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Developing Labour Constants for Building Processes from Work Study in Nigeria

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Abstract:
The study was aimed at developing appropriate labour constants suitable for cost estimation of building processes in Nigeria 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 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. Thereafter, the most probable duration time (expected time (t)) to complete each operation that makes up an activity relative to the quantity of work was observed and recorded. 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 determined. This study has undoubtedly achieved the development of labour constants which could be used to build up rates for labour by estimators during tendering for projects. It has given an insight into the output level of building operations in the study area which could serve as a base for a reliable and realizable construction programme, accurate cost estimate and reduced suboptimal job performance. It therefore recommended that the practical application of these labour constants on life building projects and an extension of such detailed analytical study in other parts of Nigeria.

Keywords: *Building processes, cost estimation, labour constants, work study*

1. Introduction

Cost of building a house is high and principally depends on cost of labour and materials. But over the years, cost estimation of building projects in Nigeria has been based on guesses and experience of the construction project planners, quantity surveyors and estimators. The result of this practice has been untold cost management altercations, claims, over/underestimation and project abandonments. The effect of labour cost on building projects though important has not been singularly treated because of scarce literature on labour dynamics (Omange, Udegbe & Dirisu, 2003). Skitmore and Wilcox (1994) note that although there is a wealth of prescriptive literature, surprisingly little descriptive material is available concerning the processes employed by builders in determining a tender price. Borcherding (2008) indicates that cost of production time can regularly account for about fifty percent of the working day, with higher levels not uncommon. The causes are usually interconnected and typically arise through unsatisfactory execution of marginal and supervisory functions surrounding short term planning, daily and weekly scheduling, materials standardization and control, information flow, constructability of designs, sub-contractor and supplier's performance, workforce goals and competency rather than specifically in the methods of working. 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.

Besides, the output of the construction industry constitutes one half of the gross capital and is 3-8% of the Gross Domestic Product (GDP) in most countries Arditi and Mochtar (2000). Labour cost represents a considerable proportion of the final cost of a building this according to Buchan, Fleming and Kelly (1993), is usually between 40 – 60 percent of the building cost. Labour productivity is adopted as an index for measuring productivity because labour is acknowledged as the most important factor of production since it is the only factor that creates value and sets the general level of production. According to Udegbe (2007), reducing the cost of building construction requires in-depth studies of the actual cost of labour. Cost reduction in building construction must take cognizance of factors like labour welfare, tactics and interplay, relationship with subordinates, skills acquired coupled with educational qualifications and the overall importance of labour force in construction.

Standardization in construction is primarily aimed at establishing standards (rates, constants) in the use of labour, materials and machines. These three elements in standardization are sometimes referred to as technological standards or constants. Standards in the use of labour are standard time (S_t) and standard output (S_{op}). Standard time is the quantum of time which it takes a workman or group of workmen to produce a good quality product under an ideally organized labour force and working condition. Its unit of measure is hrs/m, hrs/m^2, hrs/m^3 (Okereke, 2002). 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. The unit is usually m^2/hr or m^2/day, m^3/hr or m^3/day (Okereke, 2002).

According to Wood (1976) the subject of labour constants really covers a tremendous territory and becomes for the practicing estimator a life-long study of human endeavour. Thus, labour constants must allow for:-

1. Time spent going to and returning from tea and meal times.
2. Effect of inclement weather when carrying out operations.
3. Effect when working in very wet conditions.
4. Time spent receiving instructions, obtaining drawings and discussing procedures.
5. Delays awaiting key labour, materials and plant.
6. Intermittent working.
7. Effect of long periods of boring repetitive operations

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 (Wood, 1976). Mccadden (2006) observes that labour is one of the most difficult costs to predict in an estimate, because basically, it’s determined by calculating the hours required to complete a task or project, and then charging what it costs your business to compensate its field employees. But maintains that trying to predict the time required to complete a task or a project, especially if someone other than you will do the work, requires judgment and experience.

This is the problem with our estimating principles in Nigeria. This state of affair has resulted in very high variability of tender prices among contractors bidding for jobs in the building industry. Also analyses of contract sums for completed projects show very high coefficient of deviation from the original contract sums. Experts have fingered among other things the non-existence of appropriate technological constants for labour as being responsible for this ugly situation in the nations building sector. According to Olomoliaye and Ogunlana (1989), there is a dearth of information on the output levels of building operatives in Nigeria. Anecdote shows that construction firms base their labour constants for estimating on experience which at best are educated guesses. The large incidence of project abandonment in the country makes it rather unwise to attach much degree of accuracy to these guesses estimates. Without adequate knowledge of standards, it is impossible to draw reliable construction programmes or make accurate cost estimates for tendering purposes. Unrealistic cost estimates and inadequate job programming soon result in cash flow problems and subsequently, delays, cost overrun and project abandonment. While it is recognized that there are no established standards for different construction operations in the country, this is not sufficient justification to leave production outputs in the realm of guesses. Sometimes estimators depend on constants obtained from operatives on one site for estimating purposes. Needless to say that rash, off-the-cuff, wild guess can subsequently inflict a heavy financial punishment.

In addition, most or all indigenous building contractors neither have costing systems which ensure the reliable reporting back to the estimating and costing department of the latest production figures. The figures, when properly evaluated provide the data for compiling fresh up-to-date output, nor work study officers who can properly disseminate the process of production and not only check the accuracy of the costing systems but ensure that the proper method of performing work is carried out in the most economic manner. These ugly situations as catalogued above have been a source of worry to the quantity surveyors, hence the need for concerted efforts at redressing the situation. This study therefore is aimed at developing appropriate labour constants suitable for building projects in Nigeria.

2. Methodology

This study is a field survey. Six project samples coded A - F were purposely selected across the South East Nigeria due to 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.

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

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 $t = \frac{t_e + 4t_0 + t_1}{6}$

According to Okereke (2002), the measurement of the quantum of time spent for a given process or operation is subject to uncertainties (probabilistic quantum). 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) = $\frac{t}{Q}$

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

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

3. Results and Discussion

Observation days	Batchers (hrs)	Transporters (hrs)	Compactors (hrs)	Qty of concrete cast/day (m^3)
1	6.00	5.75	5.67	12.91
2	6.30	6.32	6.45	12.86
3	5.40	5.30	5.40	12.85
Average				12.87

Table 1: Basis for computation of standard time and standard output (e.g.Central Science Laboratory, Enugu State University of Science and Technology, Agbani, Enugu State)

Calculation of the most probable time to accomplish each operation

1. $$\frac{5.40 + 4 \text{ x } 6 + 6.30}{6} = \frac{35.70}{6} = 5.95hrs \ (t_1)$$

2. $$\frac{5.30 + 4 \text{ x } 5.75 + 6.32}{6} = \frac{34.62}{6} = 5.77hrs \ (t_2)$$

3. $$\frac{5.40 + 4 \text{ x } 5.67 + 6.45}{6} = \frac{34.53}{6} = 5.76hrs \ (t_3)$$

Total = 17.48

Average (t_{ka}) $\frac{17.48}{3}$ = 5.83

Average break time = 2.0

Standard time = **7.83hrs**

Similar results from different operations in different building processes as in table 1 were presented in tables 2-15

Project	No of masons/day	No of labourers/day	Standard Time (hrs)	Average qty cast per day (m^3)
A	2	12	7.89	10.81
B	2	12	7.95	11.20
C	2	14	7.92	13.11
D	3	13	7.88	12.81
E	2	14	7.91	13.63
F	2	14	7.83	12.87

Table 2: 150mm Thick Reinforced Instu Concrete 1:2:4 – 20mm Aggregate in Slab (First Floor)

Project	No of masons/day	No of labourers/day	Standard Time (hrs)	Average qty cast per day (m^3)
A	2	12	7.91	10.26
B	2	12	7.98	10.64
C	2	14	7.96	12.45
D	3	13	7.89	12.16
E	2	14	7.93	12.94
F	2	14	7.85	12.22

Table 3: 150mm Thick Reinforced Insitu Concrete 1:2:4 – 20mm Aggregate in Slab (Second Floor)

Project	No of mason/day	No of labourers/day	Standard Time (hrs)	Average qty cast per day (m^3)
A	2	7	7.92	2.41
B	2	8	7.86	2.67
C	2	6	7.84	2.15
D	3	9	7.78	3.31
E	2	7	7.90	2.49
F	2	7	7.89	2.43

Table 4: Reinforced Insitu Concrete 1:2:4 – 20mm Aggregate in Columns (Size 450 X 450 X 3000mm) (First Floor)

Project	No of mason/day	No of labourers/day	Standard Time (hrs)	Average qty cast per day (m^3)
A	2	7	7.75	2.35
B	2	8	7.80	2.53
C	2	6	7.92	2.04
D	3	9	7.82	3.14
E	2	7	7.77	2.36
F	2	7	7.78	2.30

Table 5: Reinforced Insitu Concrete 1:2:4 – 20mm Aggregate in Columns (Size 450 X 450 X 3000mm) (Second Floor)

Project	No of iron benders	No of labourers/day	Standard Time (hrs)	Average qty in kg/day
A	2	-	7.88	315
B	2	-	7.92	314
C	2	-	7.91	320.28
D	2	-	7.89	314
E	2	-	7.87	314
F	2	-	7.94	323.42

Table 6: 16mm Diameter High Yield Bars in Columns (Size 450 X 450 X 5000mm) First Floor

Project	No of iron benders/day	No of labourers/day	Standard Time (hrs)	Average qty in kg/day
A	2	-	7.94	311.08
B	2	-	7.90	311.18
C	2	-	7.88	310.08
D	2	-	7.89	308.97
E	2	-	7.93	310.46
F	2	-	7.92	309.01

Table 7: 16mm High Yield Bars in Columns (Size 450 X 450 X 5000mm) Second Floor

Project	No of benders/day	No of labourers/day	Standard Time (hrs)	Average qty in kg/day
A	2	-	7.88	37.61
B	2	-	7.89	37.62
C	2	-	7.91	38.37
D	2	-	7.87	37.62
E	2	-	7.88	37.62
F	2	-	7.93	38.75

Table 8: Fix 10mm Diameter Bars in Stirrups in Column

Project	No of benders/day	No of labourers/day	Standard Time (hrs)	Average No/day
A	1	-	7.87	135
B	1	-	7.80	130
C	1	-	7.79	128
D	1	-	7.83	133
E	1	-	7.81	133
F	1	-	7.85	135

Table 9: Cut and Bend 10mm Diameter High Yield Bars as Stirrups

Project	No of carpenters/day	No of labourers/day	Standard Time (hrs)	Average Qty in m^2/day
A	6	-	7.78	47
B	7	-	7.72	50
C	8	-	7.89	53
D	7	-	7.85	52
E	6	-	7.72	48
F	7	-	7.78	54

Table 10: Sawn Formwork to Suspended Slab (First Floor)

Project	No of carpenters/ day	No of labourers/day	Standard Time (hrs)	Average Qty in m^2/day
A	6	-	7.75	44
B	7	-	7.70	48
C	8	-	7.81	51
D	7	-	7.83	51
E	6	-	7.71	46
F	7	-	7.75	48

Table 11: Sawn Formwork to Suspend Floor Slab (Second Floor)

Project	No of carpenters/day	No of labourers/day	Standard Time (hrs)	Average Qty in m^2/day
A	3	-	7.90	2.26
B	2	-	7.87	1.82
C	2	-	7.87	1.82
D	3	-	7.92	2.21
E	2	-	7.85	1.78
F	2	-	7.89	1.82

Table 12: Sawn Formwork to Sides of Column (Size 450 X 450 X 3000mm) (First Floor)

Project	No of carpenters/day	No of labourers/day	Standard Time (hrs)	Average Qty in m^2/day
A	3	-	7.88	2.15
B	2	-	7.85	1.76
C	2	-	7.84	1.73
D	3	-	7.89	1.98
E	2	-	7.86	1.74
F	2	-	7.86	1.77

Table 13: Sawn Formwork to Sides of Column (450 X 450 X 3000mm) (Second Floor)

Project	No of tradesmen/day	No of labourers/day	Standard Time (hrs)	Av. Qty of blocks/day in m^2
A	2	1	7.78	19.84
B	2	1	7.77	19.94
C	2	1	7.77	20.04
D	2	1	7.79	19.98
E	2	1	7.76	20.00
F	2	1	7.77	20.04

Table 14: 225mm Thick Hollow Sandcrete Blockwork Bedded and Jointed in Cement Mortar (1:3) (First Floor)

Project	No of tradesmen/day	No of labourers/day	Standard Time (hrs)	Average Qty of blocks/day in m^2
A	2	1	7.87	19.64
B	2	1	7.84	19.74
C	2	1	7.80	19.84
D	2	1	7.88	19.78
E	2	1	7.83	19.98
F	2	1	7.86	19.86

Table15: 225mm Thick Hollow Sandcrete Blockwork Bedded and Jointed in Cement Mortar (1:3) (Second Floor)

Project	No of tradesmen/day	No of labourers/day	Standard Time (hrs)	Average Qty of blocks/day in m^2
A	2	1	7.76	20.04
B	2	1	7.73	20.51
C	2	1	7.68	20.44
D	2	1	7.78	20.48
E	2	1	7.70	20.38
F	2	1	7.74	20.54

Table 16: 150mm Thick Hollow Sandcrete Blockwork Bedded and Jointed in Cement Mortar (1:3) (First Floor)

Project	No of tradesmen/day	No of labourers/day	Standard Time (hrs)	Average Qty of blocks/day in m^2
A	2	1	7.83	19.84
B	2	1	7.81	20.30
C	2	1	7.75	20.23
D	2	1	7.85	20.28
E	2	1	7.78	20.18
F	2	1	7.82	20.33

Table 17: 150mm Thick Hollow Sandcrete Blockwork Bedded and Jointed in Cement Mortar (1:3) (Second Floor)

Tables 1-17 showed the results of the work study from six building projects' site on 16 different building construction processes. These showed the gang size per day for different work processes (for skilled and non skilled labour), the computed standard time per hour and average standard output per day. The result of this analysis showed a close range of both the standard time and standard output for a given work process in among the six building projects considered in the study. It is an indication that the difference in production time and quantity of work output across the region is minimal. The difference observed were as a result of differences in working conditions and location of project site, individuals involved and perception of workers. The average of these results could form the basis for development of labour standard for the region which could also be extended to other parts of Nigeria while considering variations in the working environment. Thus, the results of the work study are veritable information for developing labour constants as presented in table 18.

S/N	Building Process	Unit (m^3)	S_t (h/unit)	S_{op} (unit/m- h)
1.	150mm thick reinforced insitu concrete 1:2:4 – 20mm agg. in slab (first floor)	m^3	0.64	1.57
2.	150mm thick reinforced insitu concrete 1:2:4 – 20mm agg. in slab (second floor)	m^3	0.68	1.49
3.	Reinforced insitu concrete 1:2:4 – 20mm agg. in columns (size 450 x 450 x 3000mm) (first floor)	m^3	3.11	0.33
4.	Reinforced insitu concrete 1:2:4 – 20mm agg. in columns (size 450 x 450 x 3000mm) (second floor)	m^3	3.24	0.31
5.	16mm diameter high yield bars in columns (size 450 x 450 x 5000mm (first floor)	kg	0.025	40.09
6.	16mm diameter high yield bars in columns (size 450 x 450 x 5000mm (second floor)	kg	0.026	39.21
7.	Fix 10mm diameter high yield bars in stirrups in columns	kg	0.208	4.81
	Cut and bend 10mm diameter high yield bars as stirrups			
8.	Sawn Formwork to suspended floor slab (first floor)	kg	0.059	16.89
	Sawn Formwork to suspended floor slab (second floor)			
9.	Sawn Formwork to sides of column (size 450 x 450 x 3000mm)	m^2	0.145	6.50
10.	(first floor)	m^2	0.136	6.19
	Sawn Formwork to sides of column (size 450 x 450 x 3000mm)			
11.	(second floor)	m^2	4.08	0.25

12.	225mm thick hollow sandcrete blockwork bedded and jointed in cement mortar (1:3) (first floor)	m^2	4.27	0.23
13.	225mm thick hollow sandcrete blockwork bedded and jointed in cement mortar (1:3) (second floor)	m^2	0.39	2.57
14.	150mm thick hollow sandcrete blockwork bedded and jointed in cement mortar (1:3) (first floor)	m^2	0.40	2.53
15.	150mm thick hollow sandcrete blockwork bedded and jointed in cement mortar (1:3) (second floor)	m^2	0.38	2.64
16.		m^2	0.39	2.59

Table 18: Computation of Average Labour Constants for the Building Processes from the Results of Work Study

Table 17 showed the developed averaged labour constants for different building processes. These were computed from the results of the work study from the six building projects considered in this study. These constants would be used as basis for estimation and billing for building projects across the region of study and Nigeria in general.

4. Conclusion and Recommendation

Challenges face by building contractors and estimators in management of cost of building projects during project execution could be minimized when appropriate quantities in terms of labour constants are used in estimation and bidding of building project. In Nigeria, estimators and quantity surveyors usually guess whatever quantity they use in their estimation. In most cases, this practice leads to variations and cost overrun with its attendant cash flow problems. This study therefore, has developed reliable labour constants which could be used in cost estimation of labour items in building projects. This was done through a detailed work study on six different building construction projects in sixteen work processes. This study has also demonstrated how these constants could be used to solve the problem of accurate cost estimate of labours for various work items in building projects in Nigeria. It showed that through detailed work study on particular work section, relative quantities could be generated which could serve as basis for developing labour constants. The study undoubtedly has significantly added to the scare body of knowledge in this direction. It has achieved the development of labour constants which could be used to build up rates for labour by estimators during tendering for projects. It has given an insight into the output level of building operations in the study area which can serve as a base for a reliable and realizable construction programme, accurate cost estimate and reduced suboptimal job performance.

The study therefore recommended that the practical application of these labour constants on life building projects and an extension of such detailed analysis in other parts of Nigeria.

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