, subject to project specific constraints. However, no studies have been conducted on how on-site blockwork craft gangs learning impacts productivity within the production environment and how the craft gangs deal with the inevitable problems that arise on-site in order to optimise their productivity.

The challenges facing the human resource and it impact problem and its pervasive effects indicate the need for concerted action to improve their technical and managerial skills. In view of this, this research aim was to investigate how on-site blockwork craft gangs learning impacts productivity within the production environment and how the craft gangs deal with the inevitable problems that arise on-site in order to optimise their productivity.

The investigation comprises of information regarding the participant organisations, demographic and details of the blockwork layers craft gangs' prior

learning and the participants' views on the project specific constraints that influence the craft gangs learning outcomes and also, their views on the successful mechanism used in resolving the project specific challenges. Descriptive statistics with frequency distribution was employed in the presentation of interviews findings and where applicable, quotes from the participants were included to explain important views.

The qualitative findings from the combined opinions of the craft gangs, supervisors and project managers clearly show the level of constraints with the highest frequency that the blockwork craft gangs need to respond to, in order to optimise their productivity. The responses mechanisms reveals various interventions that the craft gangs need to employed in order to resolve the project-specific constraints such as labour skill challenges and their mechanisms, project management challenges and their mechanisms, environmental challenges and their mechanisms, health and safety related challenges and their mechanisms in order to optimise the craft gangs' productivity.

In order to conduct an objective investigation on how craft gangs adapt to the production environment on site in order to optimise their productivity, the researcher employed the use of straight-line learning model for the investigation of the application of learning curve model to the blockwork craft gangs. The learning curve model application in the construction industry is associated with some challenges. Although, there have been some unfavourable comments towards the application of the learning theory to construction industry, however previous research studies have supported the significance of this theory to craft gangs' productivity in the construction industry (Couto & Teixeira, 2005; Norfleet, 2004).

The linear regression method that is also known as ordinary least squares method was applied in the quantitative analysis of this study with an acceptance significant level of 5% reliability measure of inferences. The significant relationship between the recorded man-hours and cycle number was measured with correlation coefficient, (R) and coefficient of determination as supported by previous researchers (Jarkas, 2005; Sincich et al., 2002). In the observed

blockwork craft gangs, the independent variable are the cycle numbers while the dependent variables is the observed recorded time. The repetitive blockwork activities were converted into logarithmic figures and the dependent variable was plotted against the independent variable, subsequently, the data that were converted into logarithmic figures resulted in a straight line graph.

The findings of the influence of on-site learning to the craft gang's blockwork productivity in the observed construction project seem to support the findings from other researchers who research on formwork, precast concrete and reinforcement builderbility factors (Couto & Teixeira, 2005; Jarkas, 2005, 2010; Long et al., 2013; Thomas et al., 1986). The project-specific based constraints were investigated in relationships with the mechanism employed by the craft gangs. These findings revealed a strong relationship between the project specific constraints, i.e. Blockwork craft gangs' challenges, project management challenges, environmental challenges, health and safety and material challenges, and the mechanisms employed to resolve the challenges.

The findings of this research study were introduced in the form of practical implementation through recommendations to be introduced during the construction phase. However, it is important to note that these recommendations were supported with attendance consequences on the craft gang's productivity. The influences of the project specific constraints highlighted on the presented tables are to be interpreted within related context.

Several results and conclusions relating to the observed craft gang's blockwork learning have emerged from this research study and the craft gang's productivity improvements suggestions are summarised.

8.2 Limitations of the Study

This study investigates how on-site learning assist craft gangs to adapt to the production environment on site in order to optimise their productivity as the aim of the study and employed a mixed method research in investigating the project-specific constraints and mechanisms blockwork craft gangs employed, in order to

optimise productivity. It reached specific conclusions about the relationship between the project specific constraints and the response mechanisms employed to resolve the constraints and the influence of prior and on-site learning in the optimisation of craft gangs' productivity in the construction industry. However, there are some limitations to this research, including:

One of the problems encountered during the preliminary stage of data collection was access to the project sites this was due to reason that some organisations contacted did not respond positively in granting access to their site. This may be due to time constraints or confidentiality issues. However other organisations welcomed the research to be conducted in their organisation and subsequently, allowed access to their projects and employees for the interviews and observations.

Due to limited access to some organisation contacted, the surveys and observation investigated in this research study were limited to FCDA on-going construction projects in Abuja, Nigeria. Other construction projects outside the FCDA projects were excluded in this research sample. The limitation of this scenario is that results generated from this study may not be generalised with other construction companies in other areas or in other countries other than the FCDA in Nigeria.

In addition, challenges faced by the researcher in the observation of the blockwork craft gangs work study was at the preliminary stage, the time and effort spent in building the relationship with the craft gangs, supervisors and the project manager, in order to ensure that the access to project site was granted easier.

However, there are different work pressures for the various participants and there was often a rescheduling of meetings in the response to the researcher's enquiries. The researcher observed that there are always challenges in arranging convenient times for interviews with project managers, supervisors and the craft gangs. There were also unforeseen delays in the briefing of the craft gangs on the observation participant information sheet and the filling of the consent form.

Furthermore, there were other unforeseen challenges that were included in the interview schedule but in this case did not actually occurred. These challenges are

difficult to predict, however, such issues were addressed by the researcher by scheduling in advance for the interviews data collection, as in this instance, the researcher will begin the interview earlier than scheduled. The researcher could have also communicated more forcefully to participants on the urgency of the time schedule but this had the added risk of harming the relations with the participants.

8.3 Contributions of Research

The aim of this study is to investigate how on-site blockwork craft gang's learning impacts productivity within a project-specific environment and how the craft gangs deal with the inevitable problems that arise on-site in order to optimise their productivity. So far most prior research studies on construction labour productivity have been limited to identifying the factors affecting labour productivity and determining their impact upon craftsmen performance. These studies have mainly utilised perception surveys and interviews focusing on the key constraints and attempting to quantify the performance of the craftsmen. In this study, the researcher has tried to shift the focus to the gangs' issues and this has led to the development of the on-site blockwork craft gangs' productivity model which is based on contemporary issues. This model or the concept is the blockwork craft gangs' learning curve model which is issue based.

8.3.1 Theoretical Contributions

This research contributes to the development of an insight into the changing methods of blockwork craft gangs learning and its influence on construction craft gang's productivity. The study took a holistic approach in analysing the blockwork craft gangs project-level and trade-level productivity employing the use of the straight line learning curve modelling approaches.

The repetition effect of blockwork has a significant positive influence on blockwork gangs' productivity. Blockwork craft gangs observed at the macro level shows approximately average learning of 94.21%. A learning rate value of 100% indicates that no learning has taken place. Learning rate lesser than 100%, determine the justification of the learning curve theory. A negative correlation

between cycle numbers and man-hours was determined, that is, recorded man-hours decrease as the repetitive cycle numbers increases. From the result, the theory of learning model is applicable in the blockwork craft gang observed. In addition, the important influence of blockwork craft gangs' was revealed in wall activities: with average gains in on-site craft gang's productivity achieved in linear blockwork laying. This can be further explained that if a blockwork activity is expected to follow the 90% learning curve model and if the cost to erect the first unit of the building, for example, is 500 man-hours, then to construct the next subsequent block of building will cost 94.21% of 500 man-hours or 471 man-hours.

The study will essentially fill the gap in the literature on construction craft gangs' productivity constraints and the response mechanism for a practitioner's approach, especially in the context of Nigeria construction industry. The "construction craft gangs productivity responses mechanism" generated in this study, will provide a methodological instrument for addressing the major constraints influencing craft gangs productivity. This instrument will also open the door for future research on how project specific constraints and responses mechanism assists blockwork craft gangs to adapt to the production environment on site in order to improve productivity.

Complex phenomena such as the influence of on-site blockwork craft gangs learning in the optimisation of construction productivity may be challenging in measuring it quantitatively. Qualitative techniques can be useful in determining and characterising blockwork gang's productivity dynamics that can influence outcomes, including craft gangs' prior learning, promotions, the poor health condition of workers, delay in materials availability, the place for eating, increase in workers age, payment delay among others. This qualitative part of this study examined the project specific constraints influencing blockwork craft gangs' productivity and the mechanism used to resolve the inevitable issues affecting the blockwork gangs learning in the observed project. The researcher conducted interviews with 8 blockwork craft gangs with an average of 4 craft gang members per gang site and 7 management staffs to investigate the project specific

constraints and the mechanism used to resolve the various constraints. The findings generated a project specific constraints and the mechanism that will influence the success of blockwork craft gang's productivity. The quantified influence of project specific constraints on blockwork craft gangs optimisation in the various craft gangs observed can be used to measure the impact of the constraints on the selected craft gangs size members and costs.

8.3.2 Contributions to Practice

The findings of this investigation into the role of on-site learning in the optimisation of craft gang's productivity reveal the significant impact of the theory of learning on blockwork crafts gangs in the observed project site and may be used to provide accurate estimates for optimisation of craft gangs' productivity, activity durations or in resource planning. The important impact of the learning on craft gangs' determined in this research study can also be introduced as an important tool in the planning, to fast-track the effective utilisation of construction work in the delivery of blockwork materials and to reduce the queue time for material delivery arising from unloading and waiting on sites.

Additionally, these research findings will have a broader consequence in the construction industry. Despite that this research study focused on blockwork construction and the basic principles of application of construction method, blockwork repetitive work and standardisation, applying other types of construction materials like timbering, tilling, rendering and reinforcement steel can also have a positive influence on the construction craft gang's productivity process.

Construction supervisors, project managers and other industry practitioners can use the blockwork learning model and the response mechanism in understanding whether or not their management techniques are improving construction productivity. This will enable clients and those in the supply chain access to a possible means of changing their methods and practices in order to improve their productivity.

The study also, contributes to the development of project-specific constraints craft gangs may need to deal with in order to optimise productivity. The project-specific constraints generated in this study will help craft gangs, contractors and project managers to understand the project based constraints they need to deal with on-site in order to improve productivity. The project based constraints will fill the gap generated by a deficiency of pragmatic evidence in the literature for on-site blockwork craft gangs' constraints influencing productivity in the construction industry, especially in the context of Nigeria.

The outcomes of this investigation can also be used to advance a programme "Blockwork Production Support System". Such a programme can be advantageous for ratifying the issues facing on-site blockwork craft gangs learning and the specific-project constraints mechanism and to make them accessible to contractors and subcontractors to advance project improvement in a demand that is quicker and lesser cost delivery of completed buildings projects.

Furthermore, the findings of this research have broader suggestions within the industry. Though this study concentrated on blockwork construction, the application of the response mechanism can also be applied to other crafts gangs' trade like form work, concrete work, reinforcement and finishing and can have a noteworthy impact on the productivity.

8.4 Recommendations

This study investigated several aspects of project specific constraints influencing the activities of on-site craft gangs' blockwork productivity elements. On the other hand, this research has open-up some issues that required additional examination so that their influences on crafts gangs' productivity can be substantiated and established.

In this study, project specific constraints influencing the optimisation of craft gangs' blockwork productivity were investigated and determine other types of blockwork such as solid, hollow and u-block wall. U-block and solid walls would be the focuses of upcoming investigation.

The consequence of wall stiffener introduced at every third course of blockwork wall joints to be thoroughly rubbed on both sides after each course and block wall re-bar to be lapped with starters on craft gangs blockwork productivity could be investigated.

The investigation was limited to straight or linear walls due to the limited number of curved walls encountered during the observed projects. It is recommended that the influence of curved walls on craft gang's labour productivity be investigated further.

The various heights of walls and columns observed during the observation study in the project site were ranging from 4.00m to 5.00m. These heights are of negligible difference. Therefore, the impact of height on walls has on the blockwork craft gangs productivity could not be determined. It is on this note that it is suggested therefore that the impact of height on craft gang's blockwork be investigated further.

The majority of the resulting outcomes are in a relationship with previous research outcome and the results on the application of the learning curve model in this research are a mixed finding. In order to state the conclusions of this research, it is suggested that this exploration is replicated with a more number of cycles, i.e. investigation of several block walls in the building up to the last seventeen floors.

Finally, it is also suggested that other models used in learning theory, like piecewise or exponential, cubic model and the Stanford "8" model be explored in the investigation of the impact of the phenomenon of learning theory on blockwork craft gang's productivity.

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Appendix A: Interview Questionnaire



INTERVIEW QUESTIONS FOR BLOCK LAYERS AND SUPERVISORS

Demographic Questions

Company Name:

Gang's No:

No in a Gang:

Length of Stay with Employer:

Years of Experience:

i. Prior Learning and Development

1. How important do you think on-site craft gang's/group learning is to your organizations in order to understand how the craft gang's adapt to the production environment on site to maintain or improve productivity?
2. Does your firm offer on-site craft gang's/group learning?
3. What are the types of prior learning/training your craft (bricklayers) gangs need in order to adapt to the production environment on site to maintain productivity?

ii. Project Specific Factors/Issues

4. What are the motivations related factors your craft (bricklayers) gangs adapt to in the production environment on site to maintain productivity?
5. What are the technological related factors the craft (bricklayers) gangs adapt to in the production environment on site to maintain productivity?
6. What are the management related factors the craft (bricklayers) gangs adapt to in the production environment on site to maintain productivity?
7. What are the material related factors the craft (bricklayers) gangs adapt to in the production environment on site to maintain productivity?
8. What are the plants and equipment related factors the craft (bricklayers) gangs adapt to in the production environment on site to maintain productivity?
9. What are the environmental related factors the craft (bricklayers) gangs adapt to in the production environment on site to maintain productivity?

iii. Response to Project Specific Factors

10. How does your craft (bricklayers) gangs' response to the project specific related factors in order to maintain or improve productivity in your firm?
    a. Motivations
    b. Technological
    c. Management
    d. Material
    e. Plants and equipment
    f. Environmental

11. In your opinion, does the skills and knowledge acquired during the craft gang's learning maintain or improve productivity?
    a. Yes ☐ b. No ☐, If yes, How? If no, why?
12. In your opinion, is there any relationship between the specific responses to the specific project factors?

Do you have any other comments about on-site craft gang's learning factors influencing construction project optimization?

Appendix B: Observation Sheet



WORK STUDY DATA COLLECTION FORM								
FIRM:			STUDY NO:		DATE:			
GANG NO:			START TIME:					
NO. OF SKILLED:	NO. OF UNSKILLED:		FINISH TIME:					
NO. OF OPERATORS IN GANG:			TOTAL OBSERVED TIME:					
CONTRACT DURATION:			WALL THICKNESS:	100mm ☐	150mm ☐			
TYPE OF BUILDING	BUNGALOW ☐		225mm ☐	OTHER… ☐				
STOREY BUILDING ☐	OTHER… ☐		WALL HEIGHT	0-1.5m ☐				
NO. OF FLOORS:			1.5m – 2.1m ☐	2.1m – 3.0m ☐				
WEATHER CONDITION:			Above 3.0m ☐					
			OBSERVER:					
ELEMENT DESCRIPTION			**R**	**WR**	**OT**	**BT**	**AL**	**ST**	**REMARK**
Discharge/Loading of material								
Mixing of mortar								
Laying of blocks								
Pointing								
Others (specify)								
R = RATING; WR = WATCH READING/CUMMULATIVE; OT = OBSERVED TIME; AL = ALLOWANCE; ST = STANDARD TIME; BT = BASIC TIME								

Appendix C: Request Letter to Conduct a Research

School of Construction Economics & Management

University of Witwatersrand, Johannesburg P.O. Box 20, Wits 2050, South Africa, • Tel: +27 (0)11 717 7652/77669/77663
• Email: CEM@wits.ac.za

10th October 2015.

The Director,
Department of Public Building
Federal Capital Development Authority,
Area 11, Garki, Abuja.

Dear Sir,

REQUEST FOR RESEARCH SUPPORT INTO THE ROLE OF ON-SITE CRAFT GANG'S LEARNING

I am writing this letter to request your support for a research study that is being conducted at the University of the Witwatersrand titled '' Investigating the Role of On-site Learning in the Optimisation of Craft Gang's Productivity in the Construction Industry'' The purpose of the study is to investigate the project-specific constraints craft gang's respond to, in order to optimise their productivity and how prior learning impact upon their productivity. The findings of this research will help contractor and other project participants in developing an insight into the dynamics of project-specific constraints craft gangs respond to, in order to optimise their productivity and how prior learning impact construction productivity.

The study requires input from construction industry craft gangs, operation supervisors and project managers whose contribution will not only help make this research successful but will also ensure that construction industry perspectives are central to the research and the outcomes are relevant to the need of construction organization. It is in the light of this that I am seeking for your approval to conduct an interview and observation in some of your project sites for block layers gang's on site. In return for your assistance, the findings of the interview and observation will be fed back to you for your consideration and input.

Please, be assured that the information sought in the interview and observation will be used for research purpose only.

Thank you in advance for your cooperation and support. If you have any questions or additional information, please feel free to contact us.

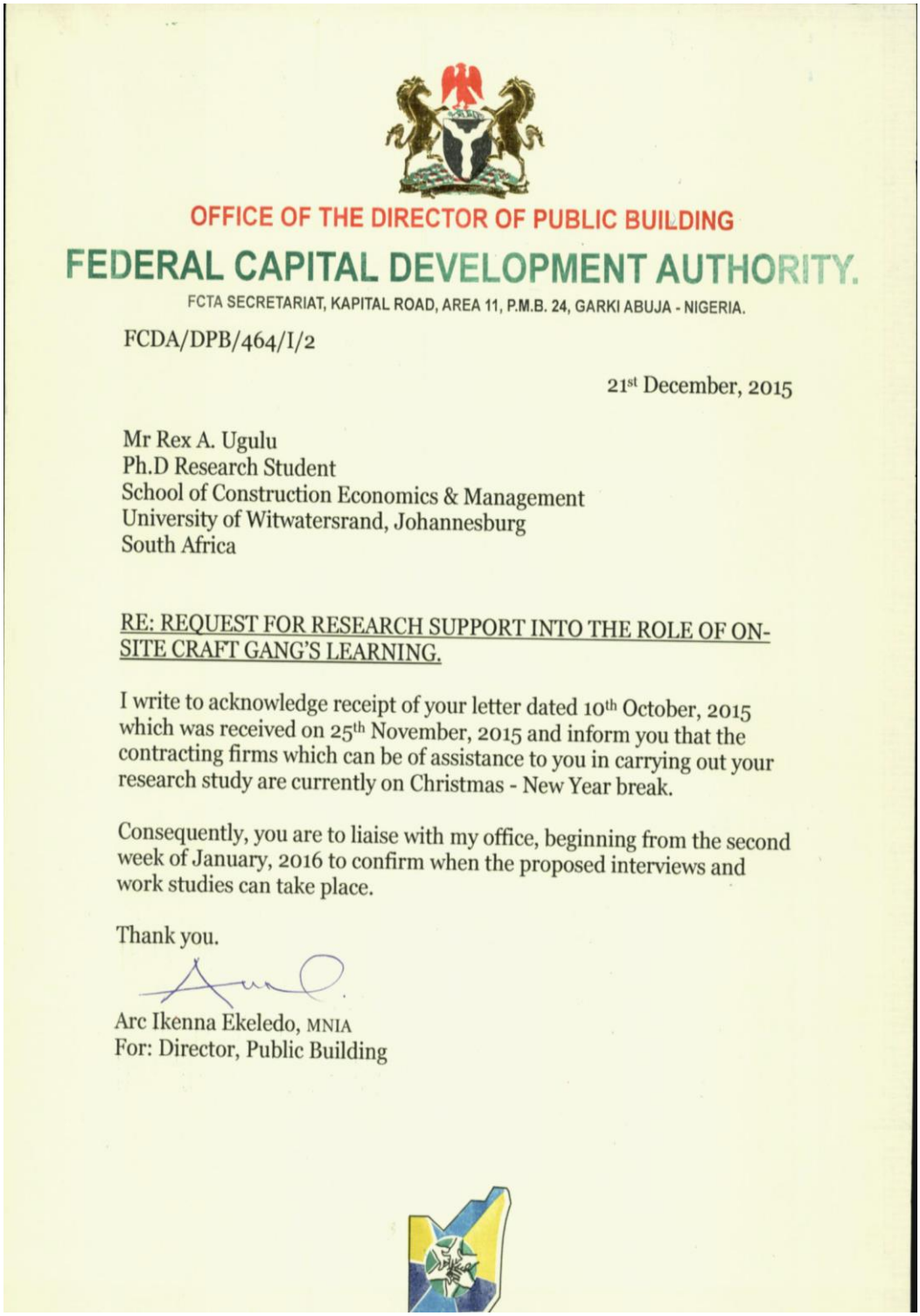
Yours sincerely,

Rex A. Ugulu
Ph.D Research Student
+27731633949

809805@students.wits.ac.za

Dr Stephen Allen
Research Supervisor

Appendix D: Approval Letter to Conduct Research



OFFICE OF THE DIRECTOR OF PUBLIC BUILDING

FEDERAL CAPITAL DEVELOPMENT AUTHORITY.

FCTA SECRETARIAT, KAPITAL ROAD, AREA 11, P.M.B. 24, GARKI ABUJA - NIGERIA.

FCDA/DPB/464/I/2

21st December, 2015

Mr Rex A. Ugulu
Ph.D Research Student
School of Construction Economics & Management
University of Witwatersrand, Johannesburg
South Africa

RE: REQUEST FOR RESEARCH SUPPORT INTO THE ROLE OF ON-SITE CRAFT GANG'S LEARNING.

I write to acknowledge receipt of your letter dated 10th October, 2015 which was received on 25th November, 2015 and inform you that the contracting firms which can be of assistance to you in carrying out your research study are currently on Christmas - New Year break.

Consequently, you are to liaise with my office, beginning from the second week of January, 2016 to confirm when the proposed interviews and work studies can take place.

Thank you.

Arc Ikenna Ekeledo, MNIA
For: Director, Public Building

Appendix E: Wits Ethics Approval Letter

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Ugulu

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H16/02/34**
PROJECT TITLE	Investigating the role of on-site learning in the optimisation of craft gang's productivity in the construction industry
INVESTIGATOR(S)	Mr R Ugulu
SCHOOL/DEPARTMENT	Construction, Economics & Management/
DATE CONSIDERED	19 February 2016
DECISION OF THE COMMITTEE	Approved unconditionally
EXPIRY DATE	09 March 2019

DATE 10 March 2016 **CHAIRPERSON** _____
(Professor J Knight)

cc: Supervisor : Dr S Allen

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

_____ _____/_____/_____
Signature **Date**

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix F: Observation Participant Information Sheet

Date:

PARTICIPATION INFORMATION SHEET FOR OBSERVATION

PROJECT TITLE: Investigating The Role of On-Site Learning in the Optimisation of Craft Gang's Productivity in the Construction Industry

Dear Sir/Madam,
My name is Rex Asibuodu Ugulu a graduate research student at the Witwatersrand University Johannesburg, South Africa. The purpose of the study is to help construction industry craft gang's like you understand the influence project-specific constraints craft gang's respond to, in order to optimise their productivity and how prior and onsite learning impact upon their productivity. Therefore, I will like carry out a work study on your block laying craft gang (upon consent) about your method of laying blocks to show an understanding of the influence of prior and onsite learning on the ongoing project which you are providing services.

I wish to invite you to take part in this research study. This is because your craft gang has been identified as one of the professional that provides block laying service on construction projects. Further, you have been selected because of your involvement in projects where on-site learning of block laying craft gangs is implemented. Your experience could therefore provide valuable insight into finding solutions to the project-specific constraints craft gang's respond to, in order to optimise their productivity.

Please note the following:

- Your participation is voluntary.
- The block work measurement record will be kept confidential.
- Your gang participation is anonymous, your name and identity will not be disclose or contained in any final report of the study.
- The work study is a record of a particular method of operation, and NOT spying or checking on an individual performance.
- The work study record data collection is not going to be passed to the employer but for **only used** for academic purpose.
- If you don't want to participate, you do not have to give a reason and no pressure will be out on you to try and change your mind.
- You can choose not to participate, during the observation this will not affect you.
- During the observation you may refuse to comment on any record(s) you do not feel comfortable.
- The report of this study will be reported to an academic and professional audience through seminars, conferences and academic journals, which may be in print versions or electronic repositories accessible through the World Wide Web.
- The summary of the research findings may be available to you upon request.

If there are any questions or clarifications, do not hesitate to contact me using the following contact details:

My contact details: Rex A. Ugulu
809805@students.wits.ac.za
Phone no: +27731633949; +2348033525286

My supervisor: Stephen Allen
Stephen.allen@wits.ac.za
+27710748590

Appendix G: Observation Consent Form



CONSENT FORM FOR OBSERVATION

PROJECT TITLE: Investigating The Role of On-Site Learning in the Optimisation of Craft Gang's Productivity in the Construction Industry

Please tick in the box after each statement to which you wish to consent.

1	I confirm that I have read and understand the information sheet for above title	
2	I have been made aware of the purpose of the study	
3	I understand that my participation is voluntary and that I am free to withdraw at anytime	
4	I agree to being observed	
5	I agree to comment on the work measurement record if requested	
6	I agree to take part in the study	

---	---	---
Name of Participant	**Date**	**Signature**
---	---	---
Name of Reseacher	**Date**	**Signature**

Appendix H: Interview Participant Information

Date:

PARTICIPATION INFORMATION SHEET FOR INTERVIEW

PROJECT TITLE: Investigating The Role of On-Site Learning in the Optimisation of Craft Gang's Productivity in the Construction Industry

Dear Sir/Madam,
My name is Rex Asibuodu Ugulu a graduate research student at the Witwatersrand University Johannesburg, South Africa. The purpose of the study is to help construction industry professional like you understand the influence project-specific constraints craft gang's respond to, in order to optimise their productivity and how prior learning impact upon their productivity. Therefore, I will like to speak with you (upon consent) about your experiences on the ongoing project where you have provided services.

I wish to invite you to take part in this research study. This is because you have been identified as one of the professional that provides service on construction projects. Further, you have been selected because of your involvement in projects where on-site learning of craft gangs block laying is implemented. Your experience could therefore provide valuable insight into finding solutions to the project-specific constraints craft gang's respond to, in order to optimise their productivity. You may be asked (upon consent) to contribute information in a face-to-face interview which might last between 45 minutes to an hour. For your convenience, the interview will take place on the site or your office. The interview will take place on a date that will be agreed with you, subject to your acceptance to participate in this study.

Please note the following:

- Your **taking part is voluntary**. If you don't want to participate, you do not have to give a reason and no pressure will be out on you to try and change your mind. You can choose to withdraw your participation at any time. If you choose not to participate, during the discussion this will **not** affect you.
- The information sheet and the interview will be kept confidential.
- During the interview you may refuse to answer any question(s) you do not feel comfortable.
- Your participation is anonymous, the interview will be confidential, your name and identity will not be disclose or contained in any final report of the study.
- The interview will be audio recorded and all data will be stored in password protected digital form with all identifying features removed. Also, information gathered through interview will only be used for research purposes and all raw data will be destroyed after 5years.
- The report of this study will be reported to an academic and professional audience through seminars, conferences and academic journals, which may be in print versions or electronic repositories accessible through the World Wide Web.
- The summary of the research findings may be available to you upon request.

If there are any questions or clarifications you wish to make, please do not hesitate to contact me using the following contact details:

My contact details: Rex A. Ugulu
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My supervisor: Stephen Allen
Stephen.allen@wits.ac.za
+27710748590

Appendix I: Interview Participant Consent Form

CONSENT FORM FOR INTERVIEW

PROJECT TITLE: Investigating The Role of On-Site Learning in the Optimisation of Craft Gang's Productivity in the Construction Industry

Please tick in the box after each statement to which you wish to consent.

1	I confirm that I have read and understand the information sheet for above title	
2	I have been made aware of the purpose of the study	
3	I understand that my participation is voluntary and that I am free to withdraw at anytime	
4	I agree to being interviewed	
5	I agree to the interview being audio recorded	
6	I agree to taking part in a follow up interview if requested	
7	I agree to take part in the study	

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Name of Participant **Date** **Signature**

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Name of Reseacher **Date** **Signature**

Appendix J: Observation Data and Preliminary Analysis

Gang No: 1601; FIELD DATA								
Date	**No of Crafts in a Gang**	**Level**	**Man Hours Observed**	**LN Man-hours**	**Cycle no**	**LN Cycle No**	**Productivity (M^2)**	
							QTY	LN QTY
				Week One				
12/4/2016	3.00	BASEMENT	445	6.10	1.00	-	8.00	2.0794
13/4/2016	3.00	BASEMENT	419	6.04	2.00	0.6931	9.50	2.2513
14/4/2016	3.00	BASEMENT	415	6.03	3.00	1.1098	10.50	2.3514
15/4/2016	3.00	BASEMENT	408	6.01	4.00	1.3862	11.00	2.3979
16/4/2016	3.00	BASEMENT	407	6.01	5.00	1.6094	11.50	2.4423
				Week Two				
18/4/2016	3.00	BASEMENT	416	6.03	6.00	1.7917	12.00	2.4849
19/4/2016	3.00	BASEMENT	455	6.12	7.00	1.9459	12.00	2.4849
20/4/2016	3.00	BASEMENT	420	6.04	8.00	2.0794	12.50	2.5257
21/4/2016	3.00	FIRST FLOOR	422	6.05	9.00	2.1972	12.00	2.4849
22/4/2016	3.00	FIRST FLOOR	413	6.02	10.00	2.3025	13.00	2.5649
23/4/2016	3.00	FIRST FLOOR	418	6.04	11.00	2.3978	13.50	2.6027
				Week Three				
25/4/2016	3.00	FIRST FLOOR	417	6.03	12.00	2.4849	12.00	2.4849
26/4/2016	3.00	FIRST FLOOR	421	6.04	13.00	2.5649	12.00	2.4849
27/4/2016	3.00	FIRST FLOOR	419	6.04	14.00	2.6390	12.50	2.5257
28/4/2016	3.00	BASEMENT	405	6.00	15.00	2.7080	12.00	2.4849
29/4/2016	3.00	BASEMENT	409	6.01	16.00	2.7725	13.00	2.5649
30/4/2016	3.00	FIRST FLOOR	420	6.04	17.00	2.8332	13.50	2.6027
				Week Four				
02/5/2016	3.00	BSEMENT	394	5.98	18.00	2.8903	14.00	2.6391
03/5/2016	3.00	BASEMENT	406	6.01	19.00	2.9444	12.00	2.4849

Date	No of Crafts in a Gang	Level	Man Hours Observed	LN Man-hours	Cycle no	LN Cycle No	Productivity (M^2)	
							QTY	LN QTY
04/5/2016	3.00	FIRST FLOOR	395	5.98	20.00	2.9957	12.00	2.4849
05/5/2016	3.00	2ND FLOOR	397	5.98	21.00	3.0445	12.50	2.5257
06/5/2016	3.00	2ND FLOOR	401	5.99	22.00	3.0918	12.00	2.4849
07/5/2016	3.00	2ND FLOOR	396	5.98	23.00	3.1355	13.00	2.5649
				Week Five				
09/5/2016	3.00	2ND FLOOR	394	5.98	24.00	3.1781	12.00	2.4849
10/5/2016	3.00	2ND FLOOR	406	6.01	25.00	3.2189	14.00	2.6391
11/5/2016	3.00	2ND FLOOR	395	5.98	26.00	3.2581	14.00	2.6391

Gang No: 1602: FIELD DATA								
Date	**No of Crafts in a Gang**	**Level**	**Man Hours Observed**	**LN Man-hours**	**Cycle no**	**LN Cycle No**	**Productivity (M^2)**	
							QTY	LN QTY
				Week One				
22/4/2016	3	BASEMENT	441	6.09	1	0	10	2.3026
23/4/2016	3	BASEMENT	425	6.05	2	0.6931	11	2.3979
				Week Two				
25/4/2016	3	BASEMENT	410	6.02	3	1.1098	8.5	2.1401
26/4/2016	3	BASEMENT	405	6.01	4	1.3862	9	2.1972
27/4/2016	3	BASEMENT	417	6.03	5	1.6094	13	2.5649
28/4/2016	3	GROUND FLOOR	422	6.05	6	1.7917	12	2.4849
29/4/2016	3	GROUND FLOOR	414	6.03	7	1.9459	15	2.7081
30/4/2016	3	GROUND FLOOR	422	6.05	8	2.0794	14	2.6391
				Week Three				
5/5/2016	3	GROUND FLOOR	403	6	9	2.1972	12	2.4849
6/5/2016	3	GROUND FLOOR	409	6.02	10	2.3025	9	2.1972
7/5/2016	3	GROUND FLOOR	403	6	11	2.3978	14.5	2.6742
				Week Four				
9/5/2016	3	GROUND FLOOR	398	5.99	12	2.4849	15	2.7081
10/5/2016	3	GROUND FLOOR	376	5.93	13	2.5649	15	2.7081
11/5/2016	3	GROUND FLOOR	378	5.93	14	2.639	13	2.5649
12/5/2016	3	BASEMENT	392	5.97	15	2.708	12	2.4849
13/5/2016	3	FIRST FLOOR	374	5.92	16	2.7725	14	2.6391
14/5/2016	3	BASEMENT	395	5.98	17	2.8332	11.5	2.4423
9/5/2016	3	GROUND FLOOR	398	5.99	12	2.4849	15	2.7081
				Week Five				
16/5/2016	3	FIRST FLOOR	396	5.98	18	2.8903	13	2.5649

Date	No of Crafts in a Gang	Level	Man Hours Observed	LN Man-hours	Cycle no	LN Cycle No	Productivity (M^2)	
							QTY	LN QTY
17/5/2016	3	BASMENT	396.5	5.97	19	2.9444	15	2.7081
18/5/2016	3	FIRST FLOOR	390	5.92	20	2.9957	12.5	2.5257
19/5/2016	3	2ND FLOOR	376	5.91	21	3.0445	14	2.6391
20/5/2016	3	2ND FLOOR	370	5.89	22	3.0918	14.5	2.6741
21/5/2016	3	2ND FLOOR	362	5.89	23	3.1355	13	2.5649
				Week Six				
23/5/2016	3	2ND FLOOR	367	5.91	24	3.1781	15	2.7081

Gang No: 1603; FIELD DATA								
Date	**No of Crafts in a Gang**	**Level**	**Man Hours Observed**	**LN Man-hours**	**Cycle no**	**LN Cycle No**	**Productivity (M^2)**	
							QTY	LN QTY
Week One								
5/5/2016	5	BASEMENT	450	6.11	1	0	22	3.0918
6/5/2016	5	BASEMENT	440	6.09	2	0.6931	21	3.0445
7/5/2016	5	BASEMENT	433,00	6.07	3	1.1098	22.5	3.1135
Week Two								
9/5/2016	5	BASEMENT	430	6.06	4	1.3862	24	3.178
10/5/2016	5	BASEMENT	411	6.02	5	1.6094	20	2.9957
11/5/2016	5	BASEMENT	410	6.02	6	1.7917	21.5	3.068
12/5/2016	5	BASEMENT	410	6.02	7	1.9459	19.5	2.9784
13/5/2016	5	BASEMENT	398	5.99	8	2.0794	20	2.9957
14/5/2016	5	FIRST FLOOR	397	5.98	9	2.1972	23	2.1354
Week Three								
16/5/2016	5	BSEMENT	380	5.94	10	2.3025	24.5	3.1987
17/5/2016	5	SECOND FLOOR	370	5.91	11	2.3978	26	3.2581
18/5/2016	5	SECOND FLOOR	402	6	12	2.4849	28	3.3322
19/5/2016	5	SECOND FLOOR	378	5.94	13	2.5649	26	3.2581
20/5/2016	5	SECOND FLOOR	406	6.006	14	2.639	29	3.3673
21/5/2016	5	SECOND FLOOR	365	5.87	15	2.708	28	3.3322
Week Four								
23/5/2016	5	SECOND FLOOR	363	5.87	16	2.7725	30	3.4012

Gang No: 1604; FIELD DATA								
Date	**No of Crafts in a Gang**	**Level**	**Man Hours Observed**	**LN Man-hours**	**Cycle no**	**LN Cycle No**	**Productivity (M^2) QTY &**	**LNQTY**
Week One								
4/5/2016	4	BASEMENT	510	6.23	1	0	12.5	2.5257
5/5/2016	4	BASEMENT	421	6.04	2	0.6931	16	2.7726
6/5/2016	4	BASEMENT	420	6.04	3	1.1098	18	2.8904
7/5/2016	4	BASEMENT	415	6.03	4	1.3862	20.5	3.0204
Week Two								
9/5/2016	4	BASEMENT	400	5.99	5	1.6094	22	3.091
10/5/2016	4	FIRST FLOOR	405	6	6	1.7917	23.5	3.157
11/5/2016	4	BASEMENT	408	6.01	7	1.9459	24	3.1781
12/5/2016	4	BASEMENT	413	6.02	8	2.0794	23.5	3.157
13/5/2016	4	FIRST FLOOR	387	5.96	9	2.1972	24.5	3.1987
14/5/2016	4	BSEMENT	401	5.99	10	2.3025	22	3.091
Week Three								
16/5/2016	4	SECOND FLOOR	383	5.95	11	2.3978	24.5	3.1987
17/5/2016	4	SECOND FLOOR	369.5	5.91	12	2.4849	25	3.2189
18/5/2016	4	SECOND FLOOR	366	5.9	13	2.5649	25.5	3.2387
19/5/2016	4	SECOND FLOOR	399	5.99	14	2.639	23	3.1354
20/5/2016	4	SECOND FLOOR	355	5.87	15	2.708	26	3.2581
21/5/2016	4	SECOND FLOOR	352	5.86	16	2.7725	26	3.2581
Week Four								
23/5/2016	4	SECOND FLOOR	388	5.96	17	2.8332	25	3.2189

Gang No: 1605; FIELD DATA								
Date	**No of Crafts in a Gang**	**Level**	**Man Hours Observed**	**LN Man-hours**	**Cycle no**	**LN Cycle No**	**Productivity (M^2)**	
							QTY	LN QTY
Week One								
4/5/2016	4	BASEMENT	525	6.2630	1	0	11	2.3978
5/5/2016	4	BASEMENT	500	6.2140	2	0.6931	18	2.8904
6/5/2016	4	BASEMENT	423	6.0520	3	1.1098	19	2.9444
7/5/2016	4	BASEMENT	424	6.0500	4	1.3862	23.5	3.1500
Week Two								
9/5/2016	4	BASEMENT	415	6.0300	5	1.6094	20.5	3.0204
10/5/2016	4	FIRST FLOOR	416	6.0300	6	1.7917	21	3.0445
11/5/2016	4	FIRST FLOOR	408	6.0100	7	1.9459	23	3.1355
12/5/2016	4	FIRST FLOOR	405	6.0040	8	2.0794	18.5	2.9178
13/5/2016	4	FIRST FLOOR	401	5.9900	9	2.1972	24	3.1781
14/5/2016	4	FIRST FLOOR	398	5.9900	10	2.3025	24.5	3.1987
Week Three								
16/5/2016	4	SECOND FLOOR	411	6.0200	11	2.3978	22	3.0910
17/5/2016	4	SECOND FLOOR	384	5.9500	12	2.4849	25	3.2189
18/5/2016	4	SECOND FLOOR	388	5.9600	13	2.5649	25.5	3.2387
19/5/2016	4	SECOND FLOOR	398	5.9865	14	2.639	23	3.1355
20/5/2016	4	SECOND FLOOR	374	5.9200	15	2.708	26	3.2581
21/5/2016	4	SECOND FLOOR	374.5	5.5700	16	2.7725	25	3.2189
Week Four								
23/5/2016	4	SECOND FLOOR	384	5.9506	17	2.8332	23	3.1355

Gang No: 1606; FIELD DATA								
Date	**No of Crafts in a Gang**	**Level**	**Man Hours Observed**	**LN Man-hours**	**Cycle no**	**LN Cycle No**	**Productivity (M^2)**	
							QTY & QTY	**LN**
Week One								
4/5/2016	3	BASEMENT	485.0000	6.1800	1.0000	-	10.5000	2.3513
5/5/2016	3	BASEMENT	480.0000	6.1700	2.0000	0.6931	14.0000	2.6390
6/5/2016	3	BASEMENT	426.0000	6.0500	3.0000	1.1098	18.5000	2.9178
7/5/2016	3	BASEMENT	421.0000	6.0400	4.0000	1.3862	18.0000	2.8904
Week Two								
9/5/2016	3	BASEMENT	410.0000	6.0200	5.0000	1.6094	18.5000	2.9178
10/5/2016	3	FIRST FLOOR	405.0000	6.0000	6.0000	1.7917	15.0000	2.7081
11/5/2016	3	FIRST FLOOR	404.0000	5.9900	7.0000	1.9459	18.5000	2.9178
12/5/2016	3	FIRST FLOOR	400.0000	5.9600	8.0000	2.0794	18.0000	2.8904
13/5/2016	3	FIRST FLOOR	388.0000	5.9400	9.0000	2.1972	18.0000	2.8904
14/5/2016	3	FIRST FLOOR	378.0000	5.9300	10.0000	2.3025	19.0000	2.9444
Week Three								
16/5/2016	3	FIRST FLOOR	366.0000	5.9026	11.0000	2.3978	17.0000	2.8332
17/5/2016	3	FIRST FLOOR	376.0000	5.9300	12.0000	2.4849	19.5000	2.9704
18/5/2016	3	FIRST FLOOR	362.0000	5.8900	13.0000	2.5649	21.0000	3.0445
19/5/2016	3	SECOND FLOOR	354.0000	5.8700	14.0000	2.6390	21.5000	3.0680
20/5/2016	3	SECOND FLOOR	380.0000	5.9400	15.0000	2.7080	23.0000	3.1355
21/5/2016	3	SECOND FLOOR	353.0000	5.8600	16.0000	2.7725	22.0000	3.0910
Week Four								
23/5/2016	3	SECOND FLOOR	366.0000	5.9000	17.0000	2.8332	23.0000	3.1355

Gang No: 1607; FIELD DATA								
Date	**No of Crafts in a Gang**	**Level**	**Man Hours Observed**	**LN Man-hours**	**Cycle no**	**LN Cycle No**	**Productivity (M^2)**	
							QTY	**LN QTY**
Week One								
3/5/2016	4	BASEMENT	523.0000	6.2600	1.0000	-	11.0000	2.3979
4/5/2016	4	BASEMENT	500.0000	6.2300	2.0000	0.6931	18.0000	2.8904
5/5/2016	4	BASEMENT	405.0000	6.0100	3.0000	1.1098	18.5000	2.9178
6/5/2016	4	BASEMENT	387.0000	5.9600	4.0000	1.3862	20.0000	2.9957
7/5/2016	4	FIRST FLOOR	425.0000	6.0500	5.0000	1.6094	19.0000	2.9444
Week Two								
9/5/2016	4	FIRST FLOOR	415.0000	6.0300	6.0000	1.7917	20.5000	3.0204
10/5/2016	4	FIRST FLOOR	416.0000	6.0300	7.0000	1.9459	21.0000	3.0445
11/5/2016	4	FIRST FLOOR	408.0000	6.0100	8.0000	2.0794	23.0000	3.1355
12/5/2016	4	FIRST FLOOR	424.0000	6.0500	9.0000	2.1972	23.5000	3.1570
13/5/2016	4	FIRST FLOOR	374.0000	5.9200	10.0000	2.3025	20.0000	2.9957
14/5/2016	4	FIRST FLOOR	401.0000	5.9900	11.0000	2.3978	24.0000	3.1781
Week Three								
16/5/2016	4	FIRST FLOOR	398.0000	5.9900	12.0000	2.4849	24.5000	3.1987
17/5/2016	4	BASEMENT	384.0000	5.9500	13.0000	2.5649	25.0000	3.2189
18/5/2016	4	SECOND FLOOR	405.0000	6.0000	14.0000	2.6390	22.0000	3.0910
19/5/2016	4	BASEMENT	388.0000	5.9600	15.0000	2.7080	25.5000	3.2387
20/5/2016	4	SECOND FLOOR	374.0000	5.9200	16.0000	2.7725	26.0000	3.2581
21/5/2016	4	SECOND FLOOR	403.0000	6.0000	17.0000	2.8332	23.0000	3.1355
Week Four								
23/5/2016	4	SECOND FLOOR	372.0000	5.9200	18.0000	2.8903	26.0000	3.2581

Appendix K1: Regression Correlation Coefficient for Craft Gang 1601

S/N	**LN Man-hours** Y	**LN Cycle No** X	**C** XY	**D** X^2	**E** Y^2	**F** $n\sum XY$	**G** $\sum X\sum Y$	**H** $n\sum X^2$	**I** $(\sum x)^2$	**J** $n\sum Y^2$	**K** $(\sum Y)^2$	**L** H-I	**M** J-K	**N** $(L*M)^{\wedge}½$	**O** F-G	**P** ϒ=O/N
1	6.10	-	0	-	37.2100											
2	6.04	0.6931	4.18632	0.4804	36.4816											
3	6.03	1.1098	6.69209	1.2317	36.3609											
4	6.01	1.3862	8.33106	1.9216	36.1201											
5	6.01	1.6094	9.67249	2.5902	36.1201											
6	6.03	1.7917	10.804	3.2102	36.3609											
7	6.12	1.9459	11.9089	3.7865	37.4544											
8	6.04	2.0794	12.5596	4.3239	36.4816											
9	6.05	2.1972	13.2931	4.8277	36.6025											
10	6.02	2.3025	13.8611	5.3015	36.2404											
11	6.04	2.3978	14.4827	5.7494	36.4816											
12	6.03	2.4849	14.9839	6.1747	36.3609											
13	6.04	2.5649	15.492	6.5787	36.4816											
14	6.04	2.6390	15.9396	6.9643	36.4816											
15	6.00	2.7080	16.248	7.3333	36.0000											
16	6.01	2.7725	16.6627	7.6868	36.1201	9579.295908	9591.644112	4209.966516	3754.35602	**24,505.59**	24504.7716	455.6104957	0.82	19.28154985	-12.348204	**-0.640415532**
17	6.04	2.8332	17.1125	8.0270	36.4816											
18	5.98	2.8903	17.284	8.3538	35.7604											
19	6.01	2.9444	17.6958	8.6695	36.1201											
20	5.98	2.9957	17.9143	8.9742	35.7604											
21	5.98	3.0445	18.2061	9.2690	35.7604											
22	5.99	3.0918	18.5199	9.5592	35.8801											
23	5.98	3.1355	18.7503	9.8314	35.7604											
24	5.98	3.1781	19.005	10.1003	35.7604											
25	6.01	3.2189	19.3456	10.3613	36.1201											
26	5.98	3.2581	19.4834	10.6152	35.7604											
∑	**156.5**	**61.2728**	**368.434**	**161.9218**	**942.5226**											

Appendix K2: Regression Correlation Determination for Craft Gang 1601

S/N	LN Man-hours Y	LN Cycle No X	$\bar{Y}$	$\dot{X}$	β	$\alpha=\bar{Y}-B\dot{x}$	$\acute{y}=\alpha+\beta xi$	yi-ýi	(yi-ýi)2	yi-$\bar{Y}$	(yi-$\bar{Y}$)2	R^2
1	6.1000	0.0000	6.0208	2.3566	-0.0271	6.0846	6.0846	0.0154	0.0002	0.0792	0.0063	
2	6.0400	0.6931	6.0208	2.3566	-0.0271	6.0846	6.0659	-0.0259	0.0007	0.0192	0.0004	
3	6.0300	1.1098	6.0208	2.3566	-0.0271	6.0846	6.0546	-0.0246	0.0006	0.0092	0.0001	
4	6.0100	1.3862	6.0208	2.3566	-0.0271	6.0846	6.0471	-0.0371	0.0014	-0.0108	0.0001	
5	6.0100	1.6094	6.0208	2.3566	-0.0271	6.0846	6.0410	-0.0310	0.0010	-0.0108	0.0001	
6	6.0300	1.7917	6.0208	2.3566	-0.0271	6.0846	6.0361	-0.0061	0.0000	0.0092	0.0001	
7	6.1200	1.9459	6.0208	2.3566	-0.0271	6.0846	6.0319	0.0881	0.0078	0.0992	0.0098	
8	6.0400	2.0794	6.0208	2.3566	-0.0271	6.0846	6.0283	0.0117	0.0001	0.0192	0.0004	
9	6.0500	2.1972	6.0208	2.3566	-0.0271	6.0846	6.0251	0.0249	0.0006	0.0292	0.0009	
10	6.0200	2.3025	6.0208	2.3566	-0.0271	6.0846	6.0222	-0.0022	0.0000	-0.0008	0.0000	
11	6.0400	2.3978	6.0208	2.3566	-0.0271	6.0846	6.0197	0.0203	0.0004	0.0192	0.0004	
12	6.0300	2.4849	6.0208	2.3566	-0.0271	6.0846	6.0173	0.0127	0.0002	0.0092	0.0001	
13	6.0400	2.5649	6.0208	2.3566	-0.0271	6.0846	6.0151	0.0249	0.0006	0.0192	0.0004	
14	6.0400	2.6390	6.0208	2.3566	-0.0271	6.0846	6.0131	0.0269	0.0007	0.0192	0.0004	**0.4101**
15	6.0000	2.7080	6.0208	2.3566	-0.0271	6.0846	6.0112	-0.0112	0.0001	-0.0208	0.0004	
16	6.0100	2.7725	6.0208	2.3566	-0.0271	6.0846	6.0095	0.0005	0.0000	-0.0108	0.0001	
17	6.0400	2.8332	6.0208	2.3566	-0.0271	6.0846	6.0079	0.0321	0.0010	0.0192	0.0004	
18	5.9800	2.8903	6.0208	2.3566	-0.0271	6.0846	6.0063	-0.0263	0.0007	-0.0408	0.0017	
19	6.0100	2.9444	6.0208	2.3566	-0.0271	6.0846	6.0048	0.0052	0.0000	-0.0108	0.0001	
20	5.9800	2.9957	6.0208	2.3566	-0.0271	6.0846	6.0034	-0.0234	0.0005	-0.0408	0.0017	
21	5.9800	3.0445	6.0208	2.3566	-0.0271	6.0846	6.0021	-0.0221	0.0005	-0.0408	0.0017	
22	5.9900	3.0918	6.0208	2.3566	-0.0271	6.0846	6.0008	-0.0108	0.0001	-0.0308	0.0009	
23	5.9800	3.1355	6.0208	2.3566	-0.0271	6.0846	5.9997	-0.0197	0.0004	-0.0408	0.0017	
24	5.9800	3.1781	6.0208	2.3566	-0.0271	6.0846	5.9985	-0.0185	0.0003	-0.0408	0.0017	
25	6.0100	3.2189	6.0208	2.3566	-0.0271	6.0846	5.9974	0.0126	0.0002	-0.0108	0.0001	
26	5.9800	3.2581	6.0208	2.3566	-0.0271	6.0846	5.9963	-0.0163	0.0003	-0.0408	0.0017	
∑	**156.5400**	**61.2728**							**0.0185**		**0.0314**	

Appendix K3: Regression Correlation Coefficient for Craft Gang 1602

S/N	LN Man-hours Y		LN Cycle No X	C XY	D X^2	E Y^2	F $n\sum XY$	G $\sum X\sum Y$	H $n\sum X^2$	I $(\sum x)^2$	J $n\sum Y^2$	K $(\sum Y)^2$	L H-I	M J-K	N (L*M)^½	O F-G	P ϒ=O/N
1	6.09		-	0	-	37.0881											**-0.84**
2	6.05		0.6931	4.19326	0.4804	36.6025											
3	6.02		1.1098	6.681	1.2317	36.2404											
4	6.01		1.3862	8.33106	1.9216	36.1201											
5	6.03		1.6094	9.70468	2.5902	36.3609											
6	6.05		1.7917	10.8398	3.2102	36.6025											
7	6.03		1.9459	11.7338	3.7865	36.3609											
8	6.05		2.0794	12.5804	4.3239	36.6025											
9	6.00		2.1972	13.1832	4.8277	36.0000											
10	6.02		2.3025	13.8611	5.3015	36.2404											
11	6.00		2.3978	14.3868	5.7494	36.0000											
12	5.99		2.4849	14.8846	6.1747	35.8801											
13	5.93		2.5649	15.2099	6.5787	35.1649	7843.49088	7865.39	3382.69	3002.58	**20605.54**	20603.73	380.11	1.80	26.19	-21.90	
14	5.93		2.6390	15.6493	6.9643	35.1649											
15	5.97		2.7080	16.1668	7.3333	35.6409											
16	5.92		2.7725	16.4132	7.6868	35.0464											
17	5.98		2.8332	16.9425	8.0270	35.7604											
18	5.98		2.8903	17.284	8.3538	35.7604											
19	5.97		2.9444	17.5781	8.6695	35.6409											
20	5.92		2.9957	17.7345	8.9742	35.0464											
21	5.91		3.0445	17.993	9.2690	34.9281											
22	5.89		3.0918	18.2107	9.5592	34.6921											
23	5.89		3.1355	18.4681	9.8314	34.6921											
24	5.91		3.1781	18.7826	10.1003	34.9281											
∑		**143.5**	**54.7958**	**326.812**	**140.9453**	**858.5640**											

Appendix K4: Correlation Determination for Blockwork Craft Gang 1602

	LN Man-hours	LN Cycle No										
S/N	Y	X	$\bar{Y}$	$\dot{X}$	β	α=$\bar{Y}$-Bẋ	ý=α+βxi	yi-ýi	(yi-ýi)2	yi-$\bar{Y}$	(yi-$\bar{Y}$)2	R^2
1	6.0900	0.0000	5.9808	2.2832	-0.0576	6.1124	6.1124	-0.0224	0.0005	0.1092	0.0119	
2	6.0500	0.6931	5.9808	2.2832	-0.0576	6.1124	6.0724	-0.0224	0.0005	0.0692	0.0048	
3	6.0200	1.1098	5.9808	2.2832	-0.0576	6.1124	6.0484	-0.0284	0.0008	0.0392	0.0015	
4	6.0100	1.3862	5.9808	2.2832	-0.0576	6.1124	6.0325	-0.0225	0.0005	0.0292	0.0009	
5	6.0300	1.6094	5.9808	2.2832	-0.0576	6.1124	6.0196	0.0104	0.0001	0.0492	0.0024	
6	6.0500	1.7917	5.9808	2.2832	-0.0576	6.1124	6.0091	0.0409	0.0017	0.0692	0.0048	
7	6.0300	1.9459	5.9808	2.2832	-0.0576	6.1124	6.0003	0.0297	0.0009	0.0492	0.0024	
8	6.0500	2.0794	5.9808	2.2832	-0.0576	6.1124	5.9926	0.0574	0.0033	0.0692	0.0048	
9	6.0000	2.1972	5.9808	2.2832	-0.0576	6.1124	5.9858	0.0142	0.0002	0.0192	0.0004	
10	6.0200	2.3025	5.9808	2.2832	-0.0576	6.1124	5.9797	0.0403	0.0016	0.0392	0.0015	
11	6.0000	2.3978	5.9808	2.2832	-0.0576	6.1124	5.9742	0.0258	0.0007	0.0192	0.0004	
12	5.9900	2.4849	5.9808	2.2832	-0.0576	6.1124	5.9692	0.0208	0.0004	0.0092	0.0001	
13	5.9300	2.5649	5.9808	2.2832	-0.0576	6.1124	5.9646	-0.0346	0.0012	-0.0508	0.0026	**0.6992**
14	5.9300	2.6390	5.9808	2.2832	-0.0576	6.1124	5.9603	-0.0303	0.0009	-0.0508	0.0026	
15	5.9700	2.7080	5.9808	2.2832	-0.0576	6.1124	5.9564	0.0136	0.0002	-0.0108	0.0001	
16	5.9200	2.7725	5.9808	2.2832	-0.0576	6.1124	5.9526	-0.0326	0.0011	-0.0608	0.0037	
17	5.9800	2.8332	5.9808	2.2832	-0.0576	6.1124	5.9491	0.0309	0.0010	-0.0008	0.0000	
18	5.9800	2.8903	5.9808	2.2832	-0.0576	6.1124	5.9459	0.0341	0.0012	-0.0008	0.0000	
19	5.9700	2.9444	5.9808	2.2832	-0.0576	6.1124	5.9427	0.0273	0.0007	-0.0108	0.0001	
20	5.9200	2.9957	5.9808	2.2832	-0.0576	6.1124	5.9398	-0.0198	0.0004	-0.0608	0.0037	
21	5.9100	3.0445	5.9808	2.2832	-0.0576	6.1124	5.9370	-0.0270	0.0007	-0.0708	0.0050	
22	5.8900	3.0918	5.9808	2.2832	-0.0576	6.1124	5.9342	-0.0442	0.0020	-0.0908	0.0083	
23	5.8900	3.1355	5.9808	2.2832	-0.0576	6.1124	5.9317	-0.0417	0.0017	-0.0908	0.0083	
24	5.9100	3.1781	5.9808	2.2832	-0.0576	6.1124	5.9293	-0.0193	0.0004	-0.0708	0.0050	
∑	**143.5400**	**54.7958**							**0.0226**		**0.0752**	

Appendix K5: Correlation Coefficient for Craft Gang 1603 Blockwork

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	J	K	L	M	N	O	P
S/N	Y	X	XY	X^2	Y^2	$n\sum XY$	$\sum X \sum Y$	$n\sum X^2$	$(\sum x)^2$	$n\sum Y^2$	$(\sum Y)^2$	H-I	J-K	(L*M)^½	F-G	ϒ=O/N
1	6.11	-	0	-	37.3321											**-0.86**
2	6.09	0.6931	4.22098	0.4804	37.0881											
3	6.07	1.1098	6.73649	1.2317	36.8449											
4	6.06	1.3862	8.40037	1.9216	36.7236											
5	6.02	1.6094	9.68859	2.5902	36.2404											
6	6.02	1.7917	10.786	3.2102	36.2404											
7	6.02	1.9459	11.7143	3.7865	36.2404	2930.476192	2942.309841	1090.57	941.40	**9197.30**	9196.04	149.17	1.26	13.72	-11.83	
8	5.99	2.0794	12.4556	4.3239	35.8801											
9	5.98	2.1972	13.1393	4.8277	35.7604											
10	5.94	2.3025	13.6769	5.3015	35.2836											
11	5.91	2.3978	14.171	5.7494	34.9281											
12	6.00	2.4849	14.9094	6.1747	36.0000											
13	5.94	2.5649	15.2355	6.5787	35.2836											
14	6.01	2.6390	15.8498	6.9643	36.0720											
15	5.87	2.7080	15.896	7.3333	34.4569											
16	5.87	2.7725	16.2746	7.6868	34.4569											
∑	**95.9**	**30.6823**	**183.155**	**68.1608**	**574.8315**											

Appendix K6: Correlation Determination for Craft Gang 1603

	LN Man-hours	LN Cycle No										
S/N	Y	X	$\bar{Y}$	$\dot{X}$	β	α=$\bar{Y}$-Bẋ	ý=α+βxi	yi-ýi	(yi-ýi)2	yi-$\bar{Y}$	(yi-$\bar{Y}$)2	R^2
1	6.1100	0.0000	5.9935	1.9176	-0.0793	6.1456	6.1456	-0.0356	0.0013	0.1165	0.0136	
2	6.0900	0.6931	5.9935	1.9176	-0.0793	6.1456	6.0906	-0.0006	0.0000	0.0965	0.0093	
3	6.0700	1.1098	5.9935	1.9176	-0.0793	6.1456	6.0576	0.0124	0.0002	0.0765	0.0059	
4	6.0600	1.3862	5.9935	1.9176	-0.0793	6.1456	6.0357	0.0243	0.0006	0.0665	0.0044	
5	6.0200	1.6094	5.9935	1.9176	-0.0793	6.1456	6.0180	0.0020	0.0000	0.0265	0.0007	
6	6.0200	1.7917	5.9935	1.9176	-0.0793	6.1456	6.0035	0.0165	0.0003	0.0265	0.0007	
7	6.0200	1.9459	5.9935	1.9176	-0.0793	6.1456	5.9913	0.0287	0.0008	0.0265	0.0007	
8	5.9900	2.0794	5.9935	1.9176	-0.0793	6.1456	5.9807	0.0093	0.0001	-0.0035	0.0000	**0.7440**
9	5.9800	2.1972	5.9935	1.9176	-0.0793	6.1456	5.9713	0.0087	0.0001	-0.0135	0.0002	
10	5.9400	2.3025	5.9935	1.9176	-0.0793	6.1456	5.9630	-0.0230	0.0005	-0.0535	0.0029	
11	5.9100	2.3978	5.9935	1.9176	-0.0793	6.1456	5.9554	-0.0454	0.0021	-0.0835	0.0070	
12	6.0000	2.4849	5.9935	1.9176	-0.0793	6.1456	5.9485	0.0515	0.0027	0.0065	0.0000	
13	5.9400	2.5649	5.9935	1.9176	-0.0793	6.1456	5.9422	-0.0022	0.0000	-0.0535	0.0029	
14	6.0060	2.6390	5.9935	1.9176	-0.0793	6.1456	5.9363	0.0697	0.0049	0.0125	0.0002	
15	5.8700	2.7080	5.9935	1.9176	-0.0793	6.1456	5.9308	-0.0608	0.0037	-0.1235	0.0153	
16	5.8700	2.7725	5.9935	1.9176	-0.0793	6.1456	5.9257	-0.0557	0.0031	-0.1235	0.0153	
∑	**95.8960**	**30.6823**							**0.0202**		**0.0789**	

Appendix K7: Correlation Coefficient for Craft Gang 1604

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	J	K	L	M	N	O	P
S/N	Y	X	XY	X^2	Y^2	$n\sum XY$	$\sum X \sum Y$	$n\sum X^2$	$(\sum x)^2$	$n\sum Y^2$	$(\sum Y)^2$	H-I	J-K	(L*M)^½	F-G	ϒ=O/N
1	6.23	-	0	-	38.8129											
2	6.04	0.6931	4.18632	0.4804	36.4816											
3	6.04	1.1098	6.70319	1.2317	36.4816											
4	6.03	1.3862	8.35879	1.9216	36.3609											
5	5.99	1.6094	9.64031	2.5902	35.8801											
6	6.00	1.7917	10.7502	3.2102	36.0000											
7	6.01	1.9459	11.6949	3.7865	36.1201											
8	6.02	2.0794	12.518	4.3239	36.2404	3394.233821	3410.20	1295.19	1123.29	**10355.01**	10353.06	171.90	1.95	18.29	-15.97	**-0.87**
9	5.96	2.1972	13.0953	4.8277	35.5216											
10	5.99	2.3025	13.792	5.3015	35.8801											
11	5.95	2.3978	14.2669	5.7494	35.4025											
12	5.91	2.4849	14.6858	6.1747	34.9281											
13	5.90	2.5649	15.1329	6.5787	34.8100											
14	5.99	2.6390	15.8076	6.9643	35.8801											
15	5.87	2.7080	15.896	7.3333	34.4569											
16	5.86	2.7725	16.2469	7.6868	34.3396											
17	5.96	2.8332	16.8859	8.0270	35.5216											
∑	**101.8**	**33.5155**	**199.661**	**76.1878**	**609.1181**											

Appendix K8: Correlation Determination for Craft Gang 1604

CORRELATION OF DETERMINATION FOR GANG 1604

S/N	LN Man-hours Y	LN Cycle No X	$\bar{Y}$	$\dot{X}$	β	α=$\bar{Y}$-B$\dot{x}$	ý=α+βxi	yi-ýi	(yi-ýi)2	yi-$\bar{Y}$	(yi-$\bar{Y}$)2	R^2
1	6.2300	0.0000	5.9853	1.9715	-0.0929	6.1684	6.1684	0.0616	0.0038	0.2447	0.0599	
2	6.0400	0.6931	5.9853	1.9715	-0.0929	6.1684	6.1040	-0.0640	0.0041	0.0547	0.0030	
3	6.0400	1.1098	5.9853	1.9715	-0.0929	6.1684	6.0653	-0.0253	0.0006	0.0547	0.0030	
4	6.0300	1.3862	5.9853	1.9715	-0.0929	6.1684	6.0397	-0.0097	0.0001	0.0447	0.0020	
5	5.9900	1.6094	5.9853	1.9715	-0.0929	6.1684	6.0189	-0.0289	0.0008	0.0047	0.0000	
6	6.0000	1.7917	5.9853	1.9715	-0.0929	6.1684	6.0020	-0.0020	0.0000	0.0147	0.0002	
7	6.0100	1.9459	5.9853	1.9715	-0.0929	6.1684	5.9877	0.0223	0.0005	0.0247	0.0006	
8	6.0200	2.0794	5.9853	1.9715	-0.0929	6.1684	5.9753	0.0447	0.0020	0.0347	0.0012	
9	5.9600	2.1972	5.9853	1.9715	-0.0929	6.1684	5.9643	-0.0043	0.0000	-0.0253	0.0006	**0.7625**
10	5.9900	2.3025	5.9853	1.9715	-0.0929	6.1684	5.9545	0.0355	0.0013	0.0047	0.0000	
11	5.9500	2.3978	5.9853	1.9715	-0.0929	6.1684	5.9457	0.0043	0.0000	-0.0353	0.0012	
12	5.9100	2.4849	5.9853	1.9715	-0.0929	6.1684	5.9376	-0.0276	0.0008	-0.0753	0.0057	
13	5.9000	2.5649	5.9853	1.9715	-0.0929	6.1684	5.9302	-0.0302	0.0009	-0.0853	0.0073	
14	5.9900	2.6390	5.9853	1.9715	-0.0929	6.1684	5.9233	0.0667	0.0045	0.0047	0.0000	
15	5.8700	2.7080	5.9853	1.9715	-0.0929	6.1684	5.9169	-0.0469	0.0022	-0.1153	0.0133	
16	5.8600	2.7725	5.9853	1.9715	-0.0929	6.1684	5.9109	-0.0509	0.0026	-0.1253	0.0157	
17	5.9600	2.8332	5.9853	1.9715	-0.0929	6.1684	5.9053	0.0547	0.0030	-0.0253	0.0006	
∑	**101.7500**	**33.5155**							**0.0272**		**0.1144**	

Appendix K9: Correlation Coefficient for Craft Gang 1605

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	J	K	L	M	N	O	P
S/N	Y	X	XY	X^2	Y^2	n∑XY	∑X∑Y	n∑X^2	$(∑x)^2$	n∑Y^2	$(∑Y)^2$	H-I	J-K	(L*M)^½	F-G	ϒ=O/N
1	6.26	-	0	-	39.2252											**-0.77**
2	6.21	0.6931	4.30692	0.4804	38.6138											
3	6.05	1.1098	6.71651	1.2317	36.6267											
4	6.05	1.3862	8.38651	1.9216	36.6025											
5	6.03	1.6094	9.70468	2.5902	36.3609											
6	6.03	1.7917	10.804	3.2102	36.3609											
7	6.01	1.9459	11.6949	3.7865	36.1201											
8	6.00	2.0794	12.4847	4.3239	36.0480	3394.727773	3418.25	1295.19	1123.29	**10407.43**	10401.98	171.90	5.45	30.61	-23.52	
9	5.99	2.1972	13.1612	4.8277	35.8801											
10	5.99	2.3025	13.792	5.3015	35.8801											
11	6.02	2.3978	14.4348	5.7494	36.2404											
12	5.95	2.4849	14.7852	6.1747	35.4025											
13	5.96	2.5649	15.2868	6.5787	35.5216											
14	5.99	2.6390	15.7984	6.9643	35.8382											
15	5.92	2.7080	16.0314	7.3333	35.0464											
16	5.57	2.7725	15.4428	7.6868	31.0249											
17	5.95	2.8332	16.8592	8.0270	35.4096											
∑	**102**	**33.5155**	**199.69**	**76.1878**	**612.2019**											

Appendix K10: Correlation Determination for Craft Gang 1605

S/N	LN Man-hours Y	LN Cycle No X	$\bar{Y}$	$\dot{X}$	β	α=$\bar{Y}$-B$\dot{x}$	ý=α+βx_i	yi-ýi	(yi-ýi)2	yi-$\bar{Y}$	(yi-$\bar{Y}$)2	R^2
1	6.2630	0.0000	5.9994	1.9715	-0.1368	6.2692	6.2692	-0.0062	0.0000	0.2636	0.0695	
2	6.2140	0.6931	5.9994	1.9715	-0.1368	6.2692	6.1743	0.0397	0.0016	0.2146	0.0460	
3	6.0520	1.1098	5.9994	1.9715	-0.1368	6.2692	6.1173	-0.0653	0.0043	0.0526	0.0028	
4	6.0500	1.3862	5.9994	1.9715	-0.1368	6.2692	6.0795	-0.0295	0.0009	0.0506	0.0026	
5	6.0300	1.6094	5.9994	1.9715	-0.1368	6.2692	6.0490	-0.0190	0.0004	0.0306	0.0009	
6	6.0300	1.7917	5.9994	1.9715	-0.1368	6.2692	6.0240	0.0060	0.0000	0.0306	0.0009	
7	6.0100	1.9459	5.9994	1.9715	-0.1368	6.2692	6.0029	0.0071	0.0001	0.0106	0.0001	
8	6.0040	2.0794	5.9994	1.9715	-0.1368	6.2692	5.9847	0.0193	0.0004	0.0046	0.0000	
9	5.9900	2.1972	5.9994	1.9715	-0.1368	6.2692	5.9685	0.0215	0.0005	-0.0094	0.0001	**0.5903**
10	5.9900	2.3025	5.9994	1.9715	-0.1368	6.2692	5.9541	0.0359	0.0013	-0.0094	0.0001	
11	6.0200	2.3978	5.9994	1.9715	-0.1368	6.2692	5.9411	0.0789	0.0062	0.0206	0.0004	
12	5.9500	2.4849	5.9994	1.9715	-0.1368	6.2692	5.9292	0.0208	0.0004	-0.0494	0.0024	
13	5.9600	2.5649	5.9994	1.9715	-0.1368	6.2692	5.9182	0.0418	0.0017	-0.0394	0.0016	
14	5.9865	2.6390	5.9994	1.9715	-0.1368	6.2692	5.9081	0.0784	0.0061	-0.0129	0.0002	
15	5.9200	2.7080	5.9994	1.9715	-0.1368	6.2692	5.8986	0.0214	0.0005	-0.0794	0.0063	
16	5.5700	2.7725	5.9994	1.9715	-0.1368	6.2692	5.8898	-0.3198	0.1023	-0.4294	0.1844	
17	5.9506	2.8332	5.9994	1.9715	-0.1368	6.2692	5.8815	0.0691	0.0048	-0.0488	0.0024	
∑	**101.9901**	**33.5155**							**0.1314**		**0.3207**	

Appendix K11: Correlation Coefficient for Craft Gang 1606

	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	J	K	L	M	N	O	P
S/N	Y	X	XY	X^2	Y^2	$n\sum XY$	$\sum X\sum Y$	$n\sum X^2$	$(\sum x)^2$	$n\sum Y^2$	$(\sum Y)^2$	H-I	J-K	(L*M)^½	F-G	ϒ=O/N
1	6.18	-	0	-	38.1924											**-0.97**
2	6.17	0.6931	4.27643	0.4804	38.0689											
3	6.05	1.1098	6.71429	1.2317	36.6025											
4	6.04	1.3862	8.37265	1.9216	36.4816											
5	6.02	1.6094	9.68859	2.5902	36.2404											
6	6.00	1.7917	10.7502	3.2102	36.0000											
7	5.99	1.9459	11.6559	3.7865	35.8801											
8	5.96	2.0794	12.3932	4.3239	35.5216	3384.558276	3404.26	1295.19	1123.29	**10319.40**	10316.99	171.90	2.41	20.36	-19.70	
9	5.94	2.1972	13.0514	4.8277	35.2836											
10	5.93	2.3025	13.6538	5.3015	35.1649											
11	5.90	2.3978	14.1533	5.7494	34.8407											
12	5.93	2.4849	14.7355	6.1747	35.1649											
13	5.89	2.5649	15.1073	6.5787	34.6921											
14	5.87	2.6390	15.4909	6.9643	34.4569											
15	5.94	2.7080	16.0855	7.3333	35.2836											
16	5.86	2.7725	16.2469	7.6868	34.3396											
17	5.90	2.8332	16.7159	8.0270	34.8100											
∑	**101.6**	**33.5155**	**199.092**	**76.1878**	**607.0238**											

Appendix K12: Correlation Determination for Craft Gang 1606

S/N	LN Man-hours Y	LN Cycle No X	$\bar{Y}$	$\dot{X}$	β	α=$\bar{Y}$-B$\dot{x}$	ý=α+βxi	yi-ýi	(yi-ýi)2	yi-$\bar{Y}$	(yi-$\bar{Y}$)2	R^2
1	6.1800	0.0000	5.9749	1.9715	-0.1146	6.2008	6.2008	-0.0208	0.0004	0.2051	0.0421	
2	6.1700	0.6931	5.9749	1.9715	-0.1146	6.2008	6.1213	0.0487	0.0024	0.1951	0.0381	
3	6.0500	1.1098	5.9749	1.9715	-0.1146	6.2008	6.0736	-0.0236	0.0006	0.0751	0.0056	
4	6.0400	1.3862	5.9749	1.9715	-0.1146	6.2008	6.0419	-0.0019	0.0000	0.0651	0.0042	
5	6.0200	1.6094	5.9749	1.9715	-0.1146	6.2008	6.0164	0.0036	0.0000	0.0451	0.0020	
6	6.0000	1.7917	5.9749	1.9715	-0.1146	6.2008	5.9955	0.0045	0.0000	0.0251	0.0006	
7	5.9900	1.9459	5.9749	1.9715	-0.1146	6.2008	5.9778	0.0122	0.0001	0.0151	0.0002	
8	5.9600	2.0794	5.9749	1.9715	-0.1146	6.2008	5.9625	-0.0025	0.0000	-0.0149	0.0002	
9	5.9400	2.1972	5.9749	1.9715	-0.1146	6.2008	5.9490	-0.0090	0.0001	-0.0349	0.0012	**0.9361**
10	5.9300	2.3025	5.9749	1.9715	-0.1146	6.2008	5.9369	-0.0069	0.0000	-0.0449	0.0020	
11	5.9026	2.3978	5.9749	1.9715	-0.1146	6.2008	5.9260	-0.0234	0.0005	-0.0723	0.0052	
12	5.9300	2.4849	5.9749	1.9715	-0.1146	6.2008	5.9160	0.0140	0.0002	-0.0449	0.0020	
13	5.8900	2.5649	5.9749	1.9715	-0.1146	6.2008	5.9069	-0.0169	0.0003	-0.0849	0.0072	
14	5.8700	2.6390	5.9749	1.9715	-0.1146	6.2008	5.8984	-0.0284	0.0008	-0.1049	0.0110	
15	5.9400	2.7080	5.9749	1.9715	-0.1146	6.2008	5.8905	0.0495	0.0025	-0.0349	0.0012	
16	5.8600	2.7725	5.9749	1.9715	-0.1146	6.2008	5.8831	-0.0231	0.0005	-0.1149	0.0132	
17	5.9000	2.8332	5.9749	1.9715	-0.1146	6.2008	5.8761	0.0239	0.0006	-0.0749	0.0056	
∑	**101.5726**	**33.5155**							**0.0091**		**0.1418**	

Appendix K13 Correlation Coefficient for Craft Gang 1607

S/N	LN Man-hours Y	LN Cycle No X	C XY	D X^2	E Y^2	F $n\sum XY$	G $\sum X \sum Y$	H $n\sum X^2$	I $(\sum x)^2$	J $n\sum Y^2$	K $(\sum Y)^2$	L H-I	M J-K	N (L*M)^½	O F-G	P ϒ=O/N
1	6.26	-	0	-	39.1876											
2	6.23	0.6931	4.31801	0.4804	38.8129											
3	6.01	1.1098	6.6699	1.2317	36.1201											
4	5.96	1.3862	8.26175	1.9216	35.5216											
5	6.05	1.6094	9.73687	2.5902	36.6025											
6	6.03	1.7917	10.804	3.2102	36.3609											
7	6.03	1.9459	11.7338	3.7865	36.3609											
8	6.01	2.0794	12.4972	4.3239	36.1201											
9	6.05	2.1972	13.2931	4.8277	36.6025											
10	5.92	2.3025	13.6308	5.3015	35.0464	3923.108982	3942.02	1521.75	1325.38	**11727.23**	11724.56	196.37	2.67	22.89	-18.91	**-0.83**
11	5.99	2.3978	14.3628	5.7494	35.8801											
12	5.99	2.4849	14.8846	6.1747	35.8801											
13	5.95	2.5649	15.2612	6.5787	35.4025											
14	6.00	2.6390	15.834	6.9643	36.0000											
15	5.96	2.7080	16.1397	7.3333	35.5216											
16	5.92	2.7725	16.4132	7.6868	35.0464											
17	6.00	2.8332	16.9992	8.0270	36.0000											
18	5.92	2.8903	17.1106	8.3538	35.0464											
∑	**108.3**	**36.4058**	**217.95**	**84.5417**	**651.5126**											

Appendix K14: Correlation Determination for Blockwork Craft Gang 1607

S/N	LN Man-hours Y	LN Cycle No X	$\bar{Y}$	$\dot{X}$	β	α=$\bar{Y}$-Bẋ	ý=α+βx i	yi-ýi	(yi-ýi)2	yi-$\bar{Y}$	(yi-$\bar{Y}$)2	R^2
1	6.2600	0.0000	6.0156	2.0225	-0.0963	6.2103	6.2103	0.0497	0.0025	0.2444	0.0598	
2	6.2300	0.6931	6.0156	2.0225	-0.0963	6.2103	6.1436	0.0864	0.0075	0.2144	0.0460	
3	6.0100	1.1098	6.0156	2.0225	-0.0963	6.2103	6.1035	-0.0935	0.0087	-0.0056	0.0000	
4	5.9600	1.3862	6.0156	2.0225	-0.0963	6.2103	6.0768	-0.1168	0.0137	-0.0556	0.0031	
5	6.0500	1.6094	6.0156	2.0225	-0.0963	6.2103	6.0553	-0.0053	0.0000	0.0344	0.0012	
6	6.0300	1.7917	6.0156	2.0225	-0.0963	6.2103	6.0378	-0.0078	0.0001	0.0144	0.0002	
7	6.0300	1.9459	6.0156	2.0225	-0.0963	6.2103	6.0229	-0.0071	0.0000	0.0144	0.0002	
8	6.0100	2.0794	6.0156	2.0225	-0.0963	6.2103	6.0101	-0.0001	0.0000	-0.0056	0.0000	
9	6.0500	2.1972	6.0156	2.0225	-0.0963	6.2103	5.9987	-0.0513	0.0026	0.0344	0.0012	**0.6825**
10	5.9200	2.3025	6.0156	2.0225	-0.0963	6.2103	5.9886	-0.0686	0.0047	-0.0956	0.0091	
11	5.9900	2.3978	6.0156	2.0225	-0.0963	6.2103	5.9794	-0.0106	0.0001	-0.0256	0.0007	
12	5.9900	2.4849	6.0156	2.0225	-0.0963	6.2103	5.9710	-0.0190	0.0004	-0.0256	0.0007	
13	5.9500	2.5649	6.0156	2.0225	-0.0963	6.2103	5.9633	-0.0133	0.0002	-0.0656	0.0043	
14	6.0000	2.6390	6.0156	2.0225	-0.0963	6.2103	5.9562	-0.0438	0.0019	-0.0156	0.0002	
15	5.9600	2.7080	6.0156	2.0225	-0.0963	6.2103	5.9495	-0.0105	0.0001	-0.0556	0.0031	
16	5.9200	2.7725	6.0156	2.0225	-0.0963	6.2103	5.9433	-0.0233	0.0005	-0.0956	0.0091	
17	6.0000	2.8332	6.0156	2.0225	-0.0963	6.2103	5.9375	-0.0625	0.0039	-0.0156	0.0002	
18	5.9200	2.8903	6.0156	2.0225	-0.0963	6.2103	5.9320	-0.0120	0.0001	-0.0956	0.0091	
∑	**108.2800**	**36.4058**							**0.0471**		**0.1482**	