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# The Inverse Reaction Cross Sections for Unit Rate Cost Model for Pricing Weld Mesh Reinforcement in Construction Projects

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**ABSTRACT**

The subsisting methods of unit rate pricing in the construction industry are either determinate on immediate use 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 as a negation cost model on the basis of each work item is idealized. Accordingly, this paper responded by generating a unit rate cost model for weld mesh reinforcement. 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 factored to the cost data to derive the unit rate cost. The paper concludes that the model enjoys flexibility of further mathematical treatment should any of the variable be constrained and recommends that other work items should be modeled if the cost of a project must be known and this model should be used to justify contractor's tender for weld mesh reinforcement bid.

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

## 1. INTRODUCTION

There has been a systematic bibliography on the subject of construction cost models up till 2015 by Egwunatum and Oboreh and Mwiya, Muya, Kaliba and Mukalula where the varying degree of precision and limitations of cost models were reported. In the review, some of the models were noted to be conditionally applicable as index of performance; notably time and cost models by Ogunsemi and Jagboro (2006), Ojo (2001), Chan (1999), Yeong (1994) etc. The review also spotted others that were somewhat attempts to predict the cost of construction projects with certain parameters like number of floors, area of floors, HVAC volume, types of external finishing etc as reported in Nabil, (2012) and Challal and Tkiouat (2012). Thereafter, Inuwa, Iro and Dantong (2013) presented a cost model generally specified for unit rate pricing of construction work items. However, the Egwunatum and Oboreh (2015) approach to cost modeling prescribed the productivity output evaluation method by determining the significant labour output, quantity and cost required to ascertain the per unit rate cost. The Egwunatum and Oboreh (20145) conceptualization on unit rate cost model seem to be a response to the industry's need of reliable and precise empirical construct for computing unit rate cost arising from cost overruns, indeterminacy and inaccurate estimation. The Egwunatum and Oboreh (2015) derivation proposed the fragmentation or decomposition of work items and extrapolation of unit quantities and prices on aggregation to output the unit rate price. On the basis of this concept, this paper draws from the aggregation algorithm approach that relies on extrapolated productivity unit and materials output data to generate unity rate cost model for weld mesh reinforcement.

## 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. 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 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 (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 arising from 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 in construction literatures (Cheng, Tsai and Sudjono 2010). Yet, cost indeterminacy continues recurrently 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 (Nida, Farooqui and Ahmed, 2008). 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 (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 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, Nabil (2012) developed parametric cost model software with Fuzzy logic algorithm. This was 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]. 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 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 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 Table 2). Again, Challal and Tkiouat (2012) 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.

Mwiya, Muya and Kaliba (2015) 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, Czarnigowska (2014) 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 Czarnigowksa (2014) 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 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 without labour component. They derived a unit rate cost model as;

$$R = N + ( N \times Z) \qquad (1)$$

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

| Source | Year | Classification | Model | System | Where studied |
|---|---|---|---|---|---|
| Bromilow | 1974 | Building Projects | $T=KC^{B}$<br>$T=313C^{0.3}$ | Generalised | Australia |
| Ireland | 1983 | Highrise Commercial | $T=219C^{0.47}$ | Derived | Australia |
| Yeong | 1994 | Building projects for private/public use | $T=161C^{0.367}$<br>$T=287C^{0.237}$<br>$T=269C^{0.215}$<br>$T=518C^{0.352}$ | Derived | Australian private buildings<br>Australian public buildings<br>All Australian projects<br>Malaysian public projects |
| Chan | 1999 | Builidng projects for private and public use | $T=166C^{0.28}$<br>$T=120C^{0.34}$<br>$T=152C^{0.29}$ | Derived | Public projects in Hong Kong<br>Private project in Hong Kong<br>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 | $T=63C^{0262}$<br>$T=55C^{0.312}$<br>$T=69C^{0.255}$ | 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. | Nabil | 2012 | Building projects | No of floors: 1<br>No of Elevators: 0<br>Area of typical/floor: 1<br>Volume of HVAC: 0<br>Type of external plastering: 1 | Evaluate cost<br>0.0233.667<br>13587 |
| 3. | Inuwa | 2013 | Building projects | R = N + ( N x Z) | |
| 4. | Czarnigowska | 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 | | $6.2\zeta_t + 0.432\text{ƻ}_\delta + 1.24\Lambda + p_n(0.062\zeta_t + 0.043\text{ƻ}\delta + 0.0124\Lambda + \frac{p_c}{8} + \Gamma_t\psi_t + Z_{max}$ | Algebraic aggregation |

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 Challal and Tkiouat (2012), Nabil (2012) and Inuwa et al. (2013).

## 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) the cost factors before applying them (Mwiya, et. al. 2015). This study identified the routine complexities of having to generate a unit rate price of steel mesh reinforcement by estimators by having to perform serial computations (stepwise) for cost of materials, cost of cutting, placing and bend, tie and fix and determination of labour hourly output etc. This paper resoundingly abstracted the cost and Quantity data required for per $m^2$ of mesh reinforcement fixing. Table 3 shows the cost components of Type 2.10m x 45m ($2.29kg/m^2$, 5mmϕ) weld mesh overall area 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 cutting, placing and fixing end lap anchorage. 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 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 Clark and Doh (2011), Cogley and Sargent (2005) and assessment check detailed in Villani (2009). The basic time for the mesh reinforcement operation was extrapolated from the theoretical relationship of their ratings below;

$$\text{Basic Time} = \text{Observed Time x } \frac{\text{Rating}}{\text{Standard rating}} \tag{2}$$

**Table 3.** Cost Synthesis of 2.10m x 45m (2.29kg/m$^2$, 5mmϕ) weld mesh.

| **2.10m x 45m (2.29kg/m$^2$, 5mmϕ) weld mesh** | | | | | |
|---|---|---|---|---|---|
| S/n | Item | Qty | Unit | Price | Amount |
| 1. | Weld mesh | 1 | m$^2$ | 481 per m$^2$ | |
| 2. | Bind wire | 0.1 | kg | 25 per kg | - |
| 3. | Add 10% for end lapping, anchorage and waste | | | | |
| 4. | Labour output for cutting, bending, tieing and fixing (1 gang) | | | | |
| 5. | Skilled labour output ($\Gamma_s$) | - | Tradesman hr/m$^2$ | } $\psi_t$ | |
| 6. | Unskilled labourer output ($\Gamma_c$) | - | Labour hr/m$^2$ | | - |
| 7. | Add profit and overhead @ Z% | | | | |
| 8. | Cost per m$^2$ | | | | |

The quality of this labour measurement approach is 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;

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

With the time ratio annulling it in three (3), this gives the dimensionless labour output coefficients $(\Gamma_s \Gamma_c)$ for the gang operations, (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 combined mean for $(\Gamma_s \Gamma_c)$ as

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

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 (3). 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 stochastic volatility impact of inflation on labour cost.

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

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 (*W*) 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 $T \leq S$

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

when $T > S$

(ii) W = SR (9)

when $T \leq S$

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

| S/N | Observed Time (mins) | Basic Time (mins) | Labour rating | Fatigue Allowance @ 2.5% | Labour Coefficient ($\Gamma_c$) | Standard Rating @ 100 | Operation Remark |
|---|---|---|---|---|---|---|---|
| 1 | 3.30 | 35 | 11 | 2.5 | 0.11 | 100 | Optimum |
| 2 | 2.80 | 36 | 13 | 2.5 | 0.13 | 100 | Optimum |
| 3 | 2.80 | 29 | 10 | 2.5 | 0.10 | 100 | Optimum |
| 4 | 2.80 | 323 | 12 | 2.5 | 0.12 | 100 | Optimum |
| 5 | 2.80 | 36 | 13 | 2.5 | 0.13 | 100 | Optimum |
| 6 | 2.00 | 30 | 15 | 2.5 | 0.15 | 100 | Optimum |
| 7 | 3.00 | 30 | 10 | 2.5 | 0.10 | 100 | Optimum |
| 8 | 2.00 | 31 | 16 | 2.5 | 0.16 | 100 | Optimum |
| 9 | 2.00 | 30 | 15 | 2.5 | 0.15 | 100 | Optimum |
| 10 | 3.30 | 35 | 11 | 2.5 | 0.11 | 100 | Optimum |
| 11 | 2.80 | 36 | 13 | 2.5 | 0.13 | 100 | Optimum |
| 12 | 2.00 | 30 | 15 | 2.5 | 0.15 | 100 | Optimum |
| 13 | 2.90 | 40 | 14 | 2.5 | 0.14 | 100 | Optimum |
| 17 | 2.80 | 33 | 12 | 2.5 | 0.12 | 100 | Optimum |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 15 | 3.30 | 35 | 11 | 2.5 | 0.11 | 100 | Optimum |
| 16 | 3.30 | 35 | 11 | 2.5 | 0.11 | 100 | Optimum |
| 17 | 2.00 | 30 | 15 | 2.5 | 0.15 | 100 | Optimum |
| 18 | 2.90 | 40 | 14 | 2.5 | 0.14 | 100 | Optimum |
| 19 | 2.00 | 31 | 16 | 2.5 | 0.16 | 100 | Optimum |
| 20 | 2.00 | 30 | 15 | 2.5 | 0.15 | 100 | Optimum |
| 21 | 2.90 | 40 | 14 | 2.5 | 0.14 | 100 | Optimum |
| 22 | 2.90 | 40 | 14 | 2.5 | 0.14 | 100 | Optimum |
| 23 | 3.30 | 35 | 11 | 2.5 | 0.11 | 100 | Optimum |
| 24 | 2.80 | 36 | 13 | 2.5 | 0.13 | 100 | Optimum |
| 25 | 2.00 | 31 | 15 | 2.5 | 0.16 | 100 | Optimum |
| 26 | 2.00 | 31 | 15 | 2.5 | 0.16 | 100 | Optimum |
| 27 | 2.80 | 36 | 13 | 2.5 | 0.13 | 100 | Optimum |
| 28 | 3.00 | 30 | 10 | 2.5 | 0.10 | 100 | Optimum |
| 29 | 2.00 | 31 | 16 | 2.5 | 0.16 | 100 | Optimum |
| 30 | 2.90 | 40 | 14 | 2.5 | 0.14 | 100 | Optimum |

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

| S/n | Observed Time (mins) | Basic Time (mins) | Labour rating | Fatigue Allowance @ 2.5% | Labour Coefficient ($\Gamma_c$) | Standard Rating @ 100 | Operation Remark |
|---|---|---|---|---|---|---|---|
| 1 | 1.7 | 39 | 23 | 2.5 | 0.23 | 100 | Optimum |
| 2 | 1.80 | 37 | 21 | 2.5 | 0.21 | 100 | Optimum |
| 3 | 1.90 | 38 | 20 | 2.5 | 0.20 | 100 | Optimum |
| 4 | 1.90 | 38 | 20 | 2.5 | 0.20 | 100 | Optimum |
| 5 | 1.90 | 38 | 20 | 2.5 | 0.20 | 100 | Optimum |
| 6 | 1.80 | 37 | 21 | 2.5 | 0.21 | 100 | Optimum |
| 7 | 1.60 | 35 | 22 | 2.5 | 0.22 | 100 | Optimum |
| 8 | 1.80 | 37 | 21 | 2.5 | 0.21 | 100 | Optimum |
| 9 | 1.90 | 38 | 20 | 2.5 | 0.20 | 100 | Optimum |
| 10 | 1.70 | 39 | 23 | 2.5 | 0.23 | 100 | Optimum |
| 11 | 1.70 | 39 | 23 | 2.5 | 0.23 | 100 | Optimum |
| 12 | 1.90 | 38 | 20 | 2.5 | 0.20 | 100 | Optimum |
| 13 | 1.60 | 35 | 22 | 2.5 | 0.22 | 100 | Optimum |
| 17 | 1.80 | 37 | 21 | 2.5 | 0.21 | 100 | Optimum |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 15 | 1.70 | 39 | 23 | 2.5 | 0.23 | 100 | Optimum |
| 16 | 1.80 | 37 | 21 | 2.5 | 0.21 | 100 | Optimum |
| 17 | 1.60 | 35 | 22 | 2.5 | 0.22 | 100 | Optimum |
| 18 | 1.70 | 39 | 23 | 2.5 | 0.23 | 100 | Optimum |
| 19 | 1.80 | 37 | 21 | 2.5 | 0.21 | 100 | Optimum |
| 20 | 1.70 | 39 | 23 | 2.5 | 0.23 | 100 | Optimum |
| 21 | 1..90 | 38 | 20 | 2.5 | 0.20 | 100 | Optimum |
| 22 | 1.60 | 35 | 22 | 2.5 | 0.22 | 100 | Optimum |
| 23 | 1.70 | 39 | 23 | 2.5 | 0.23 | 100 | Optimum |
| 24 | 1.70 | 39 | 23 | 2.5 | 0.23 | 100 | Optimum |
| 25 | 1.70 | 39 | 23 | 2.5 | 0.23 | 100 | Optimum |
| 26 | 1.70 | 39 | 23 | 2.5 | 0.23 | 100 | Optimum |
| 27 | 1.80 | 37 | 21 | 2.5 | 0.21 | 100 | Optimum |
| 28 | 1.60 | 35 | 22 | 2.5 | 0.22 | 100 | Optimum |
| 29 | 1.80 | 37 | 21 | 2.5 | 0.21 | 100 | Optimum |
| 30 | 1.60 | 35 | 22 | 2.5 | 0.22 | 100 | Optimum |

## 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 ($m^2$) of mesh reinforcement. It shows tabulation for the observed time, basic time, labour rating, fatigue tolerance, output coefficient and the required standard rating for the operation of cutting, bending, tieing and fixing 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 ($\Gamma_s$) gave 0.22, while the labourer (unskilled helper) coefficient ($\Gamma_s$) gave 0.12, while the combined mean gave 0.17 on the basis of nine (9).

### 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 Owunsonye, (2012), Brook (2008), Salami (2013), Ashworth (1986), Ashworth and Elliott (1986), Harrison (1994), Emsley and Harris (1990) and Ashworth and Skitmore (1982). 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);

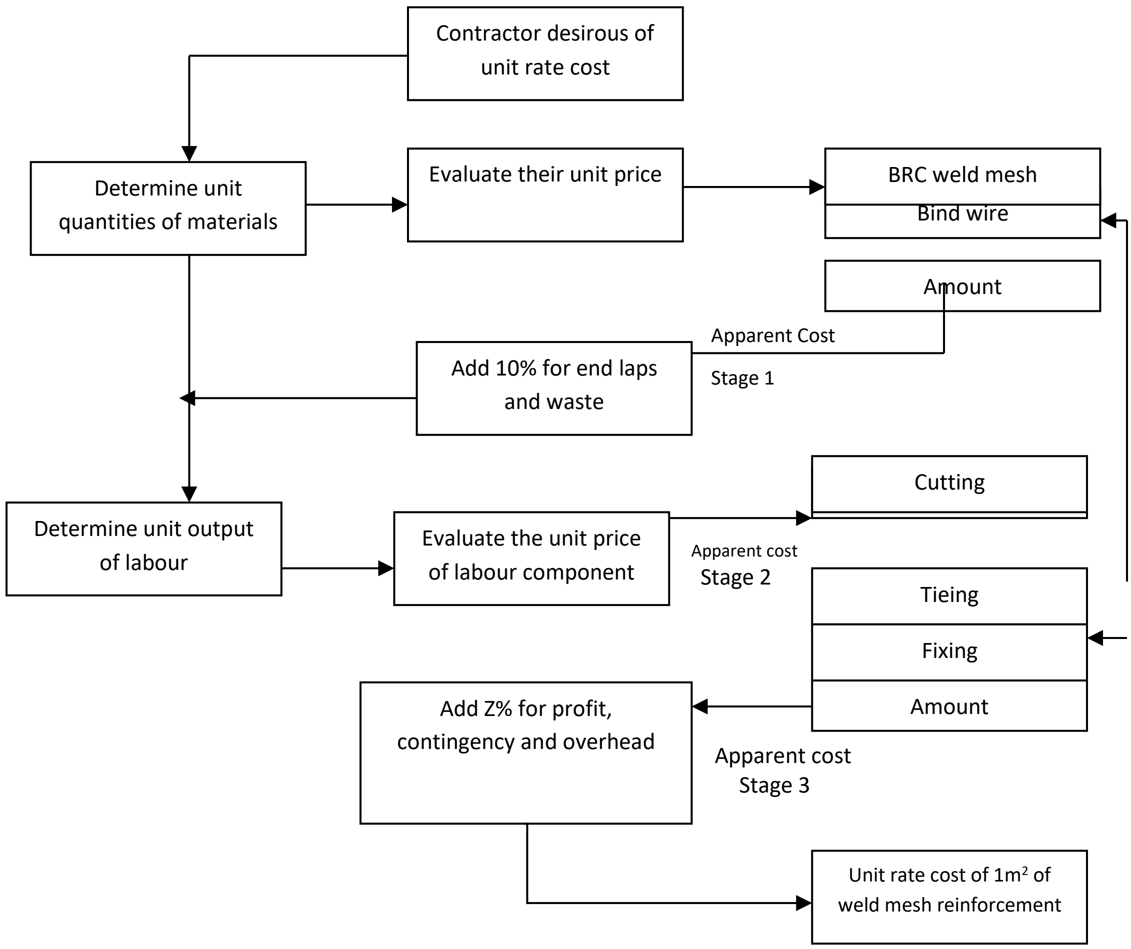


**Figure 1.** Research model Algorithm (Adapted from Egwunatum and Oboreh, (2015).

## 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 2.10m x 45m (2.29kg/m$^2$, 5mm$^2$) weld mesh.

| S/N | Output symbols | Unit Output constants |
|---|---|---|
| 1 | Unit labour cost ($\psi_t$) | $(W_t - P_t + \eta - \frac{1}{\phi} Y_t)$ |
| 2 | BRC No 65(β) | 2.10m x 45m (2.29kg/m$^2$, 5mm$^2$ |
| 3 | Cost o blackbind wire (ω) | Roll x 20kg (16SWG) |

| | | |
|---|---|---|
| 4 | Labour output for tradesman (skilled) ($\Gamma_s$) | 0.23 } $\Gamma$ = 0.35 |
| 5 | Labour output for labourer's (unskilled) ($\Gamma_c$) | 0.13 |
| 6 | % of material waste | 10% |
| 7 | % of profit and over head (z) | |

The model's flow diagram and output data were aggregated stepwise to give the cost per m$^2$ of mesh reinforcement as;

$$\prod_{\dot{m}} = 1.1\zeta_{t^m}\Lambda^{-1} + 3.7e^{-5}\zeta_{t^b} \quad + \Gamma_l\psi_t + Z_{max} \tag{10}$$

$\zeta_{t^m}$ = cost per roll of 2.10 x 45m (2.29 kg/m$^2$, 5mm) weld mesh
$\zeta_{t^b}$ = cost per roll x 20kg (16 SWG) binding wire
$\Lambda$ = Area of weld mesh (2.10m x wide x 45m long)
$\Gamma_l\psi_t$ = Labour output factor per m$^2$ multiplied by daily wag rate for reinforcement worker

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.

### 4. 3. Validation of Cost Model

#### Hierarchical Computation Method

Compute unit rate for steel wire weld mesh fabric reinforcement weighing 2.29kg/m$^2$ paid in bed to receive concrete in 98m$^2$ to BS4483: 1996

Standard size of weld mesh = 2.10m x 45m = 94.5m$^2$
Delivery price to site = N38,000

#### Materials

| | | |
|---|---|---|
| Mesh area to be reinforced | = | 98m$^2$ |
| Ad 10% { 5% waste | = | 4.9m$^2$ |
| 5% end lap | | 4.9m$^2$ |
| | | 107.80m$^2$ |

94.5m$^2$ cost N38,000
107.80m$^2$ will cost $\frac{₦38.000}{94.5} x\ 107.80$ = ₦ 43,348.15

**Labour**

a. Unloading: Take 80m2 per man day ......................Subjective value not experimented from productivity study

$107.80m^2$ will take; $\frac{107.8}{80}$ = 1.35 man day

∴1.3 x 145.63 (hourly rate) x 8 hrs = ₦ 1572.80 Arbitrary and conservative value, not prevailing

(b) Cutting and Laying: Take $66m^2$ per man day ......... Subjective value, not experimented from productivity study

| | | |
|---|---|---|
| Initial Area | = | $98m^2$ |
| Overlap | = | $4.9m^2$ |
| Final covered area | = | $102.9m^2$ |
| 102.9m2 will take; $\frac{102.9}{66}$ | = | 1.56 man day |
| ∴1.56 x 1589.04 | = | ₦ 2438.91 Arbitrary and conservative value, not prevailing |

**4. 4. Summary**

| | | | |
|---|---|---|---|
| Materials cost | = | ₦43348.15 | |
| Labour cost | | | |
| - unloading | = | ₦1572.80 | |
| Cutting, binding and tying | = | ₦2478.91 | |
| | | | 47399.86 |
| Add profit and overhead @ 25% | | | 11849.97 |

Unit rate cost = $\frac{59249.83}{98m^2}$ = ₦$604.59/m^2$

where \$1 = ₦200

**Cost Model Method**

$$\prod_{m} = 1.1\zeta_{t^m}\Lambda^{-1} + 3.7e^{-5}\zeta_{t^b} + \Gamma_l\psi_t + Z_{max}$$

$$\prod_{m} = 1.1\ x\ \frac{38000}{94.5} + 3.7e^{-5}\ x\ 3500 + 0.17\ (4500) + Z_{max} = ₦1509.32/m^2$$

## 5. CONCLUSIONS

The routine method within the construction industry for estimating unit rate cost of mesh reinforcement 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 as 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 ($m^2$) of weld mesh reinforcement and proposes that all other elements of building which include but not limited to block wall, 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 mesh reinforcement as used in Nigerian construction industry and supported by the Nigerian Institute of Quantity Surveyors' Building and Engineering Price Book.

## 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 $\beta$, $\omega$ 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 mesh reinforcement 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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