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Cost Model for Unit Rate Pricing of Concrete in Construction Projects

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Abstract The construction industry is reportedly over reported of construction cost spillover greatly due to cost indeterminacy. The subsisting methods of unit rate pricing in the industry are either determinate on ad.hoc basis (analytical pricing) or predictive (cost modeling). The literature cited in this paper showed that cost models used in the industry are spurious. Most of the models attempts to respond to whole building cost from inception to completion with a single formula. This paper argues that on the basis of the units of measurement of the various building elements, a holistic cost model for pricing a complete building cost is a near impossibility. Rather, cost model on the basis of each work item is idealized. Accordingly, this paper responded by generating a unit rate cost model for concrete Grade C25 (Reinforced concrete containing dense aggregate) in mix ratio 1:2:4 – 20mm Aggregate. This was done by abstracting and decomposing the relevant cost data 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 the cost data to derive the unit rate cost. The paper concludes that the model enjoys flexibility of further mathematical treatment if any of the variable is constrained and recommends that other work items should be modeled if the cost of a building must be known and this model should be used to justify contractor's tender for concrete cost.

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

1. Introduction

The idea that construction project contracting is a business has been well established by Harris and McCaffer (2005) and Inuwa, Iro and Dantong (2013). Management of such contracting firms are in constant search for cost optimizing processes which aims at Weath Maximization (Patel, 2004). Contracting in the construction industry takes the form of general contracting, subcontracting or prime contracting (Inuwa et. al. 2013, Laryea and Mensah, 2010, Onwusoye 2002, Popescu, Phaobunjong and Ovararin 2003 and Ricketts 2000). The actualization of wealth maximization principle in construction business essentially lies in the organization's cost expert's brief; to optimize value and minimize cost. The issue of cost in construction literature has therefore received a great deal of considerable attention with the flurry of research activities directed towards cost solving problems which include but not limited to predictability and indeterminacy.

In spite of these consolidated research efforts cost overruns has been consistently reported in several construction papers arising from subjective process of cost determination and inaccurate estimate. See Arcila (2012), Olawale (2010), Ade, Aftab, Ismail and Ahmed (2013), Frimpong, Oluwoye and Crawford (2003), Koushiki, Al – Rashied and Kartam (2005), Le – Hoai, Lee and Lee (2008), Enshassi, Mohammed and Abushaban (2009), Jergeas and Ruwanpura (2010) and Omoregie and Radford (2006) on the causes of cost overruns. The search for an almighty and grand unified formula by the industry to tell the cost of a proposed building project from inception to completion stage has become the pursuit of a mirage. The argument has always been that, there cannot be a holistic or generalised cost model responding to the seeming difficulty of cost estimation of a building. In the absence of this, contractors live with inaccurate estimates and carryout projects under conditions of uncertainty (Challal and Tkiouat, 2012). Accordingly, this paper aims at deriving a generalised unit rate cost model for pricing of concrete works.

2. Literature Survey on Construction Cost Models

Cost is important to all industry but 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.

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Several cost estimation techniques are available for that purpose from inception to completion stage. (Nabil 2012, Ibironke 2004, Obiegbu 2004, Oforeh and Alufohai 2006, Anyanwu 2013 and Hakan 2007).

Cost models have been found to be a useful tool, 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 (SAVE international, 2007). 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 (Jagboro and Aibinu, 2002).

Reliability failures of cost models have been reported to be responsible for project cost overruns and delays as a result of poor estimation parameters inherently lacking in their predictive abilities (Hakan, 2007, Gkritza and Labi 2008). The search for superior, accurate and reliable cost models within the construction industry have been sufficiently rehearsed like a recurrent decimal in construction literatures (Cheng, Tsai and Sudjono 2010).

Yet, cost indeterminacy continues unabated due to the qualitative parameters that impedes cost estimation like client's priority on construction time, contractor's planning and scheduling capabilities, procurement method and other extraneous factors (Nida, Farooqui and Ahmed, 2008). More the same, construction project cost estimators are confined to the routine traditional cost estimates and cost planning techniques which are often tempora in application rather than generalized (Baccarinibi, 1987, Elhag and Boussabaine 1998). 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. Challal and Tkiouat, (2012) developed a cost estimation software model on the basis of component prices by showing a common relationship 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, Nabil (2012) developed a parametric cost modeling software with Fuzzy logic algorithm on the basis of Lukasiewicz tri-value logic system which was an alternative of the Aristotle's bi-value logic formulation. 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]. Zadeh (1965, 1994) harped on this logical conception and incorporated it into modern day computers to resolve their rigidity in their inability to manipulate data representing subjective measures. The Nabil (2012) cost modeling software 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 Nabil (2012) 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 estimate model. (See Tables 2). Again, Challal and Tkiouat (2012) on the basis of data on project expenses in relation to the allocation of resources to activities wrote a software. The software operated on the following variables to arrive at its flat cost; namely;

P_u: Unit Price
U: Measuring Unit
UO_e: Infrastructure Component Unit
$NH_oI = TU_I$: Time Unit corresponding to the working time of an average worker.
U: Estimated Quantity of infrastructure Component Unit Materiaux Component
QMI: Quantity of Material (MI) making up (UO_eI) infrastructure Component Unit
DSI: These expenses are flat cost = Expenditure in productive employees + the purchase of material + specific material.

According to Challal and Tkiouat (2012), these expenses are termed "flat" because their values are not weighted by any surcharge coefficient.

DST: Is the sum of flat costs, being, $DST_1 + DST_2 + \ldots$ With

$$DST_1 = DS_1\,(UO_{e1}) + DS_2\,(UO_e^2) \quad (1)$$

So that, Total flat cost = $DST_1 + DST_2 + DST_3 + DST_4\ DST_5$

$$= DSTT \quad (2)$$

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 Ogunsemi and Jagboro (2006) on Time-cost model for building projects in Nigeria, Bromilow (1974), on final cost of building and duration, Ireland (1983) on Time – cost prediction of high rise commercial projects in Australia, Yeong (1994) on modified Bromilow (1974) study to Australian and Malaysian Public, Private and all project types, Kumaraswamy and Chan (1995) on extension of the Bromilow (1974) preposition to building and Civil Engineering works with a resounding affairmation. Chan (1999) also took the framework of Yeong (1994) study to Hong-Kong on private, public project categorization. The same investigation was made by Ojo (2001) in Nigeria with improved predictive abilities of the model by Ogunsemi and Jagboro (2006) and Love et. al. (2005) on relationship between gross floor area and number of floors as determinants project's cost and time.

As a follow up, Inuwa et al. (2013) 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;

$$\text{Rate} = N + (N \times Z) \quad (3)$$

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
Challal and Tkiouat	2012	Construction works	Flat cost = $DST_1 + DST_2 + DST_3 + DST_4 = DSTT$	Programming
Nabil	2012	Building projects	No. of floors: 1 No. of Elevators: 0 Area of typical/floor: 1 Volume of HVAC: 0 Type of external plastering: 1	Evaluate cost 0.0266 667 135887

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;

$$M_c \geq 0;\ L_c \geq 0;\ P_c \geq 0 \text{ and } Z_c \geq 0$$

Summarily, recent cost models are somewhat attempts to make cost estimation a predictable quadrature occasioned by their stochastic characteristics as evident in the works of Challal and Tkiouat (2012), Nabil (2012) and Inuwa. et al. (2013).

3. Research Gap Identified

Cost models reviewed in this study were various attempts to explore the parametric method of cost estimation to determine cost of proposed construction projects. These models are best fitted for use on the basis of project definition level (i.e. either at conceptual stage, feasibility stage, budget authorization stage, control stage or bid/tender stage). Ditto, time and cost models, which attempts to show a link between project cost and duration. Such project performance models are also at best informative to the client on the relationship between project duration and the amount of money available to the client. In all of these, the models predictive and precision abilities do not necessary respond to work item unit rate cost. Specifically the attempt to generalize a model for computing unit rate cost proposed by Inuwa et. al., (2013) was algebraically defective on the basis that the unit rates of all construction work items have varying units of measurements (m, m^2, m^3, tons, kg etc.). This was not accommodated in the model.

This is also true for Hakan and Tas (2007), Chen, Tsai and Sudjono (2010) and Gunaydin and Dogan (2004) derivatives. The models did not show compliance with the Fox (2008) test on Generalised Linear Models (GLM) to the extent that the models have no structural components specifying the conditional distribution of the response variable (unit rate cost) given the values of the explanatory variables in the model. The identity of such response variable which must consistently be a member of the exponential family such as Gausian (Normal), binomial, Poisson, gamma derivatives or their inverses was inherently missing in the works of Challal and Tkiouat (2012), Nabil (2012) and Inuwa et. al. (2013).

Secondly, the absence of a structural component of a linear predictor as a function of linear regressors without explanatory variables that assumes a coefficient all through the model;

$$n_i = \propto + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots\ldots\ldots\ldots + \beta_k x_{ik} \quad (4)$$

Thirdly, had no proof of smooth and invertible linearizing link function g(·) that can tansform the expectation of the response variable $\mu_i = \epsilon(Y_i)$, to the Linear predictor;

$$g(\mu_i) = \eta_i = \propto + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots\ldots + \beta_k x_{ik} \quad (5)$$

Four, had no estimation and testing parameters of generalised linear models that fit to data by method of maximum likelihood, providing not only estimates of the regression coefficients but also estimated asymptotic standard errors of the coefficients.

Five, did not comply with the dispersion test in which case the dispersion parameter is fixed to 1, so that the likelihood ratio test statistic becomes the difference in the residual deviances for Nested models wherein Inuwa et al. (2013) nested the prime cost (N) and the overheads and profits percentage (Z).

Six, the models failed the incremental F – test, having used a nested model of Inuwa et al, (2013) and the Love et. al, (2005) to test the GLM for a dispersion parameter to estimate either of the Gaussian, Gamma or the Inverse-Gaussian forms.

Accordingly, the pursuit for a holistic and a general purpose model that attempts to resolve the cost of a building and construction works by mere substitution of prices is impracticable arising from the inherent differences in the operational output of work items. As a way forward and objective of this study, the cost and quantity data of concrete item in construction projects was extrapolated and decomposed into material, labour, profit and overhead of developing a cost model for unit rate pricing of concrete item in construction project.

4. Methodology

Cost data are perquisite, 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) the cost factors before applying them. This study identified the routine complexities of having to generate a unit rate price of concrete by estimators, having to perform serial computations (stepwise) for cost of materials, cost of mixing, cost of placing and compacting, determination of labour hourly output etc. This paper resoundingly abstracted the cost and Quantity data required for per m^3 of concrete as shown below;

Table 3 shows the cost components of concrete grade C25 in 1:2:4 – 20mm Aggt. mix composed 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, placing and compaction of concrete. This was averaged to observed time for each gang with five (5) operation times. In view of the obvious conditions under which the data were obtained from the 105 gangs, a precise and optimized sample size for analysis was obtained from the distribution using Markov Chain Monte Carlo (MCMC) sampling procedure to 30. This process has been found useful in the works of Clark and Doh (2011), Cogley and Sargent (2005) and assessment check detailed in Villani (2009). The basic time was extrapolated from the theoretical relationship of their ratings below;

$$Basic\ Time = Observed\ Time \times \frac{Rating}{Standard\ \ rating} \quad (6)$$

Table 3. Cost Synthesis of 1m^3 of Concrete Work

Concrete Grade C25 in 1 : 2 : 4 – 20mm agg mix per m^3				
Item	**Qty**	**Unit**	**Price**	**Amount**
Lime Cement	6.2	Bags	1900 per bag	
Sand (sharp)	0.43	m^3	1083 per m^3	
Chippings	1.24	Tons	5909 per ton	________
Add 2.5% for transportation of materials to site				
Concrete mixer type $^{10}/_7$		Cost/m^3		
Mixing, transporting, Placing, and Compacting Concrete } Γ_s Γ_c		Trade'sman hr/m^3 Labours hr/m^3 } ψ_t		
Add profit and overhead @ Z%				
cost per m^3				________

The quality of this approach on labour measurement has been favoured from the works of Picard (2002a, 2002b), Picard (2000) on construction process measurement and performance. Ditto Niebel, (1993) on motion and Time study, Failing, Jerry, and Larry (1988) on improving productivity through work measurement, Price (1991) on measurement of construction productivity for concrete gangs. From equation (6), the following ratios were derived;

$$\frac{Observed\ \ Time}{Basic\ \ Time} = \frac{Laboure\ r's\ Rating}{Standard\ \ Rating} \qquad (7)$$

From (7), with the time ratio annulling it selves, this gives the dimensionless labour output coefficients $(\Gamma_s; \Gamma_c)$ for the gang operations, see Shankar (2004), Vrat (2002) and Milne (2008). 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 comibined mean for $\Gamma_s\Gamma_c$ as

$$\frac{1}{H} = \frac{1}{N_1 N_2}\left[\frac{N_1}{H_1} + \frac{N_2}{H_2}\ \right] \qquad (8)$$

The choice of Harmonic mean to derive a central value for all the average labour outputs, 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 (Gupta, 2004). The ratio investigated here is denoted in equation (7).

The unit labour cost was determined from Smets and Wouters (2007) model and later version by *op.cit.* King and Watson (2012) on modified real unit labour cost, in view of the obvious impact of inflation on labour cost.

$$\psi_t = (w_t - P_t) + \eta_t - \frac{1}{\Phi}\gamma_t \qquad (9)$$

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.

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

S/N	Observed time (mins)	Basic time (mins)	Labour rating	Fatigue Allowance at 2.5%	Labour coefficient (Γ_c)	Standard rating @ 100	Operation Remarks
1.	1.02	0.99	103	2.5	0.97	100	Optimum pace
2.	1.13	1.11	102	2.5	0.98	100	Optimum pace
3.	1.05	1.01	104	2.5	0.95	100	Optimum pace
4.	1.11	1.07	103	2.5	0.96	100	Optimum pace
5.	1.05	1.01	104	2.5	0.96	100	Optimum pace
6.	1.01	0.99	102	2.5	0.98	100	Optimum pace
7.	1.07	1.05	104	2.5	0.97	100	Optimum pace
8.	1.16	1.10	105	2.5	0.95	100	Optimum pace
9.	1.09	1.08	100	2.5	0.99	100	Optimum pace
10.	1.14	1.09	104	2.5	0.96	100	Optimum pace
11.	1.04	1.00	104	2.5	0.96	100	Optimum pace
12.	1.06	1.05	100	2.5	0.99	100	Optimum pace
13.	1.14	1.11	104	2.5	0.97	100	Optimum pace
14.	1.13	1.11	101	2.5	0.98	100	Optimum pace
15.	1.12	1.06	105	2.5	0.95	100	Optimum pace
16.	1.01	1.00	101	2.5	0.99	100	Optimum pace
17.	1.09	1.06	103	2.5	0.97	100	Optimum pace
18.	1.08	1.06	102	2.5	0.98	100	Optimum pace
19.	1.04	1.01	103	2.5	0.97	100	Optimum pace
20.	1.02	1.00	102	2.5	0.98	100	Optimum pace
21.	1.00	0.99	101	2.5	0.99	100	Optimum pace
22.	1.07	1.02	106	2.5	0.95	100	Optimum pace
23.	1.09	1.06	103	2.5	0.97	100	Optimum pace
24.	1.04	1.00	104	2.5	0.96	100	Optimum pace
25.	1.06	0.99	108	2.5	0.93	100	Optimum pace
26.	1.08	1.00	105	2.5	0.96	100	Optimum pace
27.	1.01	0.95	106	2.5	0.94	100	Optimum pace
28.	1.03	0.99	104	2.5	0.96	100	Optimum pace
29.	1.09	1.08	101	2.5	0.99	100	Optimum pace
30.	1.05	1.03	102	2.5	0.98	100	Optimum pace

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

S/N	Observed time (mins)	Basic time (mins)	Labour rating	Fatigue Allowance at 2.5%	Labour coefficient (Γ_s)	Standard rating @ 100	Operation Remarks
1.	0.61	0.37	103	2.5	0.58	100	Optimum pace
2.	0.59	0.34	102	2.5	0.50	100	Optimum pace
3.	0.60	0.31	104	2.5	0.52	100	Optimum pace
4.	0.61	0.35	103	2.5	0.57	100	Optimum pace
5.	0.57	0.31	104	2.5	0.55	100	Optimum pace
6.	0.56	0.28	102	2.5	0.51	100	Optimum pace
7.	0.58	0.31	104	2.5	0.53	100	Optimum pace
8.	0.54	0.31	105	2.5	0.58	100	Optimum pace
9.	0.50	0.29	100	2.5	0.54	100	Optimum pace
10.	0.60	0.30	104	2.5	0.50	100	Optimum pace
11.	0.53	0.28	104	2.5	0.52	100	Optimum pace
12.	0.59	0.33	100	2.5	0.56	100	Optimum pace
13.	0.55	0.31	104	2.5	0.57	100	Optimum pace
14.	0.52	0.30	101	2.5	0.55	100	Optimum pace
15.	0.51	0.28	105	2.5	0.53	100	Optimum pace
16.	0.53	0.28	101	2.5	0.58	100	Optimum pace
17.	0.59	0.34	103	2.5	0.55	100	Optimum pace
18.	0.56	0.29	102	2.5	0.52	100	Optimum pace
19.	0.52	0.26	103	2.5	0.50	100	Optimum pace
20.	0.51	0.29	102	2.5	0.56	100	Optimum pace
21.	0.50	0.27	101	2.5	0.53	100	Optimum pace
22.	0.61	0.31	106	2.5	0.51	100	Optimum pace
23.	0.58	0.31	103	2.5	0.54	100	Optimum pace
24.	0.54	0.31	104	2.5	0.57	100	Optimum pace
25.	0.55	0.31	108	2.5	0.58	100	Optimum pace
26.	0.59	0.30	105	2.5	0.51	100	Optimum pace
27.	0.51	0.28	106	2.5	0.55	100	Optimum pace
28.	0.54	0.31	104	2.5	0.57	100	Optimum pace
29.	0.57	0.29	101	2.5	0.50	100	Optimum pace
30.	0.56	0.29	102	2.5	0.52	100	Optimum pace

5. 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. It contains tabulation for the observed time, basic time, labour rating, fatigue tolerance, output coefficient with the required standard rating for the operation of mixing and placing concrete as specified in BS313: 1969 glossary of terms used in work study organization and methods as revised in 1979.

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 0.54, while the combined mean gave 0.65 on the basis of equation (8).

5.1. 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 summation is well cited in Owunsonye, (2012), Brook (2008), Salami (2013), Ashworth (1986), Ashworth and Elliott (1986), Harrison (1994), Emsley and Harris (1990) and Ashworth and Skitmore (1982). Presumably, this method is not generalizable for its lack of science as their results are only useful on tempora 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);

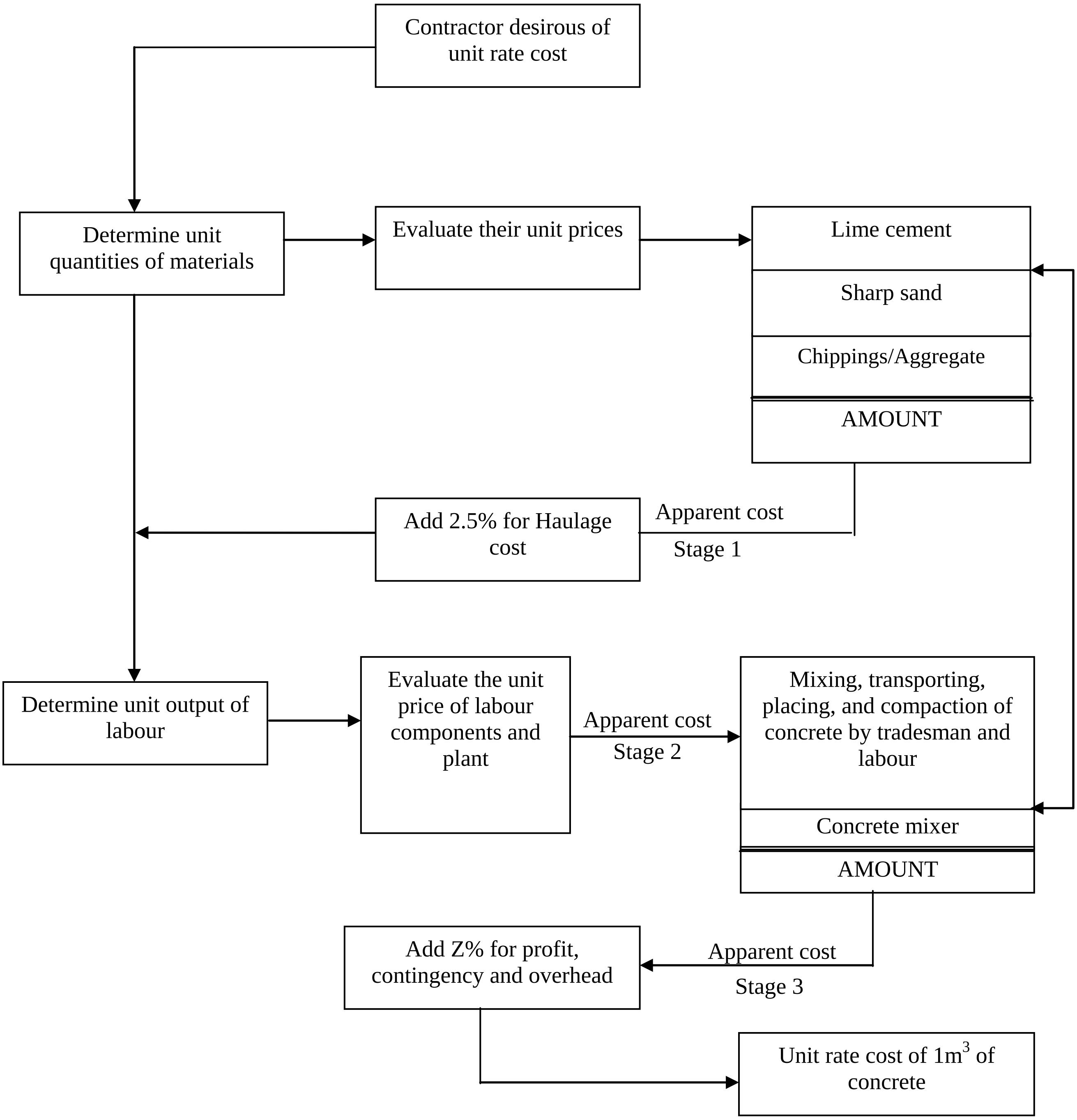

Figure 1. Research model Algorithm

5.2. Aggregation of Model's Algorithm

On the basis of the various labour output coefficients by equation (8), 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;

The model's flow diagram and output data were aggregated stepwise to give the cost per m^3 of concrete as;

$$\Pi_{cncrt} = \mathbf{6.2}\zeta_t + \mathbf{0.43}\boldsymbol{S_\delta} + \mathbf{1.24}\Lambda + \boldsymbol{\rho_h}(\mathbf{0.062}\zeta_t + \mathbf{0.0043}\boldsymbol{S_\delta} + \mathbf{0.0124}\Lambda) + \frac{\boldsymbol{\rho_c}}{\mathbf{8}} + \Gamma_{\mathbf{L}}\boldsymbol{\psi_t} + \boldsymbol{Z_{max}} \qquad (10)$$

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 Morley and Piger (2010) and their predictive likelihood and congruency with data by Geweke and Amisano (2010). Similarly, the interaction of the model's variables or close relationship with recourse to their predictive ability was justified by Geweke and Whiteman (2006) 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.

Table 5. Output Symbols and Unit Output Constants for 1m^3 of Concrete

S/N	Output Symbols	Unit Output Constants
1.	Unit labour cost (ψ_t)	$(W_t - P_t) + \eta - \frac{1}{\Phi}\gamma_t$
2.	Cost of lime cement ( )	6.2 bags (0.30 tons/0.21m^3)
3.	Cost of sand (S_s)	0.43m^3 (0.69 tons/0.43m^3)
4.	Cost of chippings (Λ)	1.24 tons (0.86m^3)
5.	Labour output for tradesman (skilled) (Γ_s)	0.96 } $\Gamma_L = 0.65$
6.	Labour output for labourer's (unskilled) (Γ_c)	0.54
7.	% of cost for materials Haulage(ρ_h)	Usually at 2.5%
8.	Cost of plant use ρ_c	Daily Rentage cost
9.	% of profit and over head (Z)	Usually at 25%

Cost Data used for Fitness 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) = 0.65

$\Pi_{cncrt.}$ = ₦11,780 + 198.23 + 10507 + 2.5(117.8 + 1.9823 + 105.07) + 375 + 2925

$\Pi_{cncrt.}$ = N26,374.38 + Z@ 25% = N32,934.22k per m^3

6. Conclusions

The routine method within the construction industry for estimating unit rate cost of concretes 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 makes 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) for concrete and proposes that all other elements of building which include but not limited to blockwork, 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 variables are constrained.

7. 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. Flexibility is recommended for ρ_h, ρ_c and Z application in the model with respect to end user's organization's policy. This model can be used to adjudicate contractors bid on concrete rate with time advantage and less subjective and generalized when the current cost are weighted in respective currencies.

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