

The Application of Transcendental Functions to Labour Optimization in the Building Construction in Edo State, Nigeria

Mike I. Udegbe

*Department of Building, Faculty of Environmental Studies,
Ambrose Alli University, Ekpoma, Nigeria*

KEYWORDS Optimization; labour; productivity; performance; materials and ability

ABSTRACT The financial involvement in building structures (home ownership) currently tends to make them far out of reach for most civil servants and businessmen. This is largely because building construction is capital intensive and is not easily affordable by working class Nigerians. This paper examined the cost involvement of labour using transcendental functions. The study used both primary and secondary data. The primary data were collected from practical cost details obtained from the inception of selected building projects to their completion, while the secondary data were obtained from published information on labour productivity, output and efficiency in Journals and official statistics in Nigeria. The transcendental function was used to analyse and compare labour costs. The study found that labour cost in any building construction work is approximately 36% of the total cost of the project. It was thus concluded that government's concerted efforts at providing shelter are undermined by the rather prohibitive cost of erecting structures, a situation further exacerbated by high labour costs in Nigeria. The paper recommends that this cost can be reduced if the automated construction process, which involves a high degree mechanisation is adopted.

INTRODUCTION

Building structure, irrespective of size, has the universal but singular purpose of providing shelter for man. Today, individuals, private organisations and government agencies have been investing very huge sums of money in the development of buildings or estates, in and around major towns and cities. The financial involvement in building structures (home ownership) these days, tends to make them far out of reach for most civil servants and businessmen.

Government concerted efforts at providing affordable shelter for the citizens are greatly undermined by the continuous rise in population. Added to this, is the prohibitive cost of erecting structures. The constantly increasing cost of construction is often attributed to the high cost of materials and labour. The cost of labour and building materials are very significant in any housing project. There is a need for an indept study into labour cost in building construction with a view to optimizing and rationalizing its salient effects. Materials and labour are the two largest components of a structure. In advanced industrialized countries, the cost of materials is relatively low and the cost of labour relatively high. In the less developed or undeveloped countries, this ratio is reversed (Salvadori and Hellie, 1975). This situation is further worsened

by the fact that the labour market is dominated by elderly personnel who are normally greatly inhibited by age, whereas younger men are better suited for construction tasks.

The situation in Nigeria, a developing nation appears to agree with the above where most construction work are manually and crudely carried out with less involvement of mechanical devices. The labour cost in the construction of two or three identical houses in the same location may not likely be the same due to different methodological approaches and technological/managerial competence.

The effects of labour cost on projects, as important as it is, is not 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 clients' expenditure in order to have value for money. In today's world of rapid population growth, amidst dwindling financial resources, the tendency towards demand for low cost housing designs and construction, is a stark reality.

Adeyemi and Alli (2000) further stated that for adequate cost consideration of buildings or their component parts, the ultimate rather than the construction costs is of utmost importance. The ultimate cost will be the addition of construction costs, running and maintenance costs and alteration and modification costs. In this assertion, the cumulative cost of home

construction is x-rayed without concentration on labour involvement details and this appears holistic.

Rationale for Study

Labour and materials are undoubtedly responsible for the cost of any building construction project. Looking into proportion of labour and materials input in terms of cost evaluation is a necessity that will alleviate the feelings of would be owners or clients. The cost of labour in the construction of two or more identical houses in the same location may not likely be the same due to the different methodological approach and managerial/technical competence. Understandably, once the percentage cost of labour is known, a client can contract out a building project using the known value as a basis for judgment. This study looks specifically into the cost of labour involvement in construction with a view to determining the following objectives:

- (a) The approximate construction cost of labour in building construction.
- (b) The statistical variation of cost of labour in building construction.

Literature Review

Literature suggests that labour productivity is a widely used term and has no generally accepted definition or measure. Olufemi (1983) contends strongly that several definitions of the concept abound in literature and he adopted "the output per worker or man-hour" as definition of "productivity". He assumed a production function of the form;

$$Q = f(L, K, R)$$

Where Q = output, L = labour input, K = capital input and R = raw material input. According to Olufemi (1983), labour productivity is given by Q/L for a country that lacks adequate resources. This equation is similar to Bluenberg's (1982) performance equation of $P=f(A,M,O)$.

Where

P	=	performance,
f	=	functional notation
A	=	ability
M	=	motivation
O	=	objective

The techniques of calculating productivity measures using either time-series or cross-

sectional data are relative to this study. The measure of productivity is an index number problem. Iyaniwura (1983) observed during the Nigerian Institute of Social and Economic Research Conference that the factor "productivity" was an important economic indicator. It has always been and continued to be a subject of fruitful research in many developing and developed economies. "In Nigeria, as in similar developed economies, there is paucity of required statistical data and there is no statistical basis for comparing the levels and trends of factors (especially labour productivity) within and between various sectors". He opined that the formula currently used in measuring productivity considers basically two groups, those based on physical units of output and those based on value units. Where output is measurable in physical units, the following index of productivity can be used".

$$X_{1,0t} = \frac{Q_t}{Q_0} \div \frac{L_t}{L_0}$$

where

Q = is gross output in physical units

L = is the labour input as defined

T and O = are current and base periods respectively.

$X_{1,0t}$ = initial and final productivities at time t

Iyaniwura, (1983) however, noted that in building and construction "The measurement of productivity in Nigeria construction industry poses more problems than in any other sector. The problem of what unit of measurement to adopt was a major one". He wondered if the output envisaged should be calculated per day per hour, per month or per year. This was compounded by the wide range and varieties of materials involved. He found himself at a cross road with the huge financial outlay and bureaucracy involved in contracting. As interesting as this author sounds, only a fair knowledge of the building construction industry was superficially treated.

Time and Cost Relationship

Various authors have stressed the importance of study in construction without specific emphasis on relating cost to time. Cale (1971) suggests that construction control may be assessed by its effect on the index of production efficiency. Accordingly,

$$\text{Production efficiency} = \frac{\text{output}}{\text{Input}} = \frac{\text{value of output}}{\text{cost of input}}$$

Cale also suggested that value = $\frac{\text{usefactor} + \text{esteem factor}}{\text{cost}}$

From the proposal put forth by Cale, the following efficiency factors were established.

$$\text{Construction efficiency} = \frac{\text{final contract sum}}{\text{Initial contract sum}}$$

$$\text{Time efficiency} = \frac{\text{final contract time}}{\text{Initial contract time}}$$

$$\text{Speed efficiency} = \frac{\text{final contract cost/final time}}{\text{Initial contract cost/initial time}}$$

There is a need for labour cost studies in the construction industry in Nigeria so that improvement can be made on the efficiency, time and quality of construction.

European Concept of Productivity

Hagewisch and Brewster (1993) note that certain parameters were unavoidable in considering human performance. These are directly linked to the innate development of the human beings involved. As comprehensive as this finding is, it tends to give credence to the findings of Bromilow (1967).

Hagewisch and Brewster summarized their performance evaluation findings under the following:

- (1) Method of recruitment, (2) Average number of days devoted to training, (3) Methods for payments agreements, (4) Human resources management strategy, (5) Manning ratio, (6) Trade union membership, (7) Influence ratio of directors.

The summary of the widely homologated and used European development in human resource management (Hagewisch and Brewster, 1993), depended on numerical values according to practical evaluation of field operatives. The values also depended on variables as enumerated below:

- 1. Methods of Recruitment

	Ability
(a) From own employee (FOE)	- 1.00
(b) By word of mouth (BWOM)	- 0.40
(c) From publicity (FP)	- 0.80
(d) From agencies (FA)	- 0.60
- 2. Average number of days devoted to training (NDT):

	Ability
(a) 0 – 1	- 0.20
(b) 1 – 2	- 0.40
(c) 2 – 3	- 0.60
(d) 3 – 4	- 0.80
(e) 4 – 5	- 1.00
- 3. Methods for payment agreements (PMA)

	Ability
(a) Collective bargaining (CB)	- 0.40
(b) Internal negotiations (IN)	- 0.60

- (c) Individual agreement (IA) - 1.00
- 4. Human resource Management strategy (HRST)

	Ability
(a) Written (W)	- 1.00
(b) Unwritten (UW)	- 0.60
(c) None (N)	- 0.30
(d) Uncertain (U)	- 0.10
- 5. Manning Ratio (Mn)

	Ability
(a) 1:1	- 1.00
(b) 1:2	- 0.80
(c) 1:3	- 0.50
(d) 1:many	- 0.30
- 6(a) Contract (C) - 1.00
- (b) sub-contract (SC) - 0.50
- (c) normal (full-time), FT - 0.20
- 7 Trade Union membership (TUM): % of affiliates

	Ability
(a) 0 – 1	- 1.00
(b) 1 – 25	- 0.80
(c) 25 – 75	- 0.40
(d) 75 – 100	- 0.20
- 8 Influence Ratio of director (IRD)

	Ability
(a) 0.69 – 0.85	- 0.40
(b) 0.85 – 1.22	- 0.60
(c) 1.22 – 2.50	- 0.80
(d) 2.50 – 3.26	- 1.00

METHODOLOGY

This study relied on primary and secondary data. The primary data involved the practical cost details obtained from the inception of some building projects to completion. This allowed the daily expenses on materials, labour, transportation, feeding and public relations to be obtained. The cumulative value assisted in approximating cost of projects. The secondary approach involved reading texts and journals on labour productivity, output and efficiency. The transcendental function was used to analyse and compare labour cost.

RESULTS

To optimize productivity, its relationship with the variables or factors that affect it must be quantified and established.

From $P = f(A, M, O)$, where P = performance, A = ability, M = Motivation and O = objectives,

Quantifiable variables affecting labour productivity are:

$$\text{Productivity} \left\{ \begin{array}{l} \text{Blocklaying} = X m^3 \\ \text{Plastering} = Y m^3 \\ \text{Painting} = Z \end{array} \right\} \text{Daily}$$

Human resources management strategy – (HRST)

(W, UW, N, U)

- Manning Ratio (Mn).
- Type of Task (TT)
- Labour cost (LC) = % of total cost of construction (T.)
- Type of structure (TS) = floor area + wall area.
- Gender ratio (GR), (M = 0.75, F = 0.25.)
- Method of Recruitment (MR)
- FOE, BWOM, FP, FA.
- Qualification Qu
- Average No. of days devoted to training (NDT)
- Methods for payment agreements, PMA.
- Trade Union Membership (TUM)
- Influence Ratio of Director (IRD)

Total cost of labour (T) = F(P, TS, GR, QU, MR, NDT, PMA, HRST, Mn, TT, TUM, IRD) (1)

But according to Bluenberg P = f (A, M, O) (2)

Where A = ambition, M = motivation and O = objective

Differentiating other variables with respect to A, M and O, and substituting in equation (1) above, using a general rule for the transformation of differentiable variables, we have:

$$T: \begin{cases} P & = & f(A, M, O) \\ GR & = & f(A, M, O) \\ QU & = & f(A, M) \\ MR & = & f(O) \\ NDT & = & f(O) \\ PMA & = & f(M) \\ HRST & = & f(M, O) \\ Mn & = & f(O) \\ TT & = & f(O) \\ TUM & = & f(M) \\ IRD & = & f(M, O) \end{cases} \dots\dots (3)$$

The Jacobian of T is

$$J = \det \begin{pmatrix} f_{p_1} & f_{p_2} & f_{p_3} \\ f_{GR_1} & f_{GR_2} & f_{GR_3} \\ 1 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \\ 0 & 1 & 1 \end{pmatrix} \# \phi \dots\dots (4)$$

From this projection, J (Po) # O, so that T has a local inverse there. The form of this must be:

$$\begin{pmatrix} \frac{\partial p}{\partial A} & \frac{\partial p}{\partial M} & \frac{\partial p}{\partial O} \\ \frac{\partial GR}{\partial A} & \frac{\partial GR}{\partial M} & \frac{\partial GR}{\partial O} \\ \frac{\partial Qu}{\partial A} & \frac{\partial Qu}{\partial M} & \frac{\partial Qu}{\partial O} \end{pmatrix}$$

..... (5)

For block-laying and applying the Hegewisch formula for productivity 'x' and considering the extreme values of the variables,

$$\Rightarrow 4.21 \left[\frac{x}{100} + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 0.20 + 1.0 \right]$$

= % of labour cost (1)
= 4.21 (8.2 + 1.14 = 9.34)
= 39.32%

Applying the correction factor of 0.50 the percentage will be equal to 38.8%
For plastering % of labour cost

$$= 4.0 \left[\frac{x}{100} + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 0.20 + 1.0 \right]$$

= 4.0 (8.2 + 0.36)
= 34.24%

Applying the correction factor of 0.50 the percentage will be equal to 34.74%

For painting % of labour cost

$$= 4.0 \left[\frac{x}{100} + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 1.0 + 0.20 + 1.0 \right]$$

= 4.0 (8.2 + 0.76)
= 35.84%

Applying the correction factor of 0.50 the percentage will be equal to 36.34%

Generally, % of Labour = K [(values of affected variables using extreme conditions) ±β].

Where β = correction factor for heavy materials handling = ± 0.50.

DISCUSSION

The values obtained using the transcendental

function shows that the cumulative financial involvement of labour in projects is approximately 36% of the total cost of any building project.

Using the practical recording for project costs, the cost analysis shows that it is approximately 36% for labour involvement.

The cost analysis of six live projects involving labour cost and total project cost is presented below with a view to arriving at approximate percentage of labour force involvement.

Substructure, superstructure, services, fittings and finishes were chosen as yardstick for the calculation of labour involvement. It is important to note that the bill of quantities subdivided the subsections into the above-mentioned divisions. Detailed daily expenditure on the six projects were put together is arriving at the total cost.

Total Cost of Project

The study shows total cost of substructure in all the six projects (A – F). A corresponding total cost of labour involvement is also shown on table 4. The percentage of labour involvement is finally reflected on the same table. This will help in establishing cost percentage involving labour force in construction.

Table 1 shows the practical values obtained for substructure and labour cost in six different site locations in Edo State, Nigeria

Table 2 shows the tabulation of total cost of superstructures and the labour cost involvement based particularly on daily site recording. The percentage of labour cost involvement was approximately 37%.

Table 3 highlights the total cost of carrying out services work and the cost of labour involvement. Labour force percentage involvement is also clearly displayed. In this section the actual cost of services and labour force cost involvement has been partially added to the superstructure and the cost of finishes or fittings and fixtures.

Table 4 shows detailed cost of labour involvement in live project construction as recorded and reflects approximately 37%.

Table 5 shows recorded labour cost and total cost of finishes in different local government areas. The average cost of labour amounted to 36%

CONCLUSION

In Edo State of Nigeria, the cost of building construction is on the increase daily. Government concerted efforts at providing shelter are undermined by increase in population and the prohibitive cost of erecting structures.

This study shows that labour cost accounts for approximately 36% of construction cost. This cost percentage is significant and can be reduced if the automated construction process, which

Table 1: Cost of substructures and labour in some live projects

	<i>Substructure Total Cost</i>	<i>(Substructure) labour cost</i>	<i>Percentage of labour cost</i>
PROJECT A Residential Project in Benin City	N2,530,740.00	N936,373.00	$\frac{936,373.80.00}{2,530,740} \times \frac{100}{1} = 37\%$
PROJECT B Housing Development In Sabogida – Ora	N883,795.00	N327,004.00	$\frac{327,004.15}{883,795.00} \times \frac{100}{1} = 37\%$
PROJECT C Shopping Mall Complex in Uromi	N8,803,795.00	3,345,245.00	$\frac{3,345,245.24}{8,803,795.00} = 38\%$
PROJECT D Bedroom Bungalow in Auchi	85,900.00	25,770.00	$\frac{25,770}{85,900} \times \frac{100}{1} = 30\%$
PROJECT E.Two Two Bedroom Bungalow in Ekpoma	16,000.00	5,440.00	$\frac{5,440}{16,000} \times \frac{100}{1} = 34\%$
PROJECT F Two Bedroom Flat in Igbanke/Igubeen	135,215.75	48,677.67	$\frac{48,677.67}{135,215.75} \times \frac{100}{1} = 36\%$

Source: Udegbe, M.I. 2004 "Analysis of Labour Cost in Building Construction in Edo State". Ph.D. Dissertation, Ambrose Alli University, Ekpoma, Nigeria.

Table 2: Cost of superstructure in some live projects

	<i>Substructure Total Cost</i>	<i>(Substructure) labour cost</i>	<i>Percentage of labour cost</i>
PROJECT A			
Residential Project in Benin City	₦4,100,870.00	₦1,394,295.80	$\frac{1,394,295.80}{4,100,870.00} \times \frac{100}{1} = 34\%$
PROJECT B			
Housing Development In Sabogida – Ora	₦724,015.00	₦260,645.40	$\frac{260,645.40}{724,015.00} \times \frac{100}{1} = 36\%$
PROJECT C			
Shopping Mall Complex in Uromi	₦182,446,418.00	₦71,154,103.20	$\frac{71,154,103.00}{182,446,418.00} \times \frac{100}{1} = 39\%$
PROJECT D			
Two Bedroom Bungalow in Auchi	₦88,835.00	₦31,905.00	$\frac{31,905.00}{88,835.00} \times \frac{100}{1} = 36\%$
PROJECT E			
Two bedroom Bungalow in Ekpoma	₦933,888.47	₦336,199.85	$\frac{336,199.85}{933,888.47} \times \frac{100}{1} = 36\%$
PROJECT F			
Two Bedroom Flat in Igbanke/Igueben	₦218,850.24	₦83,163.09	$\frac{83,163.09}{218,850.24} \times \frac{100}{1} = 38\%$

Source: Udegbe, M.I. 2004 "Analysis of Labour Cost in Building Construction in Edo State". Ph.D. Dissertation, Ambrose Alli University, Ekpoma, Nigeria.

Table 3: Cost of services in some live projects

	<i>Total Cost of Services</i>	<i>Services Labour Cost</i>	<i>Percentage of Labour Cost</i>
PROJECT A			
Residential Project In Benin City	₦830,340.00	₦298,922.40	$\frac{298,922.40}{830,340.00} \times \frac{100}{1} = 36\%$
PROJECT B			
Housing Development in Sabogida – Ora	₦270,840.00	₦94,794.00	$\frac{94,794.00}{270,840.00} \times \frac{100}{1} = 35\%$
PROJECT C			
Shopping Mall Complex in Uromi	₦6,443,582.00	₦2,384,125.34	$\frac{2,384,125.34}{6,443,582.00} \times \frac{100}{1} = 37\%$
PROJECT D			
Two Bedroom Bungalow in Auchi	₦33,100.00	₦11,254.00	$\frac{11,254.00}{33,100.00} \times \frac{100}{1} = 34\%$
PROJECT E			
Two Bedroom Bungalow in Ekpoma	Priced together with finishes	Priced together with finishes	
PROJECT F			
Two Bedroom FlatIn Igbanke/Igueben	₦246,558.80	₦91,753.97	$\frac{91,753.97}{246,558.80} \times \frac{100}{1} = 36\%$

Source: Udegbe, M.I. 2004 "Analysis of Labour Cost in Building Construction in Edo State". Ph.D. Dissertation, Ambrose Alli University, Ekpoma, Nigeria.

involves a high degree mechanisation is adopted. Apart from reducing manual involvement, it is one good process that can enhance productivity.

REFERENCES

- Adeyemi, A.Y. and O. R. Alli. 2000. *Cost implication of Alternative Staircase Design in Residential Buildings*. Effective Housing in the 21st Century, Akure, pp.16–25.
- Bluenberg, P. and C. D. Pring. 1982. "The Missing Opportunity in Organizational Research: Some Implications for a Theory of Work Performance." *Academy of Management Review*, Oct., pp. 565-567
- Bromilow, F. 1967. "Time Performance of Building Contractor". *CSIRO Div. of Building Research*, pp.34 – 38.
- Cale, G.N. 1971. *Management and Productivity Techniques*. Breck S.P.L - Construction Management. London: Longman.
- Fayol, H. 1949. *General and Industrial Management*. London: Pitmans.

Table 4: Cost of fittings and fixtures in some live projects

	<i>Total Cost of Fittings & Fixtures</i>	<i>Fitting & Fixtures Labour Cost</i>	<i>Percentage of Labour Cost</i>
PROJECT A Residential Project in Benin City	₦133,020.00	₦50,547.60	$\frac{50,547.60}{133,020.00} \times \frac{100}{1} = 38\%$
PROJECT B Housing Development in Sabogida – Ora	₦196,000.00	₦70,560.00	$\frac{70,560.00}{196,000.00} \times \frac{100}{1} = 36\%$
PROJECT C Shopping Mall Complex in Uromi	Priced together with finishes	Priced with finishes	Priced with finishes
PROJECT D Two Bedroom Bungalow in Auchi	Priced together with finishes	Priced with finishes	Priced with finishes
PROJECT E Two Bedroom Bungalow in Ekpoma	Priced together with finishes	Priced with finishes	Priced with finishes
PROJECT F Two Bedroom Flat in Igbanke/Igueben	₦331,625.00	₦116,065.75	$\frac{116,065.75}{331,625.00} \times \frac{100}{1} = 35\%$

Source: Udegbe, M.I. 2004 “Analysis of Labour Cost in Building Construction in Edo State”. Ph.D. Dissertation, Ambrose Alli University, Ekpoma, Nigeria.

Table 5: Cost of finishes in some live projects

	<i>Total Cost of Services</i>	<i>Services Labour Cost</i>	<i>Percentage of Labour Cost</i>
PROJECT A Residential Project in Benin City	₦1,886,730.00	₦679,222.80	$\frac{679,222.80}{1,886,730.00} \times \frac{100}{1} = 36\%$
PROJECT B Housing Development in Sabogida – Ora	₦703,610.00	₦260,335.70	$\frac{260,335.70}{703,610.00} \times \frac{100}{1} = 37\%$
PROJECT C Shopping Mall Complex in Uromi	₦10,607,805.00	₦4137,043.95	$\frac{4137,043.95}{10,607,805.00} \times \frac{100}{1} = 39\%$
PROJECT D Two bedroom Bungalow in Auchi	₦96,005.55	₦34,561.80	$\frac{34,561.80}{96,005.55} \times \frac{100}{1} = 36\%$
PROJECT E Two Bedroom Bungalow in Ekpoma	₦273,663.95	₦74,582.05	$\frac{74,582.05}{273,663.95} \times \frac{100}{1} = 27\%$
PROJECT F Two Bedroom Flat In Igbanke/Igueben	₦114,686.00	₦40,286.50	$\frac{40,286.50}{114,686.00} \times \frac{100}{1} = 35\%$

Source: Udegbe, M.I. 2004 “Analysis of Labour Cost in Building Construction in Edo State”. Ph.D. Dissertation, Ambrose Alli University, Ekpoma, Nigeria.

Hagewisch, A. and C. Brewster. 1993. *European Development in Human Resources Management*. London: The Canfield Management Services.

Iyaniwura, J. O and A. M. Osoba. 1983. “Measuring Productivity. Conceptual and Statistical Problems.” *Seminar Proceedings of National Conference, NISER*, Nigeria. Pp. 55 – 57

Olufemi, F. 1983. “Industrial Productivity in Nigeria.” *Seminar Proceedings at NISER Conference*,

Ibadan, Nigeria, Pp. 364 – 365.

Salvadori, M. and R. Heller. 1975. *Structure in Architecture*. New Jersey: Eaglewood Cliffs.

Udegbe, M.I. 1997. “Labour Force Utilization in Construction.” *Seminar Paper Delivered in NBRRI Lagos*, Nigeria. 1–5.

Udegbe, M.I. 2004. *Analysis of Labour Cost in Building Construction in Edo State*. Ph.D. Dissertation, Ambrose Alli University, Ekpoma, Nigeria.