LABOUR PRODUCTIVITY OF BLOCKWORK ACTIVITY IN SELECTED PUBLIC BUILDING PROJECTS IN AKWA IBOM STATE, NIGERIA

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Abstract: This study aims at establishing labour productivity norm and assignable causes of variability of construction labour productivity for blockwork activity. A descriptive survey research design approach was adopted. Data were collected on a gang comprising of a bricklayer and mate for 30 working days using project work study manual as the research instrument. Descriptive statistics and statistical control charts were the tools used for analysis. The results show that the average and baseline construction labour productivities of blockwork activity are 0.83m2/hr and 1.07m2/hr respectively. Variability in construction labour productivity of blockwork activity was observed to be due to assignable causes of weather condition and delay in supply of materials. It is recommended that ample consideration should be given to the effect of adverse weather condition during labour cost estimation by taking into cognisance the period of execution of the project. Similarly, adequate planning of construction resources will help in enhancing labour productivity on public building projects

Keywords: *Blockwork activity, construction, labour productivity, variability, work study*

1.0 Introduction

Compared to other project cost components such as material and equipment labour costs have the highest possibility of being reduced through good management (McTague and Jergeas, 2002). Increase in productivity tends to reduce labour cost in direct proportion (Hanna *et al.*, 2008). Productivity is considered as one of the most important factors affecting the success and overall performance of every organization, whether large or small, in today's competitive market (Sweis *et al.*, 2009). According to Walker (1995), construction productivity is traditionally identified as one of the three main critical success factors together with cost and quality of a construction project. However, it has been observed that construction productivity is a cause of great concern in both the construction industry and academia (Park *et al*., 2005).

Estimating manpower requirements of various activities involved in a building project by experienced estimators and planners could be determined from compilation of workers' production planning norms. However, in the absence of such planning data, Chitkara (2006) asserts that appropriate norms can be evolved using one or a combination of methods namely: analysing the past performance data, abstracting data from published norms, and work-studying the actual work process. In Nigeria, Odesola (2012) observes that there is a lack of adequate record of data on productivity for executed projects, hence utilising past performance data to evolve productivity norm may not be feasible. Although there are published production norms by the Nigerian Institute of Quantity Surveyors, their accuracy have often times been challenged because they are based on experience which may not be applicable in all cases. Therefore, work-studying the actual work process to establish accurate production norms for estimating manpower requirements is pertinent for the Nigerian building industry.

Akwa Ibom is one of Nigeria's 36 states created in 1987 from the former Cross River State and is currently among the leading oil and gas producing states in the country. Two distinct seasons characterises the state namely; the wet (rainy) season and the dry season. In the south and central parts of the state, the rainy season could last for about 10-11 months while mean annual temperature values ranges between 26 and 28°C with high relative humidity varying between 75 to 95% (Atser, 2008). Being the highest oil and gas producing state, it is presently enjoying a huge amount of funds from the federal government which has culminated into undeniable physical developments in terms of infrastructures and housing developments. Hence, promoting efficient project delivery through adequate cost estimation and improved labour productivity would assist in achieving sustainable developments in the state characterised with such climatic conditions and growing rate of physical developments.

In view of this, the problem of this study is concerned with determining construction labour productivity of blockwork activity and explaining its variability for selected public building projects using work study approach. The overall aim is to establish labour productivity norm and assignable causes of variability of construction labour productivity for blockwork activity with a view to enhancing cost estimation of building projects and improved project delivery.

2.0 Review of Related Literature

No matter the type of construction project, several activities are performed before it is completed. An activity is considered as part of a work package involving identifiable jobs, operations and processes, which consume time and possibly, other resources and are necessary for its completion i.e. an activity, comprise one or more operations (Chitkara, 2006). In view of the complex nature of construction projects, the activities making up a project may be grouped in terms of the elements making up the project or

the work trades in terms of the skilled personnel responsible for the performance of such activities. Notwithstanding, blockwork activity is one of the commonest activity encountered on most building projects.

2.1   *Activity-Oriented Models or Task Level Productivity Measures*

Tasks refer to specific construction activities such as block/brick work, concrete placement or structural steel erection and so on. Huang *et al*. (2009) opine that task-level metrics are widely used in the construction industry. Most task-level metrics are single factor measures and focus on labour productivity. Attar *et al*. (2012) maintain that at project sites contractors are often interested in labour productivity; they define it in one of the following two ways:

$$\text{Labour Productivity} = \frac{\text{Output}}{\text{Labour Cost}} \tag{1}$$

$$\text{Labour Productivity} = \frac{\text{Output}}{\text{Work-hour}} \tag{2}$$

The study also observes that there is neither a consensus as to the meaning nor a universally accepted measure of productivity and that the inverse of labour productivity, man-hours per unit (unit rate) is also commonly used.

2.2   *Work Processes*

Engineering and Physical Sciences Research Council (EPSRC) (2004) observed that the practice of the construction industry is project-based and that the basic unit of work is individual projects, which may vary in size, length and complexity. Work-flow, according to Hopp (1996) is defined as the movement of tasks through a work process. Bertelsen (2004) opined that the introduction of the concept of flow is probably the most important contribution to the understanding of the construction process made by the Lean Construction Research Community. Production in construction is regarded as that of assembly-type and there are different types of flows connected to the end product. According to Jongeling (2006) resource flows are of relative high variability and as a result the probability that they negatively impact the task result is rather high. EPSRC (2004) noted that the goal of workflow matching is to compare two versions of a workflow specification in order to detect the differences in terms of a series of workflow process changes.

Work processes for blockwork/brickwork activity as observed by researchers are quite similar except for the choice of material type, method of mixing mortar and method of transporting material to workplace (Dawood, Hobbs and Fanning, 1999; Government of India Central Public Work Department (CPWD), 2009). The procedure outlined in

Dawood, Hobbs and Fanning (1999) was adopted for reporting the work processes of blockwork activity observed on the building sites selected for the study.

2.3 Baseline Productivity

The concept of baseline has been utilised in various spheres of life as a means of setting standards or targets for performance or achievements. In relation to construction productivity Sweis *et al*. (2009) describe it as a numerical measure that shows the best productivity value that a contractor can achieve on a particular project when there are few or no disruptions. There is no universally accepted methodology for computing construction baseline productivity. Proposed methodologies could be seen in Thomas and Zavrski (1999), Thomas and Sanvido (2000), Gulezian and Samelian (2003) and Sweis *et al*. (2009). Thomas and Zavrski (1999) and Thomas and Sanvido (2000) considered baseline productivity as the median of individual productivity values in the baseline subset. Gulezian and Samelian (2003) regarded it as the mean productivity of the points falling within the control limits of the individuals' control chart. Sweis *et al*. (2009) state baseline productivity as the average of the daily productivity values that falls below the Lower Control Limit (LCL) because productivities that are below the LCL have the highest daily production or output based on the metric of productivity adopted for the study. However, Ibbs *et al*. (2007) outlined the limitations of the baseline productivity methodologies in Thomas and Zavrski (1999) and Thomas and Sanvido (2000).

This include baseline sample identified according to the best daily output instead of the best daily productivity and the 10% requirement for the baseline sample size is arbitrary and not based upon scientific principles. Similarly, the concept of baseline productivity in Sweis *et al*. (2009) mainly considered it as the highest productivity devoid of any disruptions which Ibbs *et al*. (2007) note are not uncommon in real life. Nevertheless, this study considers baseline productivity as average of the daily productivity values above the Centre Line (CL) but below the Upper Control Limit (UCL) since this is the limit for the highest productivity values based on the metric of productivity used in the study. This approach is expected to carter for some level of disruptions while serving as a basis for benchmarking labour productivity on construction sites because it is higher than the average productivity but lower than cases that could be termed abnormal. Productivity values falling outside the control limits are considered as abnormal.

2.4 Previous Studies on Construction Labour Productivity of Blockwork Activity

Odesola (2012) observes that the areas of block-work done most times are not regular. Hence, evaluating the area of work done in such cases becomes tedious and requires processing of additional data on measurements about the perimeter of the irregular area. This becomes laborious for research assistants to observe and keep accurate records. However, the number of blocks laid by a mason directly correlates with the area of

block-work done. In view of this, Odesola (2012) considers the number of blocks laid a better option for obtaining data that could be processed to give the area of work done in a day by a mason. This approach was adopted in this study as it facilitates the data collection process. Olomolaiye and Ogunlana (1989) and Ayandele (1996) studies reports that the average observed output for blockwork in an 8 hours per day schedule was 59 and 52 blocks respectively. Idiake and Bala (2012) observes that the cumulative baseline productivities for 6 projects in Abuja metropolis ranged between 1.920 and $1.003wh/m^2$ i.e. 0.521 and $0.997m^2/whr$. Most of these studies fail to indicate or note vital specifications that could affect productivity such as the size of block and work processes used in the study. Consequent upon these observed gaps, this study is poised to determine labour productivity of 225 x 225 x 450mm sandcrete block using the continuous observation method of work measurement.

3.0   Research Methods

This study adopts a descriptive research survey design approach using a project work study manual as the research instrument. The productivity data collection manual used in this study was adopted from project's work study manual developed by Pennsylvania State University and Dundee University (Thomas *et al*., 1989). It comprised of three parts namely; form 1, 2 and 3. Form 1 contained questions to collect information on the project being monitored. Form 2 contained questions designed to collect information on the work processes and work contents of the block work activity in the study. Form 3 contained questions used to obtain data on the non-working time of construction labour and the quantity of work done for the day.

Research assistants were engaged to monitor blockwork activity involving 225 x 225 x 450 mm sandcrete blocks on on-going public building projects in the study area. A total of 8 field assistants were employed and trained for the exercise. The direct continuous observation approach was adopted to collect data on the construction sites. Attempt was made to address 'Hawthorne' effects (i.e. workers working diligently because they were being watched) by holding a brief discussion with the workers to explain the purpose behind the presence of the research assistants on the site as having nothing to do with the company's management probably trying to investigate them. They were assured that the exercise was purely academic.

Direct continuous observations were made for 30 working days being the benchmark for small and large sample sizes (Lucey, 2002) to ensure that the number of observations were adequate for generalisation. Four identified on-going public building projects involving 225 x 225 x 450 sandcrete blocks were selected for the study and monitored by two research assistants each. The research assistants were to observe and record the non-working time and quantity of work done by a gang comprising of an artisan and mate noted to be the predominant gang composition for blockwork activity in the study

area (Odesola, 2012). Related previous studies have used this approach to collect data on construction sites involving work study (Noor, 1992, Choy and Ruwanpura, 2006). To ensure adequacy of data aggregated from different sites for data analysis an integer scale ranging from 1 to 5 expressing the complexity of the design in ascending order as described by Sweis *et al*. (2009) was adopted. The researcher visited the sites being monitored to ensure that method of data collection was uniform and conformed to the given procedure.

Statistical Package for Social Sciences (SPSS) version 18 was used to analyse the data collected. This study utilised the measures of deviation comprising the Individuals (I) and Moving Range (MR) charts to evaluate daily construction labour productivity for blockwork activity since the data are in the form of single observations (Hill and Schvaneveldt, 2011). Statistical control charts are employed in the study to investigate variability in daily labour productivity of blockwork activity to determine whether it is attributable to common or special causes. Four of the Western Electric Zone Tests for detecting an unstable process were utilised namely: rule 1 – one or more points beyond the upper or lower control limits; rule 2 – at least two of three successive points in zone A on the same side of the centre line; rule 3 – at least four of five successive points in zones B or beyond on the same side of the centre line; and rule 4 – at least eight successive points falling on the same side of the centre line (Smith, 2000). However, according to Smith (2000) only rule 1 is applicable to the MR charts.

4.0   Results

The blockwork activity studied on all the four construction sites were designated low work content on the project work study manual. This satisfies the condition stipulated by Sweis *et al*. (2009) for the application of statistical process control model for the evaluation of variability in the productivity of construction work activities. The conditions were that all quantities and productivity calculations are standardized and that variation in work complexity is taking into cognisance using appropriate work content rating. The results of the work processes and statistical analysis of data obtained during the work study exercise are presented below.

4.1   *Work Processes of Blockwork Activity on the Selected Public Building Projects*

Following the procedures outlined in Dawood *et al*., (1999) mentioned in the review of related literature, the work processes of the blockwork activity for the selected public building projects are depicted in Figure 1.
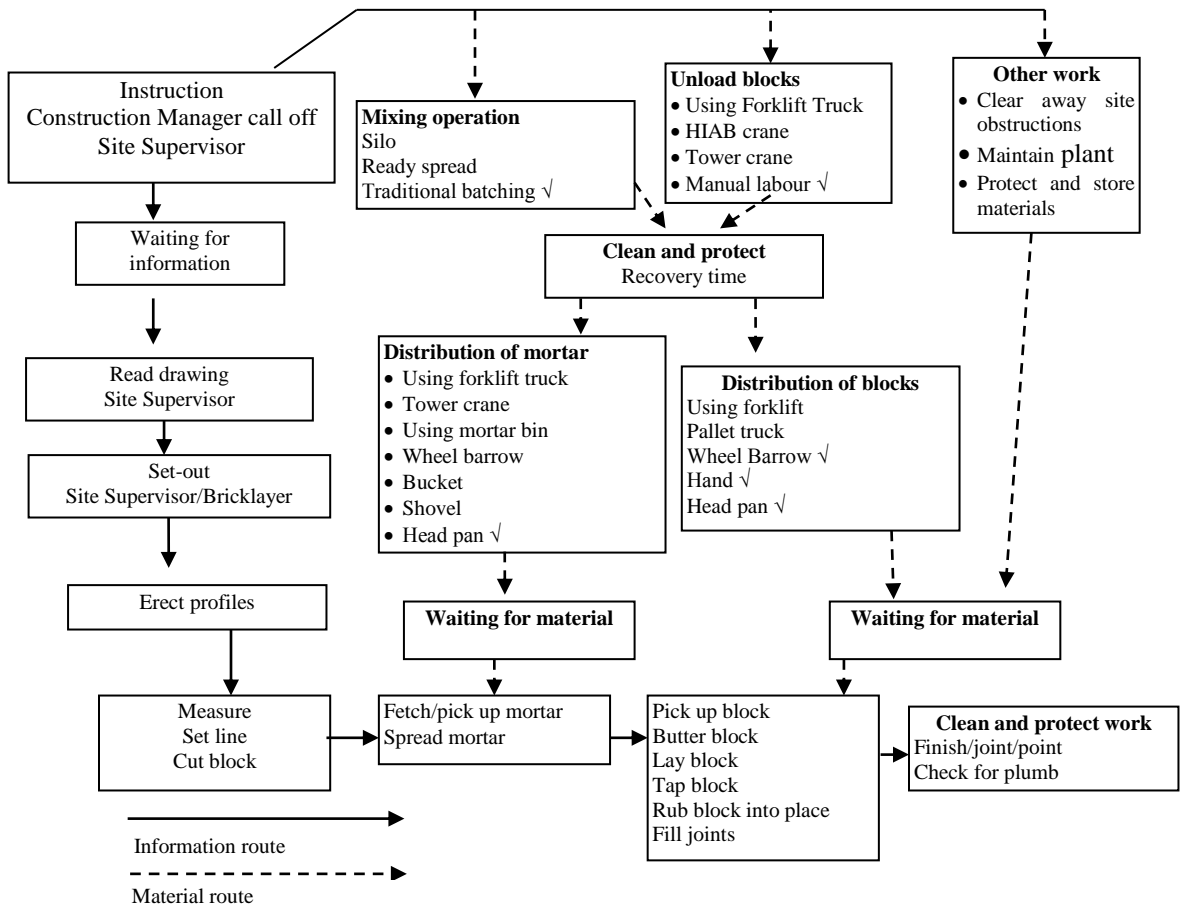
Figure 1: Blockwork production process mapping

Source: Adapted from Dawood *et al*. (1999)

It was observed that the work processes utilised on all the public building sites surveyed are the same for blockwork activity. The options adopted under mixing operations, unload blocks, distribution of mortar and distribution of blocks are traditional batching, manual labour, head pan, wheel barrow and hand respectively. The flow of information and material are as indicated in Figure 1.

4.2   *Working and Non-working Time of Construction Labour for Blockwork Activity*

Based on a block layer and mate, data were obtained on: number of blocks laid, total working hours for workers, number of approved breaks, period of time for each break and the amount of non-working time observed in a day using the project work study

manual. The amount of working time (tool time) and the productivity of blockwork activity for each day were computed using the data obtained. Figure 2 shows the average percentage working and non-working time of construction labour on blockwork activity for the sampled public building projects. The result indicates that almost half of the total worker's time is spent on non-value adding activities.
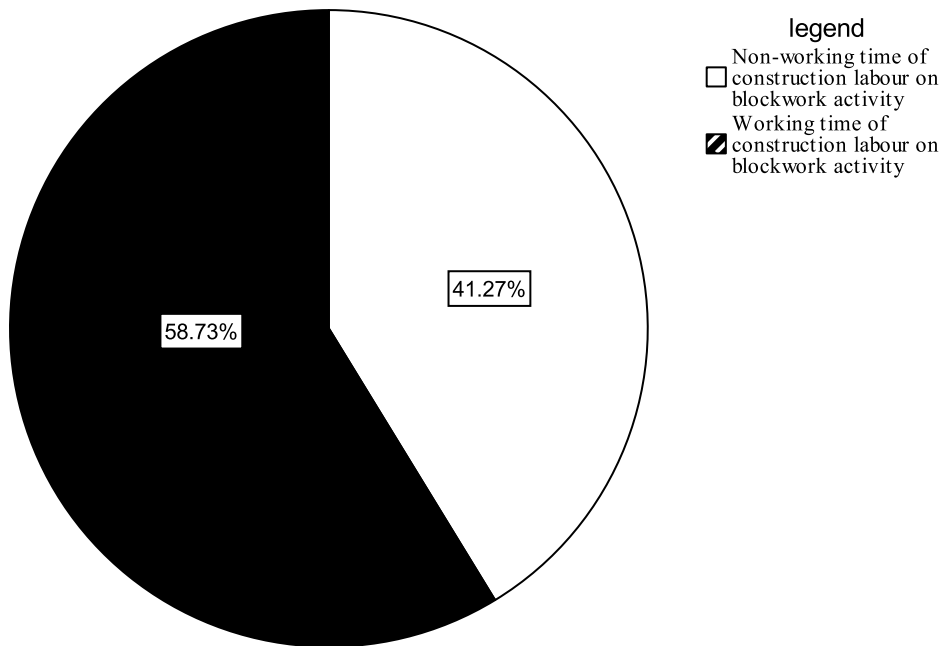

Figure 2: Percentage average working and nonworking time of construction labour on blockwork activity for public building projects in Akwa Ibom State, Nigeria

4.3   *I and MR Charts of Construction Labour Productivity of Blockwork Activity*

Figures 3 and 4 show the I and MR charts of construction labour productivities of blockwork activity on public building projects in the study area utilising the four Western Electric Tests rules . The result indicates that the individual chart of the daily construction labour productivity violates rules 3 and 4 implying that the process is not in statistical control. Investigation revealed that it was noted in the productivity manual that there was intermittent rain falls on the fourth day and delay in the supply of materials on the 10, 11, 12 and 13 working days which could be attributed to the construction labour productivities recorded on the fifth and eleventh day violating the 3rd rule. In the same vein, it was noted in the productivity manual that there was consistent delay in the supply of materials and intermittent rain fails on the 17th to the 24th working days which could also explain the violation of the 4th rule by the

construction labour productivities recorded on the 19th to the 24th working days. On the other hand, the MR chart did not violate the first rule applicable to it and therefore indicates that the variability of the daily construction labour productivity about the average productivity is consistent over the period of the investigation. Although the daily construction labour productivities were not in statistical control during the period of the study for some assignable causes, however, the average of the productivities could be said to be consistent.

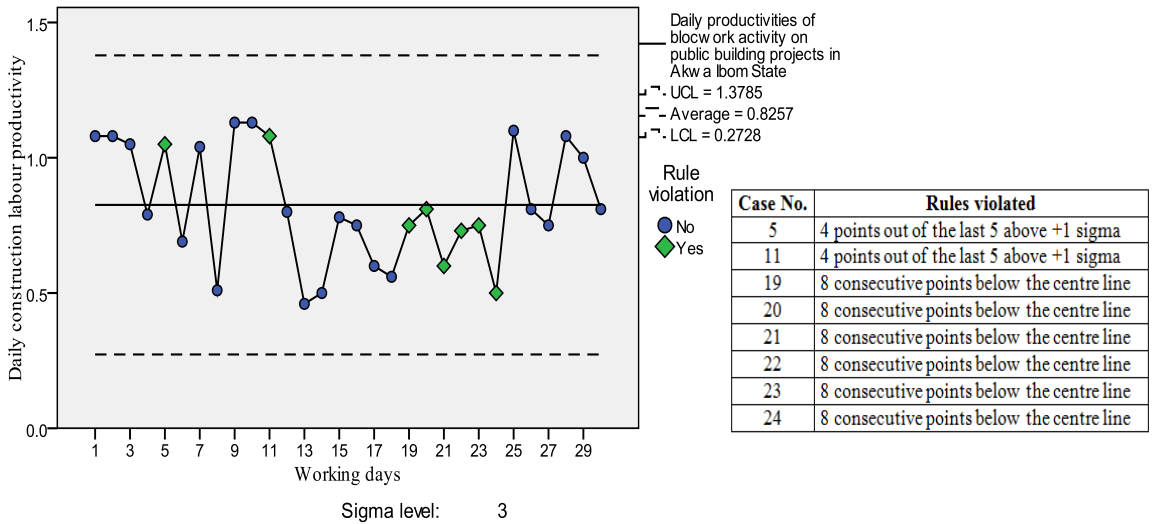| Case No.	Rules violated
5	4 points out of the last 5 above +1 sigma
11	4 points out of the last 5 above +1 sigma
19	8 consecutive points below the centre line
20	8 consecutive points below the centre line
21	8 consecutive points below the centre line
22	8 consecutive points below the centre line
23	8 consecutive points below the centre line
24	8 consecutive points below the centre line

Figure 3:   I chart of the daily construction labour productivities of blockwork activity
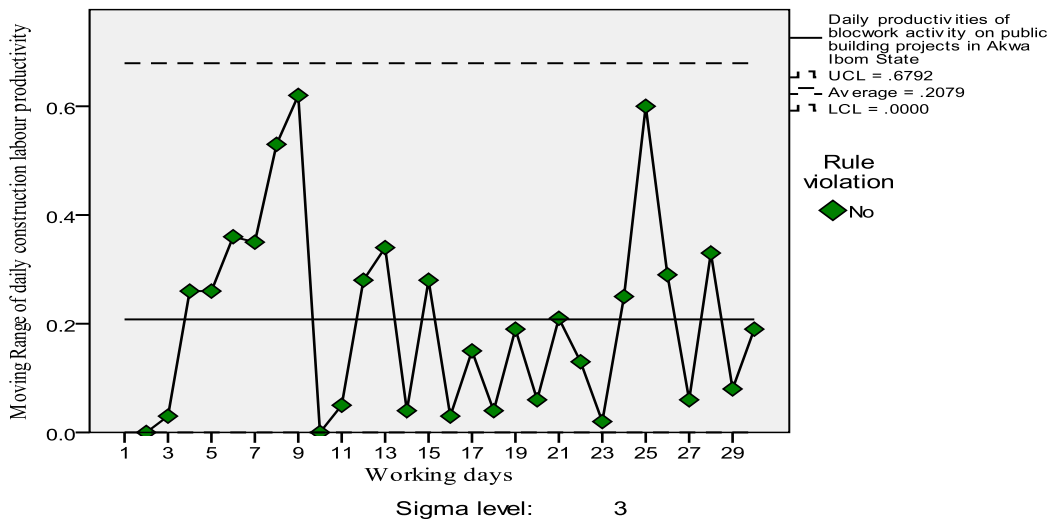

Figure 4:   MR chart of the daily construction labour productivities of blockwork activity

Average construction labour productivity of blockwork activity on public building projects based on a gang comprising of a bricklayer and mate is 0.83m²/hr which corresponds approximately to 66 blocks per day (i.e. 0.83 x 8 x 10) assuming it will require 10 blocks to lay 1m² as is the usual practice in estimation. The range of construction labour productivity during the 30 days of observation is 0.67m²/hr. There is or are no abnormal day(s) in which construction labour productivities are beyond the control limits as indicated in the I-chart. It could be observed that eleven construction labour productivities lie above the average productivity but below the Upper Control Limit. Therefore the baseline productivity as defined in the methodology is 1.07m²/hr. Table 1 presents a summary of the results of the evaluation of construction labour productivity of blockwork activity of public building projects in Akwa Ibom state.

Table 1: Summary of results of the evaluation of construction labour productivity of blockwork activity on public building projects in Akwa Ibom State, Nigeria

N (Day)	Work Content Rating	Baseline Productivity (m²/hr)	Range (m²/hr)	Min (m²/hr)	Max (m²/hr)	Mean (m²/hr)
30	1	1.07	0.67	0.46	1.13	0.83

Upper Control Limit (UCL) m²/hr	Lower Control Limit (LCL)	% WT	% NWT	Abnormal Days
1.38	0.27	58.73	41.27	0

Min = Minimum productivity; Max = Maximum productivity; WT = Working time; NWT = Nonworking time

5.0   Discussion

The average labour productivity of 225 x 225 mm sandcrete blockwork activity for a gang comprising of a bricklayer and a mate is 0.83m² for the work processes identified and reported in the results of the study. This corresponds to 66 blocks per day (i.e. 0.83 x 8 x 10) assuming it will require 10 blocks to lay 1m² as is the usual practice in estimation. The result of the study indicates some improvement in productivity compared to the findings in Olomolaiye and Ogunlana (1989) and Ayandele (1996) where it was reported that the average observed output in an 8 working hours schedule per day for blockwork was 59 and 52 blocks respectively as against the 66 obtained in this study. Apart from improvement in labour productivity in recent times which is attributed to better project management, improved contract method and the involvement of clients and contractors in project delivery observed by Otti (2012) another reason for such difference could be in terms of the gang sizes. The gang sizes used in the previous studies comprise of a labourer to two bricklayers as against the gang size of one

bricklayer to one labourer predominant on building sites in the study area.

In the same vein, the result obtained is similar to the findings in Idiake and Bala (2012) which showed that average cumulative productivity of blockwork activity on six sampled construction projects in Federal Capital Territory, Abuja is 1.13 Whr/m^2 which is equivalent to 0.88 m^2/Whr. However, in all of these previous studies the size of block used and the work processes adopted on the sampled construction sites where ignored and not reported. Nevertheless studies have shown that gang sizes (Noor, 1992) and work processes Jongeling (2006) could affect productivity. Compared with productivity reported by Odesola and Idoro (2014) indicates an overestimation of labour productivity using contractors' project records. This is in line with the observation made by Song and AbouRizk (2008) that many contractors lack accurate, consistent, and comprehensive data from past projects. Since the productivity reported in this study is based on direct continuous observation it is believed to be more accurate and more suitable for estimation.

Furthermore, the range of construction labour productivity during the 30 days of observation is 0.67m^2/hr which is equivalent to approximately 54 blocks. This value is quite high and it could be attributed to a number of causes. Investigation into the statistical stability of construction labour productivity of blockwork activity recorded in the study shows that it is not in statistical control. Further probe revealed that the variability in construction labour productivity of blockwork activity recorded in the study was due to assignable causes of intermittent rain falls and delay in the supply of materials. This support the observation recorded in literature that work environment factors such as adverse weather and unavailability of material together with other factors are prominent causes of loss of productivity (Sweis, *et al*., 2009). The range of construction labour productivity may therefore, serve as an indicator of the influence of some factors or situations on construction labour productivity on construction sites. In this study, the magnitude of the effects of these factors on construction labour productivity is high and therefore, deserves further investigation.

In addition, this study shows that the non-working time of construction labour on blockwork activity for public building projects is 41.27% of the total working time. This is similar to results in previous studies where Christian and Hachey (1995) reported 39%, Mc Tague and Jergeas (2002) 55.5% and Choy and Ruwanpura (2006) 40 to 50% to be the time spent on non-productive activities by construction workers.

6.0   Conclusion and Recommendations

This study evaluates construction labour productivity of blockwork activity on public building projects in Akwa Ibom state of Nigeria. It is concluded from the findings of the study that there is an overestimation of construction labour productivity of blockwork

activity using contractor's project records. Since determination of labour productivity through direct observation method is considered to be more reliable it is observed that the average construction labour productivity that could be used for estimation of the labour cost of blockwork activity in the study area is 0.83m^2/hr while contractors could aim at achieving labour productivity of 1.07m^2/hr being the baseline construction labour productivity. It is also concluded that variability in construction labour productivity of blockwork activity during the period of the study is assignable to weather conditions and delay in supply of materials. Therefore, statistical control charts could help in identifying assignable causes of variability in construction labour productivity. In the same vein, there exist potentials for the improvement of construction labour productivity on account of the appreciable time spent on non-value adding activities by construction workers in blockwork activity. The study therefore recommends that ample consideration should be given to the effect of adverse weather condition during labour cost estimation by taking into cognisance the period of execution of the project. Similarly, adequate planning of construction resources will help in enhancing labour productivity on public building projects.

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