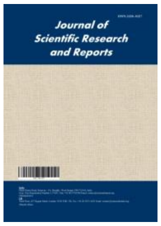

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Regression Models for Predicting Quantities and Estimates of Steel Reinforcements in Concrete Beams of Frame Buildings

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Authors' contributions

This study was carried out with the collaboration of all authors. Author SCU initiated the topic, supervised every stage of the research and compiled the first draft of the manuscript. Author EAN managed the editorial aspect of the work. Author EIUU articulated the study into a publishable format in accordance with the journal template/guidelines. Author OGO carried out the literature search. Author ECE performed the data acquisition and analysis. All authors read and approved the final manuscript.

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ABSTRACT

The traditional method of quantifying reinforced concrete steel reinforcements via taking off can be tedious, time consuming and prone to errors which can affect project success due to cost and schedule overruns, disputes and in certain cases, outright abandonment. In Nigeria, some quantity surveyors have developed 'rule of thumb' techniques to quantify reinforcements in order to beat pre-contract datelines based on their past experience, but there are still not widely accepted and a unified formulae or empirical basis of generating these quantities is still lacking. This study thus, developed easy-to-apply, time saving regression models for predicting the quantities/weight and material cost estimates of 16mm, 12mm and 8mm diameter high yield reinforcement bars in beams of varying sizes, using the volume of beam concrete as the independent or predictor variable. Data on concrete volume, weight of Y16, Y12 and Y8 reinforcement was collected via taking

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off/measurement process from 30 structural drawings of frame buildings of varying nature obtained from registered structural engineers and analyzed using correlation and regression statistics. Results indicate high coefficients of determination (R^2) ranging from 0.82 to 0.92 which indicate that the predicted values from a forecast models fit with the real-life data. Thus, 3 predictive models were advanced as follows: W_{Y16}= -811.265+ 177.339 (Vc) ;W_{Y12}= -510.189 + 63.218(Vc); W_{Y8} = -43.273+ 22.533 (Vc), where: W = reinforcement weight and Vc = volume of concrete. The study concludes that concrete volume is a good predictor variable when establishing the weight of reinforcement in beams. The import of these predictive models for construction cost professionals cannot be overemphasized for ease and accuracy of feasibility estimating, preparation of bills of quantities, material ordering, auditing construction costs, vetting consultants' estimates and contractors' quotations.

Keywords: Reinforcement; concrete; beams; modeling; quantification; estimation; Nigeria.

1. INTRODUCTION

Early cost planning and estimation response to construction projects cost volatility assures great success for projects [1]. Unfortunately, accurate quantities and estimates are hard to obtain at this stage due to the fact that construction projects are recently becoming highly complicated, diversified and even bigger, with the level of uncertainty of success rising. This has been exacerbated by dearth of predictive models for costing construction materials for projects in developing countries like Nigeria. According to the [2,3], reinforcement works accounts for approximately 20% of the completed infrastructure, making it a cost significant construction material. Thus, estimation of steel reinforcement quantity is a necessary step in calculating the cost of reinforced concrete structures and plays an important role in the overall costing of the project. Construction cost professionals like Quantity Surveyors in Nigeria still rely heavily on manual measurement (taking off) of concrete reinforcement which is not bad in itself since it is the traditional procedure of quantification, but it is time consuming and prone to errors and this often has grave consequences on the project such as cost and schedule overrun, dissatisfied clients, disputes/litigation and in some cases project abandonment. Some of them have over the years developed rule of thumb methods to quantify reinforcements, but these are largely based on experience and not widely used or accepted.

Anecdotal evidence suggests that the aforementioned effects of dearth of predictive models for quantifying and estimating concrete reinforcement leads to financial losses for the government and private investors due to inflated estimates by opportunistic and unscrupulous consultants and contractors, loss of income, reputation and client base for construction cost consultants and professionals in both public and private employ which is not sustainable for Nigeria's infrastructural and economic growth particularly after annual budgets have been approved. This scenario is corroborated by [4] who surmise that wrong estimates is a contributory factor to abandoned projects in Nigeria. [5] also reveal that there are about 4000 abandoned projects belonging to the federal government with an estimated cost of about N300billion which will take 30 years to complete. This figure relates only to federal government projects, aside from other tiers of government, talk more of private sector projects whose data is not readily available.

It is in view of the foregoing that this study sets out to develop regression models to predict reinforcement quantities and estimates of beams albeit accurately and reliably too in order to improve project success in Nigeria. It will also enable quantity surveyors to generate reinforcement quantities faster in order to beat deadlines and ease the pressure and stress they face from their clients thus, the time saved can be used for other productive ventures. The model will also serve as a platform for the development of other predictive cost models of other concrete components. The scope was delimited to Y16, Y12 and Y8 reinforcement bars in beams and not other concrete elements like suspended slab, columns and stairs so as to reduce the cumbersomeness of the research.

1.1 Aim and Objectives of the Study

The aim of this study is to develop regression models for predicting the quantities and estimates of various reinforcement bar sizes in beams

a) To measure and quantify the weights of Y16, Y12 and Y8 reinforcement bars of beams from the surveyed structural drawings;

b) To measure and quantify the corresponding cubic content or concrete volume of the beams;
c) To determine the statistical relationship between the reinforcement weights and concrete volume of the beams;
d) To develop the predictive models for the relationship between the reinforcement weights and concrete volume;
e) To illustrate the practical usage of the models in estimation.

1.2 Research Hypothesis

The following are the hypotheses postulated and validated in the study.

H_0: There is no significant relationship between volume of beam concrete and weight of Y16 reinforcement.

H_0: There is no significant relationship between volume of beam concrete and weight of Y12 reinforcement.

H_0: There is no significant relationship between volume of beam concrete and weight of Y8 reinforcement.

2. LITERATURE REVIEW

2.1 Nature of Reinforced Concrete Frame Buildings

Frame buildings are structures having the combination of horizontal beams, vertical columns and slab to resist lateral and gravity loads. They basically consist of skeletal framework supporting all loads as well as resisting all forces acting on the building and through which all loads are transferred to the soil on which that very same building is resting (see Plate 1) They can be made from timber, steel but most commonly used is reinforced concrete which is a composite material formed by combining concrete and steel reinforcement. It has the main goal of compensating for the relatively low tensile strength and ductility of concrete [2].

2.1.1 Reinforced concrete beams

A beam is a structural element which is usually horizontal and narrow in proportion to its depth, whose main function is to carry loads transverse to its longitudinal axis by its internal resistance to bending [6]. During the erection of the frame, the beam is self-supporting and when incorporated in the final construction, interacts with the floor and can thereby support heavy loads. The loads carried by a beam are transferred to columns, walls, or girders, which then transfer the force to adjacent structural compression members. Beams can be used in the construction of office buildings, apartment houses and industrial buildings. It has a large load-bearing capacity and excellent fire-resistance characteristics. A principal structural material for beams in frame buildings is steel reinforcement *(*see Fig. 1) which represents all the interconnected bars inside the concrete beam that strengthens its construction. During the quantification process, concrete in beams are usually measured by volume in cubic (m^3).

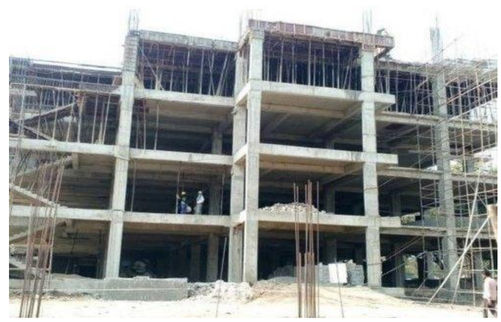

Plate 1. Typical RC frame building [7]

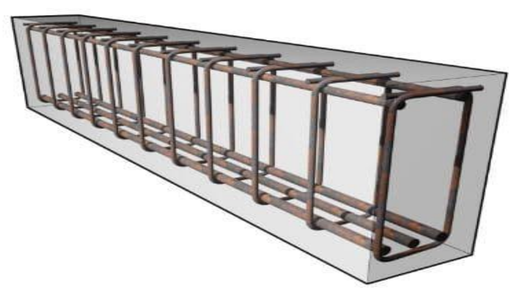

Fig. 1. A reinforced concrete beam [7]

2.1.2 Steel reinforcement

The compressive strength of normal structural concrete is about one-sixteenth that of steel, but its tensile strength is only about one-fourteenth to one-eighth of its compressive strength. Its stiffness is low compared with steel and its strength or weight ratio is low. To overcome this weakness, steel bars are embedded in the concrete. Steel bars thus, are high in ductile strength material and may have ribbed surfaces to improve bonding with concrete (see Plates 2 and 3). They are considered the most suitable building material among metallic materials. This is due to a wide range and combination of physical and mechanical properties they have. By suitably controlling the carbon content, alloying elements and heat treatment, a desired combination of hardness, ductility and strength can be obtained in steel. Steel is used extremely widely in all types of structures, due to its relatively low cost, high strength to weight ratio and speed of construction [2]. During the quantification process, reinforcement bars are usually measured by weight in kilograms (kg). Hot rolled deformed steel bars are the most common type of reinforcement for regular RC structures.

Hot rolling is done in the mills which involves giving it deformations on the surface i.e. ribs so that it can form bond with concrete. It has typical tensile yield strength of 60,000 psi. Mild steel plain bars have no ribs on them. These are often used as rings or stirrups for beams and columns and in small projects where economy is the real concern. Plain bars cannot bind very well with concrete; hence hooks have to be provided at the ends.

Plate 2. Hot rolled deformed bars

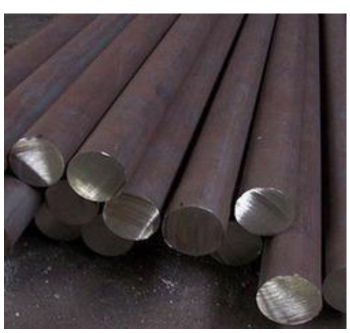

Plate 3. Mild steel bars [2]

2.2 Relationship between Quantity (Weight) of Steel Reinforcement and Concrete Volume

Previous studies and civil engineering literature abound on what constitutes the appropriate weight and percentage of steel reinforcement in concrete for structural design purposes. According to [8], the economy of the structural design of reinforced concrete buildings is usually evaluated by comparing the concrete volume per unit area and rebar weight per unit volume with certain empirical values depending on the type of the structure and the past experience of the judging engineer. They further submit that the most widely accepted values for slab reinforcements are 60-80 kg/m3 for solid slab and 120-140 kg/m3 of flat slabs. [9] maintains that 196.25kg steel is ideal for 1m3 of column and beam concrete. An average of 120 kg/m3 for beam and slab according to [10] is ideal. [11,12] and [13] opine that the quantity of steel per m^3 of concrete for slab/lintel ranges from 55 kg/m3 to 78.5 kg/m3, that of beam ranges from 78.5 kg/m3 to 157 kg/m3, column ranges from 62.80 kg/m3 to 471 kg/m3, while foundation ranges from 38.25 kg/m3 to 62.8 kg/m3. The position of [14] is that footing = 80 kg/m3, column = 160 kg/m3. Beam = 110/m3 and slab = 80 kg/m3.

[15] holds that 100 kg/m3 is the general standard for all concrete components, while [16] puts it at 150 – 300 kg/m3. Other civil engineering experts like [17] are of the view that footings and mat foundations require the least amount and the range is between 80 kg – 90 kg/m3; slabs and beams require some more with a range of 100 kg – 110 kg/m3 while columns require the most amount which can go up to 180 kg/m3. [18] posits that 1m3 of concrete in footings require 50 kg of steel, beams require 150 kg, columns 200 kg and slabs 80kg. [19] submits his as 100 kg/m3 in raft foundation, 90 kg/m3 in columns or even less, 80–85 kg/m3 for beams and for slab it is 100 kg/m3. [20] submits his as 100 kg/m3 for raft, 90 – 110 kg/m3 for columns and 70 kg for beams.

Results from the calculations of quantity surveyors like [21] yielded: column and roof beams = 181.42 kg/m3; roof Slabs (240 mm thick) = 158.9 kg/m3; small bases (below3m3) = 89.06 kg/m3; grade beams = 206.94 kg/m3; medium bases (between10-20m3) = 144.03 kg/m3 ; retaining wall = 69.25 kg/m3; ground floor slab (240mm thick) = 67.09 kg/m3; area paving (100mm thick) = 69.65 kg/m3; duct bank = 59.76 kg/m3; sleeper pedestals = 71.62

kg/m3;building walls (300mm thick) = 157.63 kg/m3. [22] maintains the approximate ratio of steel for beams is 160 kg/m3. In the view of [23], footings = 80 kg/m3, columns = 160 kg/m3, beams = 110 kg/m3, slab = 80 kg/m3, while [24], who is also an estimator maintains that it is depends on the design and may be vary between 105 kg/m3 to 160 kg/m3 and will be less for plinth beam as compared to floor beam.

According to the [7] and [25], the simplest method of determining the weight of reinforcement in concrete is the thumb rule method which is actually based on the type of structure and the volume of the reinforced concrete elements. They further provide the **a**verage values for typical concrete frames as heavy industrial = 130 kg/m^3; commercial = 100 kg/m^3; institutional = 90 kg/m^3 and residential = 85 kg/m^3. However, they advise that while this simplest method to check on the total estimated quantity of reinforcement, it is also the least accurate and requires considerable experience to breakdown the tonnage down to Standard Method of Measurement requirements. Among all the experts, they provide one of the most detailed RC elemental breakdown and their corresponding steel weight per cubic meter as shown in Table 1, but they also emphasize that the figures are for guideline only and may vary for different projects.

From the submissions of civil engineering and quantity surveying experts as outlined above, there appears not to be a standard quantity of reinforcement for different concrete components because it depends largely on the type of structure, loading conditions or capacity, concrete specifications, grade of reinforcing bar and code requirements. The reinforcement quantities per cubic meter provided by these experts are generic and given from their past experience of similar structures which can be considered tentative or based on thumb rule which yields approximate or rough values. This study attempts to bridge this gap for concrete beams specifically by advancing a uniform reinforcement quantities model using regression modeling approach.

2.3 Overview of Cost Modeling

Cost models are tools, techniques, methods or procedures used for forecasting the cost of a project. [26,27,28] define a cost model as the symbolic representation of a system, expressing the content of that system in terms of the factors which influence its costs. According to [29], cost models have been found to be useful tools, been financial representations in the form of spread sheet, mathematical expression, chart, and/or diagram used to illustrate the total cost of systems, components, or parts within a total complex product, system, structure or facility. The main aim of cost models is to simulate a current or future scenario in such a way that decision makers can make use of the results to decide their investment decision [30] and designers can optimize their design and carry out cost planning and control. Cost models typically function through the input of data or parameter that describe the attributes of the product or project in question and possibly physical resource requirement. The model then provides as output various resources requirement in form of cost or monetary values.

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. Since the 1950’s, efforts have been made in order to understand the cause- effects relationship between the design parameters and costs, and to develop models in order to estimate construction cost from inception to completion. Previous studies applied scoring methods and established common rules or mathematical methods to assess approximate estimates. [31] employed genetic algorithms with case-based reasoning to generate a preliminary cost estimation model while [1] employed parametric method for estimating various elemental costs.

Cost models in the form of mathematical equations like regression models have also been applied in previous studies to predict construction costs. For instance, [32] developed multiple linear regression models for preliminary cost estimating of road construction activities as a function of project’s physical characteristics such as terrain conditions, ground conditions and soil drillability. [33] developed linear regression models in order to predict the construction cost of buildings, based on 286 sets of data collected in the United Kingdom. They identified 41 potential independent variables, and, through the regression process, showed five significant influencing variables such as gross internal floor area (GIFA), function, duration, mechanical installations, and piling. [34] developed regression models using real data of 140 projects in Jordan (comprising residential, commercial, heavy and industrial projects) in order to predict project cost and duration. The input variables were project type, job type, project area, original bid price and original project duration.

Table 1. Weights and percentages of steel reinforcement per cubic meter of concrete

Concrete Building Element	Weight of reinforcement (kg/m^3)
Bases	90-130
Beams *(lightly loaded)*	100-150
Beams	150-300
Capping beams	135
Columns *(lightly loaded)*	110-200
Columns	200-450
Ground beams	230-330
Footings	70-100
Pile Caps	110-150
Plate slabs	95-135
Rafts	115
Retaining walls	110-150
Ribbed floor slabs	80-120
Slabs – one way	75-125
Slabs – two way	67-135
Stairs	130-170
Tie beams	130-170
Transfer slabs	150
Walls – normal	70-100
Walls – wind	90-150

Source: [7] and [25]

These cost models were various attempts to explore the parametric method of cost estimation to determine cost of construction projects (often a single monetary value). 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). The models cost predictive and precision abilities do not necessary respond to any specific material but deals with the entirety of the project, which is the gap this study intends to bridge. The closest study to a specific material estimation model was carried out by [35], but their focus was on developing a cost model for unit rate pricing of concrete as a composite item with labour, material, plant rates and prices as well profit and overheads as the independent variables.

3. METHODOLOGY

The study adopts a correlational research design via the following procedures: Thirty (30) structural drawings of executed projects (from which the quantities of concrete volumes and reinforcement weights of 16mm, 12mm and 8mm bars (variables for the analysis) were measured via the taking off process) were used for this study. The researchers consider 30 drawings adequate or 'large enough' sample size in order to ensure scientific or statistical significance in line with the submission of [36].These drawings were sourced from registered structural engineers practicing in the south-west and south-east part of Nigeria. The nature of projects comprised beam layout of first and upper floors of residential framed buildings. The quantities were further validated by a registered quantity surveyor to ensure accuracy. The data was analysed using inferential statistics like Pearson correlation and regression with the aid of SPSS (Statistical Package for Social Sciences) software version 25.

3.1 Correlation Analysis

The Karl Pearson correlation analysis was carried out to investigate the relationship between the volume of concrete in beams and weight of reinforcement in beams. Karl Pearson's coefficient of correlation is also known as the product moment correlation coefficient is denoted by *'r'*. The value of '*r*' lies between 0 and 1. Positive values of *r* indicate positive correlation between the two variables (i.e., changes in both variables take place in the statement direction), whereas negative values of '*r*' indicate negative correlation i.e., changes in the two variables taking place in the opposite directions. A zero value of '*r*' indicates that there is no association between the two variables. When r = (+) 1, it indicates perfect positive correlation and when it is (–) 1, it indicates perfect negative correlation, meaning thereby that variations in independent variable (*X*) explain 100% of the variations in the dependent variable (*Y*). We can also say that for a unit change in independent variable, if there happens to be a constant change in the dependent variable in the same direction, then correlation will be termed as perfect positive. But if such change occurs in the opposite direction, the correlation will be termed as perfect negative. The value of '*r*' nearer to +1 or –1 indicates high degree of correlation between the two variables.

3.2 Regression Analysis and the Generic Models

Regression is the determination of a statistical relationship between two or more variables. In simple regression, we have only two variables, one variable (defined as independent) is the cause of the behavior of another one (defined as dependent variable). The linear regression analysis (adopted by the study) is used to predict one variable based on another variable. It is a technique that will find a formula or mathematical model which best describes some set of data collected. The factor whose value we wish to estimate is referred to as dependent variable and denoted by Y. the factor from which these estimates is made is called the independent variable and is denoted by X. Regression can only interpret what exists physically i.e., there must be a physical way in which independent variable *X* can affect dependent variable *Y*.

The relationship between the dependent and independent variables could be expressed with the generic linear regression equation as shown in equation 1.

$$Y = a + bx \quad (1)$$

Where,

Y = the dependent variable or quantity being predicted
x = the independent variable
a = the value of Y when = 0, i.e. the interceptor of the line with Y – axis
b = the slope or gradient. It estimates the rate of change in Y for a unit change in X.

It is positive for direct and negative for inverse relationships.

In view of this, 3 generic regression models (equations 2, 3 and 4) for predicting the weight of reinforcement bars are proposed for the study as follows:

$$W_{Y16} = c + b_1X_1 \quad (2)$$

Where,

W_{Y16}= Weight of 16mm high yield reinforcement
c = regression constant
b_1 = Slope or gradient that estimates the rate of change in weight of Y16 for a unit change in volume of beam concrete
X_1= Volume of concrete in beam

Table 2. Summary outline of the methodology

S/N	Objective	Research method		
		Data source/collection procedure	**Data analysis method**	**Data analysis soft ware**
1	To determine the relationship between concrete volume and weight of Y16 reinforcement in beams.	Quantity take-off (measurement)of thirty structural drawings crosschecked by an experienced QS	Pearson Correlation analysis	SPSS (Statistical Packages for the Social Sciences) version 25
2	To determine the relationship between concrete volume and weight of Y12 reinforcement in beams.	Quantity take-off (measurement)of thirty structural drawings crosschecked by an experienced QS	Pearson Correlation analysis	SPSS version 25
3	To determine the relationship between concrete volume and weight of Y8 reinforcement in beams.	Quantity take-off (measurement)of thirty structural drawings crosschecked by an experienced QS	Pearson Correlation analysis	SPSS version 25
	To develop predictive models for estimating the weight of Y16, Y12 and Y8 reinforcement in beams.	Quantity take-off (measurement)of thirty structural drawings validated by an experienced QS	Regression analysis	SPSS version 25

$$W_{Y12} = c + b_2X_2 \quad (3)$$

Where,

$W_{Y12=}$ Weight of 12mm high yield reinforcement
c = regression constant
b_2 = Slope or gradient that estimates the rate of change in weight of Y12 for a unit change in volume of beam concrete
X_2= Volume of concrete in beam

$$W_{Y8} = c + b_3X_3 \quad (4)$$

Where,

$W_{Y8=}$ Weight of 8mm high yield reinforcement
c = regression constant
b_3 = Slope or gradient that estimates the rate of change in weight of Y8 for a unit change in volume of beam concrete
X_3= Volume of concrete in beam

Table 2 summarizes the methodology of the study.

4. DATA PRESENTATION, ANALYSIS AND RESULTS

As earlier mentioned, data used for the analysis was generated from measurement/quantification of structural drawings of past projects. The concrete and reinforcement quantities generated are as shown in Table 3.

4.1 Interpolation of Volume of Beam Concrete and Weight of 16 mm Reinforcement Bars

Tables 4 – 6 show the results obtained from the correlation and regression analysis carried out between volume of beam concrete and weight of Y16 reinforcement from which model 1 was formulated.

Table 3. Measured quantities of beam concrete and reinforcement

Project ID	Conc Qty(M^3)	RQtyY16(kg)	RQtyY12(kg)	RQtyY8(kg)
1	16.84	1776.73	1000.81	275.52
2	17.84	1973.89	1111.88	437.15
3	18.91	2138.58	1204.64	392.37
4	11.17	775.27	291.08	176.44
5	19.53	2904.13	1635.87	461.37
6	17.47	834.19	469.89	276.83
7	15.14	1047.99	385.88	234.97
8	26.58	1595.78	599.69	424.85
9	15.27	985.87	370.18	242.55
10	12.76	497.09	280.01	239.81
11	81.61	9608.79	5412.54	1928.02
12	14.39	642.18	361.73	225.79
13	46.17	3439.25	1290.68	738.04
14	16.51	2265.72	851.12	514.78
15	11.08	449.62	253.27	174.46
16	12.78	581.96	327.81	200.62
17	19.78	1957.69	470.63	377.31
18	19.07	1193.83	159.99	303.96
19	13.09	540.11	304.24	210.74
20	17.48	1055.17	396.21	417.42
21	7.76	354.22	199.53	147.44
22	12.94	534.44	301.04	201.89
23	12.91	557.47	314.02	203.24
24	5.55	215.29	121.27	228.80
25	24.91	1360.58	766.41	589.99
26	10.79	656.98	370.07	258.14
27	14.51	599.33	337.59	344.46
28	21.28	912.67	514.09	500.26
29	21.54	822.33	463.21	513.29
30	18.55	762.03	429.25	400.12

ConcQty= Concrete quantity; RQty= Reinforcement quantity

Table 4. Descriptive statistics and correlations between concrete volume and weight of Y16 bars

		Descriptive Statistics	
	Mean	**Std. Deviation**	**N**
RQtyY16	1434.6393	1730.88122	30
ConcQtyM3	19.1403	13.81516	30
	Correlations		
		RQtyY16	ConcQtyM3
Pearson Correlation	RQtyY16	1.000	.937
	ConcQtyM3	.937	1.000
Sig. (1-tailed)	RQtyY16	.	.000
	ConcQtyM3	.000	.
N	RQtyY16	30	30
	ConcQtyM3	30	30

Table 5. Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					
					R Square Change	F Change	df 1	Df 2	Sig. F Change	Durbin-Watson
1	.937[a]	.877	.873	617.47638	.877	199.872	1	28	.000	1.900

a. Predictors: (Constant), ConcQtyM3, b. Dependent Variable: RQtyY16

Table 6. ANOVA and Coefficients for relationship between concrete volume and weight of Y16 bars

			ANOVA[a]			
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	76206786.395	1	76206786.395	199.872	.000[b]
	Residual	10675758.224	28	381277.079		
	Total	86882544.619	29			
a. Dependent Variable: RQtyY16						
b. Predictors: (Constant): ConcQtyM3						
Coefficients[a]						
		Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**
Model		**B**	**Std. Error**	**Beta**		
1	(Constant)	-811.265	194.797		-4.165	.000
	ConcQtyM3	117.339	8.300	.937	14.138	.000
a. Dependent Variable: RQtyY16						

Table 7. Descriptive statistics and correlations between concrete volume and weight of Y12 bars

		Descriptive Statistics	
	Mean	**Std. Deviation**	**N**
RQtyY12	699.8210	963.68970	30
ConcQtyM3	19.1403	13.81516	30
	Correlations		
		RQtyY12	ConcQtyM3
Pearson Correlation	RQtyY12	1.000	.906
	ConcQtyM3	.906	1.000
Sig. (1-tailed)	RQtyY12	.	.000
	ConcQtyM3	.000	.
N	RQtyY12	30	30
	ConcQtyM3	30	30

Table 8. Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					
					R Square Change	F Change	df 1	Df 2	Sig. F Change	Durbin-Watson
2	.906[a]	.821	.815	414.55820	.821	128.712	1	28	.000	1.763

a. Predictors: (Constant), ConcQtyM3, b. Dependent Variable: RQtyY12

Table 9. ANOVA and Coefficients for relationship between concrete volume and weight of Y12 bars

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
2	Regression	22120199.174	1	22120199.174	128.712	.000[b]
	Residual	4812038.083	28	171858.503		
	Total	26932237.258	29			

a. Dependent Variable: RQtyY12
b. Predictors: (Constant): ConcQtyM3

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
2	(Constant)	-510.189	130.782		-3.901	.001
	ConcQtyM3	63.218	5.572	.906	11.345	.000

a. Dependent Variable: RQtyY12

From the result of the analysis, model (1) can be given as:

$$\text{Weight of Y16} = -811.265 + 177.339\, V_C \quad (5)$$

Where Vc = Volume of concrete.

Table 5 shows the coefficient of correlation between concrete quantity (volume) and Y16 Reinforcement quantity (weight) is 0.937 which implies that there exists a strong positive relationship between concrete volume and Y16 reinforcement in beams. Furthermore, the coefficient of determination (R^2)= 0.877 indicates that only 12.3% (1 — 0. 877) of change in the Y16 reinforcement is not explained by change in concrete volume or that 88% of the dependent variable (reinforcement quantity) is predicted by the independent variable (concrete quantity). Hence, the predicted equation is statistically significant and the Y16 reinforcement using the model will be reliable.

This inference is based on the fact that coefficient of determination (R^2)is a key output of the regression analysis which shows the proportion of the variance in the dependent variable that is explained by the independent variable when predicting the outcome of a given event. It assesses the strength of the linear relationship between the two variables. In other words, it tells us how well the observed data fits the regression model (goodness of fit).

This measure (R^2) is represented as a value between 0.0 and 1.0. A value of 1.0 indicates a perfect fit, and is thus a highly reliable model for future forecasts, while a value of 0.0 indicates that the calculation fails to accurately model the data at all. In the case of the developed model (equation 5), the coefficient of determination of 88% shows that 88% of the data fit the regression model, which though is not a perfect fit, but still shows a very good fit for the model which can be considered reliable for prediction.

4.2 Interpolation of Volume of Beam Concrete and Weight of 12 mm Reinforcement Bars

The results obtained from the correlation and regression analysis carried out between volume of beam concrete and weight of Y12 reinforcement (from which model 2 was formulated) are shown in Tables 7 – 9.

From the result of the analysis above, model (2) can be expressed as:

$$\text{Weight of Y12} = -510.189 + 63.218\, V_C \quad (6)$$

Where Vc = Volume of concrete.

As shown in Table 8, the correlation coefficient of concrete quantity (volume) and Y12 Reinforcement quantity (weight) is 0.906 which shows a strong positive relationship between both variables. In addition to this, the coefficient of determination (R^2) = 0.821 indicates that only 17.9% (1 — 0. 821) of change in the Y16 reinforcement is not explained by change in concrete volume or that 82% of the dependent variable (reinforcement quantity) is predicted by the independent variable (concrete quantity). Hence, the predicted equation is statistically significant and the model generated thereof will be reliable. The R^2 of the developed model as depicted by equation 6 further suggests that 82% of the observed data or quantities fit the regression model, which though is not a perfect fit, but a very good fit that means high predictability.

4.3 Interpolation of Volume of Beam Concrete and Weight of 8 mm Reinforcement Bars

The results obtained from the correlation and regression analysis carried out between volume of beam concrete and weight of Y8 reinforcement which yielded the third model are shown in Tables 10 – 12.

Table 10. Descriptive statistics and correlations between concrete volume and weight of Y8 bars

		Descriptive Statistics	
	Mean	**Std. Deviation**	**N**
RQtyY8	388.0210	323.88910	30
ConcQtyM3	19.1403	13.81516	30
	Correlations		
		RQtyY8	ConcQtyM3
Pearson Correlation	RQtyY8	1.000	.961
	ConcQtyM3	.961	1.000
Sig. (1-tailed)	RQtyY8	.	.000
	ConcQtyM3	.000	.
N	RQtyY8	30	30
	ConcQtyM3	30	30

Table 11. Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					
					R Square Change	F Change	df 1	Df 2	Sig. F Change	Durbin-Watson
3	.961[a]	.924	.921	91.00475	.924	339.335	1	28	.000	2.054

a. Predictors: (Constant), ConcQtyM3, b. Dependent Variable: RQtyY8

Table 12. ANOVA and Coefficients for relationship between concrete volume and weight of Y8

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
3	Regression	2810328.105	1	2810328.105	339.335	.000[b]
	Residual	231892.226	28	8281.865		
	Total	3042220.331	29			
a. Dependent Variable: RQtyY8						
b. Predictors: (Constant): ConcQtyM3						
Coefficients[a]						
		Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**
Model		**B**	**Std. Error**	**Beta**		
3	(Constant)	-43.273	28.709		-1.507	.143
	ConcQtyM3	22.533	1.223	.961	18.421	.000
a. Dependent Variable: RQtyY8						

Table 13. Generated quantification Models

Reinforcement size	Generic regression equation	Generated Model
Y16	$W_{Y16} = c + b_1X_1$	Weight of Y16 = -811.265+ 177.339 (V_C)
Y12	$W_{Y12} = c + b_2X_2$	Weight of Y12 = -510.189 + 63.218 (V_C)
Y8	$W_{Y8} = c + b_3X_3$	Weight of Y8 = -43.273+ 22.533 (V_C)

V_c= Volume of concrete

From the result of the analysis above, model (3) can be indicated as:

$$\text{Weight of Y8} = -43.273 + 22.533V_C \qquad (7)$$

Where Vc = Volume of concrete.

The third regression model for the relationship between concrete volume and Y8 reinforcement has a coefficient of correlation R of 0.961 which suggests a strong positive relationship. The coefficient of determination R^2 of 0.924 further indicates that 92% of the reinforcement weight is predicted by the volume of concrete, which is a near perfect goodness fit to evidence predictability. In other words, the model will be realistic and the forecast will fit real life data. The use of this model is thus recommended for construction professionals in determining the weight of Y8 reinforcement in concrete beams.

The 3 generated models are summarized in Table 13.

4.4 Illustration of the Practical Usage of the Models

The illustration indicated below is meant to serve as an easy to use guide for contractors, iron fitters, quantity surveyors and other construction professionals as well as construction clients on how to make use of the models for beam reinforcement quantification, estimation, usage or purchase or during project execution.

It is paramount that for the model to be used effectively, clients who are not construction inclined that want to crosscheck the quantities of beam reinforcement quoted by the contractor or indicated in the Bill of Quantity by the quantity surveyor should have some basic knowledge of mensuration; involving computation of simple volume which comes handy during calculation of concrete volume from the structural drawings. Furthermore, they should also have an idea of basic prices of reinforcement bars. Where this is not the case, they can make enquiries from suppliers or embark on market survey.

It should be noted that the model only predicts the quantity and estimate for material cost only. For competitive bid, like public projects, the appropriate profit and overhead margin, waste factor, transportation cost, loading and offloading cost and labour cost will need to be added. For purchase purposes by the contractor and client, only transportation and waste factor will be included. Loading and off loading cost can be done at point of purchase or after delivery and offload.

The illustration is done for the 3 reinforcement bar sizes (Y16, Y12 and Y8) for which the models were generated and is as follows:

Assume volume of beam concrete as measured from the drawings or indicated in the BOQ = 20m^3

Weight of Y16 = ?

1 Length of Y16 = 12m = 18.96Kg
Price of 1 Length of Y16 = ₦4,000
Using Weight of Y16 = -811.265 + 177.339 (V_C)
= -811.265 + 177.339(20)
=-811.265+3546.78 = 2735.52 Kg
Weight/m^3 = 136.78kg/m^3
Therefore: estimated cost of Y16 = 2735.52/18.96
= 144 Lengths x ₦4000 per length = ₦576,000

Weight of Y12 = ?

1 Length of Y12 = 12m = 10.68Kg
Price of 1 Length of Y12 = ₦2,150
Using Weight of Y12 = -510.189 + 63.218 Vc
= - 510.189 + 63.218 (20)
=-510.218+1264.36 = 754.14Kg
Weight/m^3 = 37.71kg/m^3
Therefore: estimated cost of Y12 = 745.14/10.68
= 70 Lengths x ₦2150 per length = ₦150,500

Weight of Y8 = ?

1 Length of Y8 = 12m = 4.68Kg
Price of 1 Length of Y8 = ₦1,200
Using Weight of Y8 = -43.273+ 22.533(Vc)
= - 43.273+ 22.533(20)

= -43.273+450.66 = 407.39Kg
Weight/m^3 = 20.37kg/m^3
Therefore: estimated cost of Y8 = 407.39/4.68
= 87 Lengths x ₦1200 per length = ₦104,400

Total kg/m^3
Y16 = 136.78
Y12 = 37.71
Y8 = 20.37
194.86 kg/m3

Total reinforcement cost (material only)
Y16 = ₦576,000.00
Y12 = ₦150,500.00
Y8 = ₦104,400.00
₦830,900.00

4.5 Validation of Hypotheses

The following explains the test of the hypotheses earlier postulated.

4.5.1 Hypothesis 1

H_0: There is no significant relationship between volume of beam concrete and weight of Y16 reinforcement.

The coefficient of correlation, R = 0.937) (Table 5) shows a very strong positive relationship between the volume of the beam concrete and weight of Y16; hence it is statistically significant. The $H_0$is thus rejected and it is inferred that there is a significant relationship between volume of beam concrete and weight of Y16 reinforcement bars.

4.5.2 Hypothesis 2

H_0: There is no significant relationship between volume of beam concrete and weight of Y12 reinforcement.

The Correlation coefficient R (0.906) as shown in Table 8 indicates a strong positive relationship between the volume of the beam concrete and weight of Y12; hence the relationship is statistically significant. The H_0 is thus rejected and we conclude that there is a significant relationship between volume of beam concrete and weight of Y12 reinforcement.

4.5.3 Hypothesis 3

H_0: There is no significant relationship between volume of beam concrete and weight of Y8 reinforcement.

Table 11 shows that the correlation coefficient (R) of 0.961 is a very strong positive relationship between both variables, implying statistical significance. Therefore, we reject H_0 and infer that there is a significant relationship between volume of beam concrete and weight of Y18 reinforcement.

5. CONCLUSION

The study advances empirically, that volume of beam concrete is reliable for estimating the weight of Y16, Y12 and Y8 reinforcement bars in beams. This is as indicated by the high coefficients of determination (R^2), implying high predictability potentials.

The developed regression models are expected to prove very useful to clients, contractors and construction professionals, especially the construction cost professionals or quantity surveyors because of their simplicity to be handled by calculators or a simple computer program. It has potential benefits in estimating reinforcement quantities at the early stages of the contract or frame construction of residential buildings, which can save pre-contract time. However, the challenge here is that the structural drawing (specifically the beam layout) prepared by the structural engineer will have to be ready. When this is delayed, the purpose of saving time is defeated. The study (or models developed) can also be useful for researchers since it forms a basis for researches of similar nature, such as predicting reinforcement weights for other structural components.

Since, the model development is based on analysis of a number of structural drawings, validated by experienced quantity surveyors; the model has the potentials of improving the accuracy of beam reinforcement quantities which will further boost clients' confidence in the professional expertise or capabilities of quantity surveyors. This does not however preclude the stance that for construction clients to avoid falling victims of scrupulous contractors or poor quantification by the quantity surveyors, they should have some basic knowledge of volumes computation and material prices in order to apply the model effectively and vet submissions of the contactors and the quantity surveyor's BOQS.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Hakan Y, Tas E. A building cost estimation model based on functional elements. Faculty of Architecture, Istanbul, Turkey; 2007.
2. Concrete Reinforcing Institute. Economy of construction; 2020. Available:http://www.crsi.org
3. Liu L, Zhu K. Improving cost estimate of construction projects using phased cost factors. Journal of Construction Engineering and Management. 2007;133(1):91 – 95.
4. Nwanekezie O, Nwanguma W. A study of causes of uncompleted/abandoned building projects and its effect on real property in Uyo Metropolis, Nigeria. Architecture Research. 2019;9(2):45 – 50.
5. Akhanolu IA, Ikpetan OA, Chibuzor OT. Project financing: Causes and effects of financing abandoned projects in Nigeria. Social Sciences. 2016;11(24):5818 – 5823.
6. Raymond W. Construction technology: framed buildings; 2003. Available:https://personal.cityu.edu.hk/~bswmwong/contents/ebook/construction_technology/2a.pdf.
7. Anonymous. Reinforcement Quantity Estimation; 2018. Available:https://theconstructor.org/concrete/reinforcement-quantity-estimation/6802/(Accessed 11 June 2020)
8. Amr A, Ebid AM. Estimating the economic quantities of different concrete slab types. International Journal of Innovative Research in Science. 2015;4(5):2661–2669.
9. Anu S. Quantity of steel for 1m^3 of concrete: framed buildings; 2018. Available:https://www.quora.com/How-much-quantity-of-steel-required-for-1m3-concrete /answer/Sarath - Anu) (Accessed 15 July 2020)
10. Bista JR. Quantity of steel for 1m^3 of concrete: framed buildings; 2018. Available:https://www.quora.com/How-much-quantity-of-steel-required-for-1m3-concrete/answer/Jay Raj-Bista) (Accessed 15 July 2020)
11. Anonymous.Quantity of seel per m^3 of concrete; 2018. Available:https://wecivilengineers.wordpress.com/2018/01/26/quantity-of-steel-per-m%C2%B3/(Accessed 11 June 2020)
12. Bhargav S. Quantity of steel for 1m^3 of concrete: framed buildings; 2012. Available:https://www.quora.com/How-much-quantity-of-steel-required-for-1m3-concrete /answer/Bhargav-S) (Accessed 15 July 2020)
13. Shridhar M. Quantity of steel for 1m^3 of concrete: framed buildings; 2015. Available:https://www.quora.com/How-much-quantity-of-steel-required-for-1m3-concrete /answer/Mayank-Shridhar) (Accessed 15 July 2020)
14. Krishnan A. Quantity of steel for 1m^3 of concrete: framed buildings; 2017. Available:https://www.quora.com/How-much-quantity-of-steel-required-for-1m3-concrete /answer/Ashwath-Krishnan) (Accessed 15 July 2020)
15. Bhatt L. Quantity of steel for 1m^3 of concrete: framed buildings; 2017. Available:https://www.quora.com/How-much-quantity-of-steel-required-for-1m3-concrete /answer/Lokesh-Bhatt) (Accessed 15 July 2020)
16. Mahood C. Quantity of steel for 1m^3 of concrete: framed buildings; 2017. Available:https://www.quora.com/How-much-quantity-of-steel-required-for-1m3-concrete /answer/Ciaran-Mahood) (Accessed 15 July 2020)
17. Issa S. Quantity of steel for 1m^3 of concrete: framed buildings; 2019. Available:https://www.quora.com/How-much-quantity-of-steel-required-for-1m3-concrete /answer/Sherif-Issa) (Accessed 15 July 2020)
18. Dusane S. Quantity of steel for 1m^3 of concrete: framed buildings; 2016. Available:https://www.quora.com/How-much-quantity-of-steel-required-for-1m3-concrete /answer/Sanjay-Dusane) (Accessed 15 July 2020)
19. Dey P. Quantity of steel for 1m^3 of concrete: framed buildings; 2016. Available:https://www.quora.com/How-much-quantity-of-steel-required-for-1m3-concrete /answer/Prasanta-Dey) (Accessed 15 July 2020)
20. Patil DP. Quantity of steel for 1m^3 of concrete: framed buildings; 2016. Available:https://www.quora.com/How-much-quantity-of-steel-required-for-1m3-concrete /answer/DP-Patil) (Accessed 15 July 2020)
21. Dissanayake L. How much is the common weight of reinforcement in kg/m^3 for beams; 2017. Available:https://specialties.bayt.com/en/specialties/q/85541/how-much-is-the-

common-weight-of-reinforcement-in-kg-m%C2%B3-for-beams/(Accessed 9 June2020)

22. Ahmed T. How much is the common weight of reinforcement in kg/m^3 for beams; 2016. Available:https://specialties.bayt.com/en/specialties/q/85541/how-much-is-the-common-weight-of-reinforcement-in-kg-m%C2%B3-for-beams/(Accessed 9 June 2020)
23. Sekar K. How much is the common weight of reinforcement in kg/m^3 for beams; 2018. Available:https://specialties.bayt.com/en/specialties/q/85541/how-much-is-the-common-weight-of-reinforcement-in-kg-m%C2%B3-for-beams/(Accessed 9 June 2020)
24. Pathan J. How much is the common weight of reinforcement in kg/m^3 for beams; 2018. Available:https://specialties.bayt.com/en/specialties/q/85541/how-much-is-the-common-weight-of-reinforcement-in-kg-m%C2%B3-for-beams/(Accessed 9 June 2020)
25. Anonymous. Reinforcement Estimates; 2016. Available:https://www.yourspreadsheets.co.uk/reinforcement-estimates.htmlReinforcementEstimates(Accessed 11 July 2020)
26. Ashworth A, Hogg K. Willis's practice and procedure for the quantity surveyor. 12th Ed. Oxford: Blackwell Science; 2007.
27. Ashworth A. Cost studies of buildings. 5th Ed. USA: Pearson Education; 2010.
28. Ajator UO. Project cost control fundamentals. Enugu: Rojoint Communications; 2012.
29. Society of American Value Engineers (SAVE). Value Standard and Body of Knowledge, SAVE International Value Standard; 2007.
30. Kirkham R, Greenhalgh B, Waterman A. Ferry and Brandon's cost planning of buildings. 8th Ed. UK: Blackwell Publishing; 2007.
31. Kim KJ, Kim K. Preliminary cost estimation model using case-based reasoning and genetic algorithms. Journal of Computing in Civil Engineering. 2010;24(6):499– 505.
32. Mahamid I. Early cost estimating for road construction projects using multiple regression techniques. Australasian Journal of Construction Economics and Building. 2011;11(4):78– 101.
33. Lowe DJ, Emsley MW, Harding A. Predicting construction cost using multiple regression techniques. Journal of Construction Engineering and Management. 2006;132(7):750– 758.
34. Abu HA, Ali AS, Sweis G, Bashkir A. Prediction model for construction cost and duration in Jordan. Jordan Journal of Civil Engineering. 2008;2(3):266– 273.
35. Egwunatum IS, Oboreh JS. Cost model for unit rate pricing of concrete in construction projects. 2015;4(4):149–158. DOI: 10.5923/j.ijcem.20150404.05
36. Lenth RV. Some practical guidelines for effective sample size determination. The American Statistician. 2001;55(3):187–193.

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