Methodical Approach of Determining Labour Constants Models for Building Construction Processes in Nigeria

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Abstract— Construction planners and estimators in Nigeria often guess the standards of building tradesmen. These standards are usually given as constants in the form of time necessary for the manual completion of a defined quantity of work – standard time (St), or in the form of unit output – standard output (Sop) for a specified working period. Since it is difficult to draw reliable construction programmes or make accurate cost estimates without any available baseline standards or constants, this study therefore, systematically developed statistical models for determining labour constants for building construction processes. It was a field survey where detailed work study was carried out on two major work sections (concrete work and blockwork) in six building project purposely selected across the South East, Nigeria. Time study technique and a three-time estimate technique were used to determine the most probable duration time (expected time (t)) to complete each operation that makes up an activity relative to the quantity of work performed. From this, the duration time (t_{ka}), of key process was determined and subsequently, the standard time (S_t) and standard output (S_{op}) (labour constants) were evolved. Thereafter, these were fitted into regression models and the resultant showed that labour constant could be statistically determined. The models were further tested for adequacy, and it was found that all the generated models for various building operations considered were statistically adequate, good and fit for the purpose. The result indicated that the labour constants were realistic and appropriate for pricing, and could assist in effective project planning and control through realistic determination of optimal labour force in the execution of building projects. This is because, once a specific time is given, the labour output could be determined. The study then recommended a practical application of this model in different building construction processes across Nigeria.

Keywords— Building Processes, Construction Planning, Estimation, Labour Constants, Models, Standards, Work study

INTRODUCTION

The Nigerian building industry is strongly characterized with the desire for cheap labour ignoring the proper use of a realistic basic wage rates for tradesmen. Most of the construction workers are casual workers (Okoye, Okolie & Aderibigbe, 2014), who have not properly learnt, or stayed on the trade and/or do not belong to the unions. The level of their productivity is not known, and determining the wage rate by using the all in labour rate becomes a little difficult. Wages are determined instead by mere agreement between the employer and the workers (Udegbe, 2007), but, labour rate should be paid based on the productivity of a worker. Omange, Udegbe and Dirisu (2003) argues that the effect of labour cost on building projects though important has not been singularly treated because of scarce literature on labour dynamics. Adeyemi and Alli (2000) believe that the primary purpose of cost analysis is to optimize the client's expenditure in order to have good value for money. However, Wood (1976) argues that labour constants for establishing the cost of labour in an item of work in the Bills of Quantities need not be guessed, imagined or thought. It is then, difficult to draw reliable construction programmes or make accurate cost estimates without any available baseline standards thus, this situation in Nigeria came with many problems such as inaccurate estimation, cost overrun, claims and litigations and project abandonment. In furtherance of this, Olomolaiye and Ogunlana (1989) observe that the output of joinery and steel workers in seven public institution building projects in Oyo State of Nigeria, determined on the sites were lower than the claimed output of operatives. The differences between claimed and determined output in each task vary between 3% and 42%.

In project implementation, be it the erection of a building construction, a road or providing water scheme, the site engineer or supervisor not only needs to have a sound knowledge of the necessary skills involved but in addition should be able to determine the optimum composition of each skill in order to accomplish a task at shorter duration and reduced cost. This is of possible through the

use technological standards for labour. Such standards are usually given as constants in the form of time necessary for the manual or mechanical completion of a defined quantity of work – standard time (S_t), or in the form of unit output – standard output (S_{op}) for a specified working period. According to Okereke (2002), standard time is the quantum of time which it takes a workman or a group of workmen to produce a good quality product under an ideally organized labour force and working condition. It is measured in hr/m, hr/m^2 or hr/m^3. While standard output is the quantum of good quality work accomplished by a workman or group of workmen in one working shift or working hour or day under an ideally organized labour and working condition. It is measured in m^2/hr or m^2/day, m^3/hr or m^3/day. Standardization in construction is primarily aimed at establishing standards in the use of labour, materials and machines. Thus these three elements in standardization are sometimes referred as technological standards or constants (Okereke, 2002). In view of the peculiarities of each construction site in terms of climatic conditions, social and cultural differences in the level of technological development, organizational, structure of contracting firms and the quality of available machines and materials, it is recommended that every construction organization should establish its own standards. The benefits to be derived among others:

i. increase in individual and collective productivity of labour;
ii. objective tendering;
iii. rational use of available resources;
iv. adaptation of more progressive management techniques.

The cumulative effect of the above benefits in having technological standards is that the contract time is correctly predetermined on the basis of available human and materials resources. In addition, Ayeni (1997) observes that most practicing firms of quantity surveyors maintain cost library within their organization. Such pool of information consists of labour wages and price of various materials and plants. They make references to them whenever they are computing the cost of a given project. Such information is of great importance to a quantity surveyor when preparing cost advice for a client on a new project. It also forms the basis of preparing final estimate for checking tenders received. Nevertheless, the productivity rate of a construction worker is measured by the quantum of good quality work he is able to perform within a unit time (hour, day, month, year). For comparison of the productivity rate of construction workers, the unit of measure usually adopted is the standard time (S_t) and standard output (S_{op}).

Work study particularly work measurement is concerned with measuring time required for specific task that is time required to perform a task so that an output standard of production for a worker or group of workers may be established (Calvert, Bailey & Coles, 1995). According to Khanna (2007), work study involves observing the worker at work. The methods used by the worker are observed and recorded in a work measurement study; the time taken by the worker to carry out an operation is recorded. It is the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance (International Labour Organization, ILO, 1979). Such information is required for estimating, planning, setting financial incentives, as part of the data in the method study, determination of optimal labour force in the execution of building projects, and also in monitoring actual production performance against the established standard (ILO, 1979; British Standard Institute, 1992). Interestingly, Harris and McCaffer (2005) observe that this method is increasingly finding its way in the building industry thereby bringing improvements to the badly organized environment often found on construction projects. To this end, Oxley and Poskitt (2007) avow that the purpose of work study is the provision of factual data to assist management in making decisions and to enable them to utilize with the maximum of efficiency all available resources (that is labour, plant, materials, and management) by applying systematic approach to problems instead of using intuitive guess work.

Further still, the construction price book contains information mainly on prices of labour and materials in Nigeria (Oforeh, 2002). Though there are many price books in the British market today such as Spons, Architect and Builder's price books, mechanical, electrical and services books, Griffiths price book, Laxton building price book, Royal Institution of Chartered Surveyors (RICS) building maintenance price books, which contain information on standards that formed sources of cost library, none contained information on standards which is the major data for computing realistic unit rates, but the Consol's Nigerian Building Price Book (Consol Associate, 2011), which contain few information on Nigeria construction workers' average output and local daily charges. Further attempt by Alumbugu et al (2014) only yielded minimal improvement but was not able to develop labour constants that can be generalized. The dearth of labour standards and data for construction planning and cost control in Nigeria as substantiated by Olomolaiye and Ogunlana (1989) and Udegbe (2007) is the driving force behinds this study.

METHODOLOGY

This study is a field survey. Six project samples were purposely selected across the South East Nigeria based on the researchers' knowledge of the population, the nature and purpose of the study. The building processes being studied were concrete works and blockwork in superstructure. These work sections were broken into operations to facilitate subsequent synthesis. Concrete works involve batching of materials into a mixer, transportation, placing and compaction. Blockwork involves batching of materials into a mixer, transportation of mortar, placing of mortar and setting of blocks in place. Each operation involves certain number of tradesmen and unskilled labourers that form the gangs.

Activity sampling was carried out particularly field counts. Field counts were carried on concreting, carpentry, bending and fixing of reinforcement, and block laying. Field count involves a quick count at random intervals of the numbers of operatives working and those not working at a given time. An indication of performance is known as activity rating.

Thus, activity rating = $\dfrac{\text{No. of active observers}}{\text{Total no. observed}}$

In each case, the average activity rating from the observations was greater than 40%. Thereafter, a full scale time study was carried out using stop watch for each operation that makes up the activity for each process by observing and recording the start and finish duration of each operation per shift for different cycles. The quantity of work carried out by each gang per eight-hour working day was subsequently measured and recorded

The uniformity of gang size and mode of operation made comparative analysis possible. For each operation that make up an activity and on each project, time study was carried out randomly on chosen days (not less than three times) during the entire investigation period in order to obtain different durations and quantity of work completed. The most probable duration time (expected time (t)) to complete each operation that make up an activity relative to the quantity of work performed is given as

Expected time (**t**) = $\dfrac{t_e + 4t_0 + t_1}{6}$

In order to eliminate inaccuracies beyond tolerable limits, the duration of operation consists of the following components:

t_e = optimistic time, the probable earliest time if all goes well

t_0 = most likely time the most probable time

t_1 = pessimistic time, the probable longest completion time if everything goes worst

For manually executed activities the duration time of key process is determined from the formula $t_{ka} = t_1 + t_2 + t_3 + \ldots\ldots\ldots\ldots + t_m$

Where $t_1 + t_2 + t_3 + \ldots\ldots\ldots\ldots + t_m$ are observed duration time of the individual operations that make up the activity relative to a unit quantity of work performed.

The standard time (S_t) is obtained by adding up the duration of the key activity (t_{ka}), the time spent for break and workmen individual needs or rest.

Standard time (S_t) = $\dfrac{t}{Q}$

Where **t** = time taken to accomplish Q quantum of work in an eight-hour working day.

Standard output (S_{op}) = $\dfrac{Q}{t}$

To establish the nature of relationship between standard time and standard output, regression analysis was used. The developed labour constants (Standard time (S_t) and Standard output (S_{op})) were fitted into a regression model, $Y = \alpha + \beta x + e$.

Where S_t is the independent variable (x) and S_{op} is the dependent variable (**Y**), α and β are constants, and e is the error margin. T statistic was used to test the significance of the relation at confidence interval of $\alpha = \beta_o$

Then (1- α) 100% confidence interval of β_o is given as (1 - α) 100% confidence interval $\left(\beta_0 = \hat{\beta}_o \pm t_{\frac{\alpha}{2}}, n - 2 \ Se \ \hat{\beta}_o \right)$

Thereafter, the model was subjected to statistical hypothesis test to confirm if the model is good. If the model is good, β will be statistically different from zero, otherwise.

i.e. **H$_0$: β = 0** vs **H$_1$: $\beta \neq 0$**

Decision: Reject **H$_0$** if **t** is greater than $t_{\alpha/2, \ n-2}$

RESULTS AND DISCUSSIONS

Table 1: Computation of Average Labour Constants for Reinforced Insitu Concrete 1:2:4 – 20mm agg

S/N	Building Process	Unit (m^3)	S_t (x) (h/unit)	S_{op} (y) (unit/m-h)	xy	x^2	y^2
1.	150mm thick in slab (first floor)	m^3	0.64	1.57	1.0048	0.4096	2.4649
2.	150mm thick in slab (second floor)	m^3	0.68	1.49	1.0132	0.4624	2.2201
3.	in columns (size 450 x 450 x 3000mm) (first floor)	m^3	3.11	0.33	1.0263	9.6721	0.1089
4.	in columns (size 450 x 450 x 3000mm) (second floor)	m^3	3.24	0.31	1.0044	10.4976	0.0961
	Total		**7.67**	**3.70**	**4.0487**	**21.0417**	**4.89**

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Table 1 showed the developed averaged labour constants for reinforced insitu concrete 1:2:4 – 20mm agg. These were computed from the results of the work study from the six building projects considered in this study. The above values were fitted into a regression model and the result is as presented in table 2 below.

Table 2: Result of Regression Analysis for Reinforced Insitu Concrete 1:2:4 – 20mm agg.

$\hat{\beta}$	$\hat{\alpha}$	$\hat{\delta^2}$	t_{cal} H_0: ($\alpha = 0$)	MSE	SSR	SSE	t_{cal} H_0: ($\beta = 0$)	$t_{\alpha/2, v}$	Remark
-0.48	1.85	0.0017	345.177	0.0016	1.4643	0.0032	-30.246	4.303	Reject H_0 in both cases. $\hat{\alpha}$ is significantly different from zero. The model is statistically good and adequate.

From table 2, the result of regression analysis for reinforced insitu concrete 1:2:4 – 20mm agg gave the model as: $\hat{Y} = 1.85 – 0.48x$. The model relation showed that we can fit the line of best fit into the scatter diagram of *y* and *x*. This also implied that the standard output (y) is related to the standard time (*x*) and that the model can predict the values of y for a given value of *x*. The result also revealed that $\hat{\alpha}$ is significantly different from zero since t_{cal} **(345.177)** $> t_{0.05/2, n-2}$ **(4.303).** Likewise, the result confirmed that the model is good, adequate and suitable for the relationship, since t_{cal} **(-30.246)** $> t_{0.05/2, n-2}$ **(4.303),** β is significantly different from zero and H_0 is rejected.

Table 3: Computation of Average Labour Constants for Fixing of High Yield Reinforcement Bars

S/N	Building Process	Unit (m^3)	S_t (x) (h/unit)	S_{op} (y) (unit/m-h)	xy	x^2	y^2
1.	16mmØ in columns (size 450 x 450 x 5000mm (first floor)	kg	0.025	40.09	1.00225	0.000625	1607.2081
2.	16mmØ in columns (size 450 x 450 x 5000mm (second floor)	kg	0.026	39.21	1.01946	0.000680	1537.4241
3.	10mmØ stirrups in columns	kg	0.208	4.81	1.00048	0.043264	23.1361
4.	Cut and bend 10mmØ as stirrups	kg	0.059	16.89	0.99651	0.003481	285.2721
	Total		**0.318**	**101.00**	**4.0187**	**0.04805**	**3453.0404**

Table 3 showed the developed averaged labour constants for fixing of high yield reinforcement bars. These were computed from the results of the work study from the six building projects considered in this study. The observed output in cut and bend 10mm diameter high yield bars as a stirrup is not relative and might not be comparable with other operations. However, the above values were fitted into a regression model for further analysis and statistical testing and the result is as presented in table 4 below.

Table 4: Result of Regression Analysis for Fixing of High Yield Reinforcement Bars.

$\hat{\beta}$	$\hat{\alpha}$	$\hat{\delta^2}$	t_{cal} H_0: ($\alpha = 0$)	MSE	SSR	SSE	t_{cal} H_0: ($\beta = 0$)	$t_{\alpha/2, v}$	Remark
-176.11	39.25	98.24	7.92	98.23	706.32	196.47	2.683	4.303	Reject H_0. α is significantly different from zero. But the model is statistically not good and adequate enough, since $t_{cal} < t_{\alpha/2, n-2}$ ($\beta = 0$).

From table 4, the result of regression analysis for fixing of high yield reinforcement bars gave the model as: $\hat{Y} = 39.24 – 176.11x$. The model relation showed that we can fit the line of best fit into the scatter diagram of *y* and *x*. a change in *x* will cause a significant change in *y*. This also implied that the standard output (y) is related to the standard time (*x*) and that the model can predict the values of y for a given value of *x*. The result also revealed that $\hat{\alpha}$ is significantly different from zero since t_{cal} **(7.920)** $> t_{0.05/2, n-2}$ **(4.303).** But in this case, though, there would be a significant change in *y* for any change in *x*, the result revealed that the model is not good and adequate enough for the relationship. Thus, t_{cal} **(2.663)** $< t_{0.05/2, n-2}$ **(4.303),** and since t_{cal} **(2.663)** $< t_{0.05/2, n-2}$ **(4.303),** H_0 is accepted and

conclude that β is significantly not different from zero. This is of particular significance in that the operation of fixing of reinforcement bars could not be adequately modelled into a regression fit because of handling of different sizes of reinforcement at the same time for a particular work section. This could also be due to combining different operations involved in the fixing of reinforcement bars which are not relative and comparable. Notwithstanding, the model could still predicts some changes in the amount of labour output of fixing reinforcement bars in the considered section of building construction work when there is a significant change in the time provided for the work.

Table 5: Computation of Average Labour Constants for Sawn Formwork

S/N	Building Process	Unit (m^3)	S_t (x) (h/unit)	S_{op} (y) (unit/m-h)	xy	x^2	y^2
1.	to suspended floor slab (first floor)	m^2	0.145	6.50	0.9425	0.0210	42.2500
2.	to suspended floor slab (second floor)	m^2	0.136				
3.	to sides of column (size 450 x 450 x 3000mm) (first floor)	m^2		6.19	0.8418	0.0185	38.3161
			4.08				
4.	to sides of column (size 450 x 450 x 3000mm) (second floor)	m^2		0.25	1.0200	16.6464	0.0625
			4.27				
			.	0.23	0.9821	18.2329	0.0529
	Total		**8.631**	**13.17**	**3.7864**	**34.9188**	**80.6815**

Table 5 showed the developed averaged labour constants for sawn formwork. These were computed from the results of the work study from the six building projects considered in this study. The above values were fitted into a regression model and the result is as presented in table 6 below.

Table 6: Result of Regression Analysis for Sawn Formwork in Slab and Column.

$\hat{\beta}$	$\hat{\alpha}$	$\hat{\delta^2}$	t_{cal} H_0: ($\alpha = 0$)	MSE	SSR	SSE	t_{cal} H_0: ($\beta = 0$)	$t_{\alpha/2, v}$	Remark
-1.51	6.56	0.0442	62.348	0.0446	37.23	0.0892	-28.890	4.303	Reject H$_0$ in both cases. $\hat{\alpha}$ is significantly different from zero. The model is statistically good and adequate.

From table 6, the result of regression analysis for sawn formwork in slab and column gave the model as: $\hat{Y} = 6.56 – 1.51x$. The model relation showed that we can fit the line of best fit into the scatter diagram of *y* and *x*. This also implied that the standard output (*y*) is related to the standard time (*x*) and that the model can predict the values of y for a given value of *x*. The result also revealed that $\hat{\alpha}$ is significantly different from zero since t_{cal} **(62.348) >** $t_{0.05/2, n-2}$ **(4.303).** Likewise, the result confirmed that the model is good and adequate and suitable for the relation, since t_{cal} **(-28.890) >** $t_{0.05/2, n-2}$ **(4.303),** β is significantly different from zero and H_0 is rejected.

Table 7: Computation of Average Labour Constants for Hollow Sandcrete Blockwork Bedded and Jointed in Cement Mortar (1:3)

S/N	Building Process	Unit (m^3)	S_t (x) (h/unit)	S_{op} (y) (unit/m-h)	xy	x^2	y^2
1.	225mm in (first floor)	m^2	0.39	2.57	1.0023	0.1521	6.6049
2.	225mm in (second floor)	m^2	0.40	2.53	1.0120	0.1600	6.4009
3.	150mm in (first floor)	m^2	0.38	2.64	1.0032	0.1444	6.9696
4.	150mm in (second floor)	m^2	0.39	2.59	1.0101	0.1521	6.7081
	Total		**1.56**	**10.33**	**4.0276**	**0.6086**	**26.6835**

Table 7 showed the developed averaged labour constants for hollow sandcrete blockwork bedded and jointed in cement mortar (1:3). These were computed from the results of the work study from the six building projects considered in this study. The above values were fitted into a regression model and the result is as presented in table 8 below.

Table 8: Result of Regression Analysis for Hollow Sandcrete Blockwork Bedded and Jointed in Cement Mortar (1:3)

$\hat{\beta}$	$\hat{\alpha}$	$\hat{\delta^2}$	t_{cal} H_0: ($\alpha = 0$)	MSE	SSR	SSE	t_{cal} H_0: ($\beta = 0$)	$t_{\alpha/2, v}$	Remark
-5.50	4.73	0.000 0125	1338.5 5	0.000 025	0.0060 5	0.0000 5	-15.556	4.303	Reject H_0 in both cases. $\hat{\alpha}$ is significantly different from zero. The model is statistically good and adequate for the relationship.

From table $\hat{6}$, the result of regression analysis for hollow sandcrete blockwork bedded and jointed in cement mortar (1:3) gave the model as: **Y = 4.73 – 5.50x.** The model relation showed that we can fit the line of best fit into the scatter diagram of y and x. This also implied that the standard output (y) is related to the standard time (x) and that the model can predict the values of y for a given value of x. The result also revealed that α is significantly different from zero since t_{cal} **(1338.55) > $t_{0.05/2, n-2}$ (4.303).** Likewise, the result confirmed that the model is good and adequate and suitable for the relation, since t_{cal} **(-15.556) > $t_{0.05/2, n-2}$ (4.303),** β is significantly different from zero and H_0 is rejected.

CONCLUSION

Construction planners and estimators in Nigeria are usually faced with the challenges of making accurate cost estimate, cost plan, pricing and preparing reliable construction programme thereby pushing the contractors to run into cash flow problems due to non existence of reliable and realistic labour standards. The dearth of unreliable cost data bank impelled this current study. Thus, this study was concerned with developing the appropriate labour constant models for different building construction processes in Nigeria. It has successfully demonstrated that relationship existed between the labour constants (standard time (S_t) and standard output (S_{op})), and convincingly developed different statistical models for different building construction operations. The study has also established that labour constants could be modelled into regression fit where any change in standard time would cause a significant change in the standard output and that standard labour output could be predicted from the model for any given standard time. The adequacy or otherwise of the models was also confirmed through the test of statistical hypotheses and the models were found to be good and adequate for the purpose except for fixing of reinforcement bars.

This study therefore has found to be very significant and has contributed substantially to the insufficient body of knowledge in this research direction. With this development, the work of construction planners, estimators, work study officers and other construction practitioners have been made easier in the sense that for any observed and calculated standard time, the standard output for any of the building processes would be obtained from the model for manually executed activities and similar working ratios of the gang. The developed labour standard at the same time would serve as veritable tools for realistic and accurate pricing thereby reducing the tendencies of guess estimates and at the same time serving the purpose of optimizing the client's expenditure in order to have good value for money. The results of this study would also minimized the challenges of accurate cost estimate, construction programme, project planning and control, and pricing of bills of quantities through realistic determination of optimal labour force in the execution of building projects. The study recommended a practical application of the labour constants and models in different building construction processes, an insight and holistic study into other building processes as this would significantly improve the performance of building practice in Nigeria.

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