Linearized Algebraic Model For Unit Rate Pricing Of Concrete Grade C20P In Construction Project Bid

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***Abstract*—Investigation into construction cost estimating models was extended to C20P concrete (mix ratio 1:3:6-38mm aggregate) in this study. The study reflected on the subsisting analytical method of pricing unit rate cost of concrete per m^3 as providing windows of subjective serial computations that puts the estimate in spurious condition. Literatures reviewed in this study showed gained comments that the spuriousness of such analytical pricing methods are significant contributors to construction cost overruns arising from indeterminacy of unit rate cost derived. This paper approached derivation of unit rate cost by modeling. This was done by disaggregating the various cost component of 1m^3 of C20P concrete and using productivity study by time and motion to determine the various outputs for materials and labour. These were subsequently applied as co-factors to component costs to derive the unit rate model. A validation test between e routine method and the cost model was carried algebraically to show fitness with a resounding result consistent with prevailing unit rate cost in the Nigerian construction industry. The paper concludes that the model enjoys flexibility of further mathematical treatment should any of the variables be constrained and recommends that contractor's bid on concrete item C20P be evaluated with the model.**

Keywords—Cost model, Estimate, Labour output constant, Time and motion study, Unit rate, Aggregation

1. INTRODUCTION

There has been a similar investigation on the subject of cost model for unit rate pricing of concrete type C25 in reinforced from by [1]. Their work was a timeous in the wake of inaccurate and indeterminate construction cost estimate and price volatility which researchers have linked to cost overruns in the industry [2], [3], [4] and [5]. The arguments against these models arising from their reliability, predictability and deterministic failures have been shown to be traceable to their algebraic defects and non empiricism of their derivation method. [1] reported that most of the models were irresolute to labour output per unit of the work item and algebraically unconscious of the units of measurement of work items e.g. linear meters (m), square meter (m^2), meter cube (m^3), weight (tons/or kg) e.t.c when aggregating the model's components. Significantly, [1] observed that the subsisting models for estimating cost within the industry failed to show compliance with the [6] test on generalized linear models. Specifically, the models have no structural components specifying the conditional distribution of the response variable i.e. the unit rate costs, secondly have no structural component of a linear predictor as a function of linear regressors without explanatory variables that takes coefficients. Further, they have no proof of invertability that linearizes a link function that can transform the expectation of the response variable to the linear predictor. Also, most of the nested models failed the incremental F-test and failed to comply with dispersion test wherein the dispersion parameter is fixed to 1, so that the likelihood ratio test (predictability test) becomes the difference in the residual deviances and lastly they had no estimation and testing parameters that fit to data by method of maximum likelihood.

In view of these obvious defects associated with unit rate cost models enumerated above, [1] averred that a holistic and general purpose model that attempts to compute the cost of a building by mere substitution and aggregation of prices is congruous with algebraic properties of linear models and by extension are inefficient in predicting cost which often gives rise to inaccurate estimate. Rather, each work item cost model is idealized to compute each work item cost on unit rate basis and thereafter aggregate to give the entire project cost. Accordingly, this paper sought for cost model for unit rate pricing of concrete type C20P with mix-ratio 1:3:6-38mm aggregate.

2. LITERATURE SURVEY ON CONSTRUCTION COST MODELS

The construction industry is by far the most reported industry of cost volatility. Early cost planning and estimation response to construction projects cost volatility assures great success of the project. Several cost estimation techniques are available for that purpose from inception to completion stage. [7], [8], [9], [10], [11] 2013 and [12]. Cost models have been found to be useful in this respect, been a financial representation in the form of spread sheet, mathematical expression, chart, and/or diagram used to illustrate the total cost of families of systems, components, or parts within a total complex product, system, structure or facility [13]. The usefulness of cost models are exemplified in their ability to minimize project cost overruns and delays depending on their reliability levels and their derivation method [14].

Reliability failures of cost models have been reported to be responsible for project cost overruns and delays arising from poor estimation parameters inherently lacking in their predictive abilities [12], [15]. The search for superior, accurate and reliable cost models within the construction industry have been sufficiently rehearsed in construction literatures [16]. Yet, cost indeterminacy continues unabated due to the qualitative parameters that hinders cost estimation like client's priority on construction time, contractor's planning and scheduling capabilities, procurement method and other extraneous factors [17]. More the same, construction project cost estimators are confined to the routine traditional cost estimating and cost planning techniques which are often tempora in application [18], [19]. In recent times, sophisticated cost models have been developed within the industry, in response to earlier cost estimation techniques that were in need of precision. [20] developed a cost estimation software on the basis of component prices by showing the nexus between expenses and project management capabilities. The model on its face value could not show the quantitative values of the components and was irresolute to labour output.

Before then, [7] developed a parametric cost software model with Fuzzy logic algorithm on the basis of Lukasiewicz tri-value logic system which was a substitute form of the Aristotle's bi-value logic system. With this alternative form, logical thinking shifted from True or False [0,1] to True, Partly true or False, False [-1, 0, +1] rather than [0,1,2]. [21], [22] harped on this logical conception and incorporated it into modern day computers to resolve their rigidity in their i[7]ity to manipulate data representing subjective measures. The [7] (2012) cost model was a beneficiary of the fuzzy logic conception. The model identified five (5) predominant cost drivers to include; Area of Typical floor, Number of floors, Number of elevator's, volume of HVAC and Type of plastering (rendering). The conception of the [7] study is that these cost drivers defines the building's formal characteristics and the amount of materials required for the structural and Architectural considerations of buildings. These costs were subjected to Fuzzy logic operation with a triangular membership function to generate a cost estimating model (See Table 2). Again, [20] on the basis of data from project expenses in relation to the allocation of resources to activities wrote a cost model software for constructions project estimation.

[23] proposed the unit rate cost factoring method using neural networks to identify the essential factors that affects unit cost estimation. With the aid of neural network approach, the identified 25 factors were zeroed to 8. The study showed that political environment accounted for 44% proportion of cost factors in unit rate and closely followed by contractor's capacity of 22%. Financial delays, project feasibility, profit and overhead accounted for 11%. Other extraneous factors enumerated in the study were project location, material availability and corruption perception index contributed the rest percentage. The application of the findings lies in the incorporation of the quantified cost factors in unit cost estimation model to earn estimate accuracy. However, this approach does not show labour cost contribution to unit rate estimation, as it depends on extrapolated baseline unit cost model and then factored to generate its own rate. In contrast, [24] idealized a general purpose model that tend to price the construction cost of a built facility by product summation of all item's quantity and their unit price plus value added tax using;

$$P = \sum_{i=1}^{n} P_i q_i + T$$

where P = total price to be paid to the contractor

q_i = quantity related with the item

P_i = unit price of the item

i = number of the priced item, i < 1, n>

T = amount of value added tax calculated in

accordance with applicable regulation

The algebraic presentation of the [24] model showed some appeal but technically defective in content to the extent that the model had no buffer zone for materials waste nor contractor's mark-up and contingency, neither does it have labour output cost incorporated in the model. There have been other models which seek to rationalise project performance with recourse to value for money in terms of time and cost. See Table 1 for [25] on Time-cost model for building projects in Nigeria, [26], on final cost of building and duration, [27] on Time – cost prediction of high rise commercial projects in Australia, Yeong (1994) on modified [26] study to Australian and Malaysian Public, Private and all project types, [28] on extension of the [25] preposition to building and Civil Engineering works with a resounding affirmation. [29] also took the framework of [30] study to Hong-Kong on private, public project categorization. The same investigation was made by [31] in Nigeria with improved predictive abilities of the model by [25] and [32] on relationship between gross floor area and number of floors as determinants project's cost and time. As a follow up, [33] extended the frontiers of cost modeling by proposing a Linearized cost estimation model for construction work items. Their construct considered the Unit rate cost of construction work items' as the summation of the prime, cost, overhead charges and profit for each work item in a project. They derived a unit rate cost model as;

R = N+ (N x Z)(1)

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Table 1. Summary of Time-Cost Models for Construction Projects

Source	Year	Classification	Model	System	Where studied
Bromilow	1974	Building Projects	$T=KC^B$ $T=313C^{0.3}$	Generalised	Australia
Ireland	1983	Highrise Commercial	$T=219C^{0.47}$	Derived	Australia
Yeong	1994	Building projects for private/public use	$T=161C^{0.367}$ $T=287C^{0.237}$ $T=269C^{0.215}$ $T=518C^{0.352}$	Derived	Australian private buildings Australian public buildings All Australian projects Malaysian public projects
Chan	1999	Builidng projects for private and public use	$T=166C^{0.28}$ $T=120C^{0.34}$ $T=152C^{0.29}$	Derived	Public projects in Hong Kong Private project in Hong Kong All Hong Kong projects
Ojo	2001	Building projects	$T=27C^{0.125}$	Generic	South Western Nigeria
Love, Tse and Edward	2005	Building Project	Log(T)=3.178 + 0.274 Log(GFA) +0.142log(floor)	Generic	Australia
Ogunsemi and Jagboro	2006	Building projects public/private	$T=63C^{0262}$ $T=55C^{0.312}$ $T=69C^{0.255}$	Derived	South Western Nigeria for all projects (public/private)

Table 2. Cost Predicting Models for Construction Projects

	Source	Year	Classification	Model		System
1.	Challah and Tkiouat	2012	Construction works	Flat cost = $DST_1 + DST_2 + DST_3 + DST_4 = DSTT$		Programming
2.	[7]	2012	Building projects	No of floors No of Elevators Area of typical/floor Volume of HVAC Type of external plastering	1 0 1 0 1	Evaluate cost 0.0233.667 13587
3.	Inuwa	2013	Building projects	R = N+ (N x Z)		
4.	[24]	2014	Construction works	$P = \sum_{i=1}^{n} P_i q_i + T$		
5.	Mwiya et al	2015		Unit rate factor model		Algebraic extrapolation
6.	Egwunatum and Oboreh	2015		$6.2\zeta_t + 0.432z_\delta + 1.24\Lambda + p_n(0.062\zeta_t + 0.043z\delta + 0.0124\Lambda + \frac{p_c}{g} + \Gamma_t\psi_t + Z_{max}$		Algebraic aggregation

Source: Literature Survey

Where N – is the prime cost and Z – is a percentage of overheads and profits, such that; N = $M_c + L_c + P_c$ with the linear combination condition as; $Mc \geq 0$; $L_c \geq 0$; $P_c \geq 0$ and $Z_c \geq 0$

Summarily, recent cost models are somewhat attempts to make unit rate cost estimation a predictable quadrature occasioned by their stochastic characteristics as evident in the works of [20], [7] and [33].

3. METHODOLOGY

Cost data are perquisites, to cost modeling and the precision of these models are intrinsically linked to the manner in which the data were recorded. It is important to identify, isolate and decompose (into variable and fixed cost items) of the cost factors before applying them [23]. This study identified the routine complexities of having to generate a unit rate price of steel concrete grade C20P in 1:3:6-38mm aggregate by estimators by having to perform serial computations as follows:

i. Mixing method to be used i.e. either by hand or a mixing plant

ii. The size of the mixing plant

iii. The distance of the concrete will pass through to its place of use

iv. The method of transportation

v. Percentage of shrinkage

vi. Method of hoisting, placing and compaction

vii. Ready mix or site mixed

viii. Sources of materials especially cement and the form i.e. whether in 50 kilogrammes bag or in bulk which will stored at site in silos

(stepwise) for cost of materials, labour, plant e.t.c. and determination of labour hourly output e.t.c. This paper resoundingly abstracted the cost and Quantity data required for per m^3 of concrete grade C20P in 1:3:6-38mm aggregate. Table 3 shows the cost components of concrete grade C20P fragmented with a failure to quantify labour in terms of unit output coefficients $(\Gamma_s \Gamma_c)$. Productivity study by time and motion study on labour measurement from building and Civil Engineering sites was employed to generate labour output data using the short cycle and time study continuation forms. One hundred and five (105) gang operations were investigated involving mixing, transporting, placing and compaction. This was averaged to observed time for each gang with five (5) operation times. Arising from the obvious conditions under which the data were obtained from the 105 gangs, a precise but optimized sample size for analysis was obtained by work pace filtration index from the distribution using Markov Chain Monte Carlo (MCMC) sampling procedure to 30. This process has been found useful in the works of [34], [35] and assessment check detailed in [36]. The basic time for the concrete grade C20P in 1:3:6-38mm aggregate operation was extrapolated from the theoretical relationship of their ratings below;

$$\text{Basic Time} = \text{Observed Time x } \frac{\text{Rating}}{\text{Standard rating}} \quad (2)$$

Table 3. Cost Synthesis of Concrete Grade C20P 1:3:6-38mm

Concrete Grade C20P 1:3:6-38mm aggregate				
S/n Item	Qty	Unit	Price	Amount
1. Lime Cement	4.3	Bags	1900 per bag	
2. Sand (sharp)	0.45	m^3	1087 per m^3	-
3. Chippings	1.30	Tons	5909	
4. Add 2/5% for transportation of materials to site				
Concrete mixer type $^{10}/_7$		Cost/m^3		
5. Mixing, transportation, Placing, and (Γ_s)		Tradesman hr/m^2	ψ_t	
Compacting concrete (Γ_c)	-	Labour hr/m^2		-
6. Add profit and overhead @ Z%				
7. Cost per m^3				

The quality of this labour measurement approach is favoured from the works of [37, [38], [39] on construction process measurement and performance.

[40], on motion and time study, [41] on improving productivity through work measurement, [42] on measurement of construction productivity for concrete gangs. From equation (2), the following ratios were derived;

$$\frac{\text{Basic time}}{\text{Observed time}} = \frac{\text{Labourer's Rating}}{\text{Standard Rating}} \quad (3)$$

With the time ratio annulling itself in equation (3), this gives the dimensionless labour output coefficients $(\Gamma_s \Gamma_c)$ for the gang operations, [43], [44] and [45]. The study tabulated for observed time, basic time, labour rating and labour coefficient per gang. The generalized labour coefficient was obtained by Harmonic Mean from;

$$H_m = \frac{1}{\frac{1}{n}\left[\frac{1}{\Gamma_1} + \frac{1}{\Gamma_2} + \cdots + \frac{1}{\Gamma_n}\right]}$$

and a combined mean for $(\Gamma_s \Gamma_c)$ as

$$\frac{1}{H} = \frac{1}{N_1 N_2}\left[\frac{N_1}{H_1} + \frac{N_2}{H_2}\ \right] \quad (4)$$

The choice of Harmonic mean to derive a central value for all the average labour output, stems from the fact, that Harmonic mean value is a rigidly defined number and it is based on all the observations under investigation. With emphasis, since the reciprocals of the values of the variable are involved, it gives greater weight to observations with small values and therefore cannot be affected by one or two big observations. It is found to be very much applicable and useful in averaging special types of rates and ratios with time constrains while the act being performed remains constant [33]. The ratio investigated here is denoted in equation (3). The unit labour cost was determined from [46] model and later version by *op.cit.* [47] on modified real unit labour cost, in view of the obvious stochastic volatility impact of inflation on labour cost.

$$\psi_t = (w_t - P_t) + \eta_t - \frac{1}{\Phi}\gamma_t \quad (5)$$

W= Prevalent wages (nominal compensation per hour)

η= Total hours of employment

P= Price levels arising from Gross Domestic price deflator

γ= Output

Φ= Ratio of total cost to total output.

This was used in preference to two other wage payment models given consideration namely:

1.Halsey premium plan, where wage (iv) paid to a worker is expressed as:

(i)$W = TR + \frac{1}{100} R(S+T)$ (6)

when T > S

Or (ii)W = SR (7)

When T ≤ S

Given that S = standard time in hours

T=Time taken in hours

R=Wage rate per hour

Incentive or premium = wage for 1% of time saved at a rate of R naira per hour.

2.Rowan plan

(i)$W = SR + \frac{(S-T)}{S} R$ (8)

when T > S

(ii)W = SR (9)

when T ≤ S

4. RESULTS

This section presents the results of the productivity study carried out on time and motion study conducted at construction sites to measure the labour output coefficient per unit (m^3) of concrete grade C20P in 1:3:6-38mm aggregate. It shows tabulation for the observed time, basic time, labour rating, fatigue tolerance, output coefficient and the required standard rating for the operation of mixing, transporting, placing and compaction as specified in BS 4483: 1996 glossary of terms used in work study organization. The results were subjected to Harmonic mean test for a central value. The tradesman (Skilled) labour coefficient (Γ_s) gave 0.96, while the labourer (unskilled helper) coefficient (Γ_c) gave 0.36, the harmonized mean for Γ_s Γ_c on the basis of equation (9) gave 0.66.

4.1. Conceptualization of Model's Algorithm

The industry routine practice of generating unit rate cost by analytical pricing or hierarchical determination of cost components and ultimately optimizing the cost by aggregation is well cited in [48], [49], [50], [51], [52], [53], [54] and [55]. Presumptively, this method is not generalizable for its lack of science as their results are only useful on temporary (see appendix) basis. In consonance with work study practice, an adaptive model is proposed in this paper by aggregating a three (3) stage, stepwise walk of variables of unit cost price, labour output and incorporation of profits and contingencies. The simplest of their relationship is deduced from the flow diagram representation of the model below (fig 1);

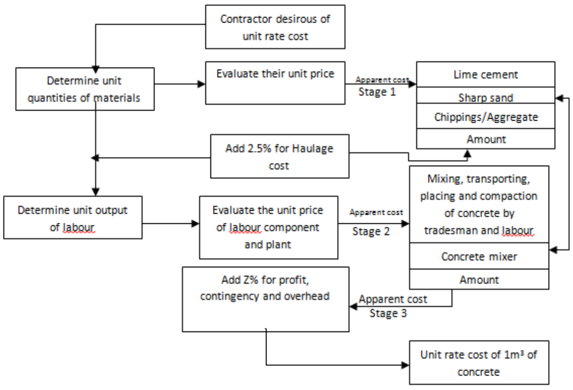

Fig. 1: Research model Algorithm (Adapted from Egwunatum and Oboreh, 2015.

Table 4a. Time and Motion Study Labour Output for Tradesman

S/N	Gang No	Observed Time (mins)	Basic Time (mins)	Labour rating	Fatigue Allowance @ 2.5%	Labour Coefficient (Γ_c)	Standard Rating @ 100	Operation Remark
1	11	1.02	0.99	103	2.5	0.97	100	Optimum
2	14	1.13	1.11	102	2.5	0.98	100	Optimum
3	23	1.05	1.01	104	2.5	0.95	100	Optimum
4	27	1.11	1.07	103	2.5	0.96	100	Optimum
5	82	1.05	1.01	104	2.5	0.96	100	Optimum
6	46	1.01	0.99	102	2.5	0.98	100	Optimum
7	20	1.07	1.05	104	2.5	0.97	100	Optimum
8	36	1.16	1.10	105	2.5	0.95	100	Optimum
9	31	1.09	1.08	100	2.5	0.99	100	Optimum
10	66	1.14	1.09	104	2.5	0.96	100	Optimum
11	60	1.04	1.00	104	2.5	0.96	100	Optimum
12	89	1.06	1.05	100	2.5	0.99	100	Optimum
13	15	1.14	1.11	104	2.5	0.97	100	Optimum
17	53	1.13	1.11	101	2.5	0.98	100	Optimum
15	73	1.12	1.06	105	2.5	0.95	100	Optimum
16	94	1.01	1.00	101	2.5	0.99	100	Optimum
17	05	1.09	1.06	103	2.5	0.97	100	Optimum
18	41	1.08	1.06	102	2.5	0.98	100	Optimum
19	58	1.04	1.01	103	2.5	0.97	100	Optimum
20	69	1.02	1.00	102	2.5	0.98	100	Optimum
21	18	1.00	0.99	101	2.5	0.99	100	Optimum
22	25	1.07	1.02	106	2.5	0.95	100	Optimum
23	98	1.09	1.06	103	2.5	0.97	100	Optimum
24	103	1.04	1.00	104	2.5	0.96	100	Optimum
25	86	1.06	0.99	108	2.5	0.93	100	Optimum
26	101	1.08	1.00	105	2.5	0.96	100	Optimum
27	79	1.01	0.95	106	2.5	0.94	100	Optimum
28	90	1.03	0.99	104	2.5	0.96	100	Optimum
29	28	1.09	1.08	101	2.5	0.99	100	Optimum
30	09	1.05	1.03	102	2.5	0.98	100	Optimum

Table 4b. Time and Motion Study Labour Output for Labourer (Unskilled)

S/n	Gang No	Observed Time (mins)	Basic Time (mins)	Labour rating	Fatigue Allowance @ 2.5%	Labour Coefficient (Γ_c)	Standard Rating @ 100	Operation Remark
1	11	4.1	2.4	23	2.5	0.38	100	Optimum
2	14	3.8	2.2	21	2.5	0.33	100	Optimum
3	23	4.1	2.1	20	2.5	0.34	100	Optimum
4	27	4.1	2.3	20	2.5	0.37	100	Optimum
5	82	3.8	2.1	20	2.5	0.36	100	Optimum
6	46	3.7	1.9	21	2.5	0.33	100	Optimum
7	20	3.9	2.1	22	2.5	0.34	100	Optimum
8	36	3.6	2.1	21	2.5	0.38	100	Optimum
9	31	3.4	2.0	20	2.5	0.35	100	Optimum
10	66	4.0	2.0	23	2.5	0.33	100	Optimum
11	60	3.5	1.9	23	2.5	0.34	100	Optimum
12	89	3.8	2.2	20	2.5	0.36	100	Optimum
13	15	3.7	2.1	22	2.5	0.37	100	Optimum
17	53	3.6	2.0	21	2.5	0.36	100	Optimum
15	73	35	1.9	23	2.5	0.34	100	Optimum
16	94	3.5	1.9	21	2.5	0.38	100	Optimum
17	05	3.8	2.2	22	2.5	0.36	100	Optimum
18	41	3.7	2.0	23	2.5	0.34	100	Optimum
19	58	3.6	1.8	21	2.5	0.33	100	Optimum
20	69	3.5	2.0	23	2.5	0.36	100	Optimum
21	18	3.3	1.8	20	2.5	0.34	100	Optimum
22	25	4.1	2.1	22	2.5	0.33	100	Optimum
23	98	3.9	2.1	23	2.5	0.35	100	Optimum
24	103	3.6	2.1	23	2.5	037	100	Optimum
25	86	3.7	2.1	23	2.5	0.38	100	Optimum
26	101	3.8	2.0	23	2.5	0.33	100	Optimum
27	79	3.4	1.9	21	2.5	0.36	100	Optimum
28	90	3.6	2.1	22	2.5	0.37	100	Optimum
29	28	3.8	2.0	21	2.5	0.33	100	Optimum
30	09	3.8	2.0	22	2.5	0.34	100	Optimum

4.2. Aggregation of Model's Algorithm

On the basis of the various labour output coefficients by equation (3), the research model algorithm in fig 1 and the data values of table 3 are aggregated to show a new relationship between variables. We note specifically the variables operated as;

Table 5. Output Symbols and Unit Output Constants for Concrete Grade C20P 1:3:6-38mm

S/N	Output symbols	Unit Output constants
1	Unit labour cost (ψ_t)	$(W_t - P_t + \eta - \frac{1}{\phi} Y_t)$
2	Cost of lime cement	4.3 bags (0.21 tons/0.15m^3)
3	Cost of sand	0.45m^3 (0.72 tons/0.45m^3)
4	Cost of chippings (A)	1.30 tons (0.86m^3)
4	Labour output for tradesman (skilled) (Γ_s)	0.96 Γ= 0.66
5	Labour output for labourer's (unskilled) (Γ_c)	0.36
6	% of cost for material Haulage	Usually at 2.5%
	Cost of plant use P_c	Daily Rentage cost
7	% of profit and over head (z)	Usually at 25%

The model's flow diagram and output data were aggregated stepwise to give the cost per m^3 of concrete grade C20P in 1:3:6-38mm aggregate as;

$$\prod_{\dot{m}} = \mathbf{4.3}\zeta_t + \mathbf{0.45}\mathfrak{S}_{\mathfrak{d}} + \mathbf{1.30}\,\Lambda + \rho_{\mathfrak{h}}\nabla + \frac{\rho_c}{8} + \Gamma_l\psi_t + Z_{max} \quad (10)$$

Where

∇ =0.043 ζ_t + 0.0045 $\mathfrak{S}_{\mathfrak{d}}$ + 0.0130 Λ = linear operator

Λ=Cost of chippings

$\Gamma_l\psi_t$ =Labour output factor per m^3 multiplied by daily wage rate for concreter

ζ_t=Cost of 50kg lime cement

$\mathfrak{S}_{\mathfrak{d}}$=Cost of sand

Cost Data used for Validation Test:

$\rho_h = 2.5$, $\rho_c =$ ₦3000, k=Nigerian Kobo ₦ = Nigerian Naira, \$1 = ₦197

14 tons of silica Quartz sand (S_δ)	= ₦15,000; 0.43 tons (S_δ)	= ₦461
30 tons of Aggregate (Granite) (Λ)	= ₦205,000; 1.24 tons (Λ)	= ₦8473
1 bag of cement (ζ_t)	= ₦1900	
8 – Man Hourly labour cost (ψ_t)	= ₦4500,	

Labour output constant for 1m^3 (Γ_L) = 0.66

The need to assess the overall model's fitness is exigent in order to report its predictive ability. Such fitness assessment test has been reported to be useful by [56] and their predictive likelihood and congruency with data by [57]. Similarly, the interaction of the model's variables or close relationship with recourse to their predictive ability was justified by [58] interpolation. Specifically, the assessment of equation (10) follows the 3 tests cited above by numerical substitution of cost data extrapolated from the Nigerian Institute of Quantity Surveyors (NIQS) price book, 2014, fitted in the 3 – step algorithm of fig 1.

Validation of Cost model

Analytical Pricing Method

Plain concrete (1:3:6-38mm aggregates) in foundation. Not exceeding 3000mm thick

Cost of materials

1m^3 of Portland cement delivered to site48,960

Add labour unloading assume 1,000

49,960

Allow 10% for waste4,996

Cost per m^{3}54,456

3m^3 fine aggregates @ 23006,900.00

Allow 10% waste 690.00

7,500.00

6m^3 coarse aggregates @ 3125 =18,750.00

Add 10% waste 1,875.00

20,625.00

83,169.00

Add 50% for loss of bulk41,582.50

124,747.50

Cost per m^3 materials = 124,747.00

(1 + 3 + 6 = 10m^3) 10 =N12,474.75

Assume 0.20m3 mixer at 1,800.00

and output of 2m^3/hr

Therefore, the cost of mixing = 1,500

2 = 750.00

Cost of mixer concrete labour13,224.75

Placing in foundation

2 hrs @ N125= 200.00

Allow 5% waste (5% of 13,224375) 661.24

14,085.99

Allow 25% profit and overheads 3,521.49

Unit rate per m^{3}17,607.49

₦18,000/m^3

(as at 2010)

Cost model method

$$\prod_{\dot{m}} = 4.3\zeta_t + 0.45\mathfrak{S}_{\mathfrak{d}} + 1.30\wedge + \rho_{\mathfrak{h}}\nabla + \frac{\rho_c}{8} + \Gamma_l\psi_t + Z_{max}$$

$$\prod_{\dot{m}} = 4.3\,(1900) + 0.45\,(461) + 1.30\,(8473) + 2.5\,(81.70 + 2.07 + 11.0.149) + 375 + 485 + Z_{max}$$

= **₦29,027.51** per m^3

5. CONCLUSION

The routine method within the construction industry for estimating unit rate cost of concrete grade C20P in 1:3:6-38mm aggregate by analytical pricing was identified in this paper to be non generalizable as it requires serial subjective computations, stepwise of labour cost, materials cost and Quantities to arrive at the Unit rate cost. This paper observed that the various elements that make up a building have various measuring units and ditto various labour outputs. Therefore, the possibility of using a single formula to predict the cost of a building is unjustifiable because the difference in units makes them not plusable. Consequently, this paper approached this gap by generating an adaptive model (see equation 10) to predict the cost of a unit rate (m^3) of concrete grade C20P in 1:3:6-38mm aggregate and proposes that all other elements of building which include but not limited to blockwall, rendering, excavation, roof members, painting, etc. to be modeled in their unit rate form. With the various quantities multiplied by their unit rate cost and subsequently summed up with prime cost items, will give the cost of the building. A major feature of this model is that it can be subjected to further mathematical treatment of change when any of the variables is constrained. The model's value of unit rate cost was found to be consistent with the prevailing unit rate cost of concrete grade C20P in 1:3:6-38mm aggregate as used in Nigerian construction industry and supported by the Nigerian Institute of Quantity Surveyors' Building and Engineering Price Book.

6. RECOMMENDATIONS

The model derived in this paper is recommended for use on the basis of output constant derived from productivity study in respect of tables 4a and 4b. Price flexibility is recommended for ζ_t, $\wedge$ and $\mathfrak{S}_{\mathfrak{d}}$ application in the model with respect to end user's organization's policy. This model can be used to adjudicate contractors bid on concrete grade C20P in 1:3:6-38mm aggregate work item rate with time advantage and less subjectivity in computation. It could be generalized when the current cost are weighted in respective currencies.

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