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VALIDATING A TIME-SAVING REGRESSION MODEL FOR QUANTIFYING INTERNAL WALLS IN RESIDENTIAL BUILDINGS

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Abstract

Manual quantification or measurement of construction projects is the most time-consuming cost estimation process of all the cost management processes deployed by cost managers. While it is true that the adoption of measurement-oriented building information modelling (BIM) authoring tools reduces this time consumption, anecdotal evidences suggest that the use of such tools is the exception rather than being the norm within the quantity surveying community of practice in Nigeria. It is against this backdrop that the model, BOQ wall qty. = -7.643 + 0.89blockwall girth *wall height, was developed as a time-saving quantification model for obtaining the quantities of blockwork in residential buildings without the hassle of deducting numerous openings. The coefficient of determination (r^2) of the linear regression model is 98.6%. This implies that 98.6% of the variation in the BOQ wall quantity is accounted for by the block wall girth and the wall sectional height. The objective of the current paper is to test the validity of the model in predicting the quantities of blockwork in internal walls in residential buildings. In order to achieve this, the internal block wall quantities of 30 residential building floors (floors in block of flats and residential buildings) were generated using both BESMM4-guided, measurement-oriented analysis and the linear regression model above. In order to assess whether a statistically significant difference exist in the quantity of wall generated by the model and that generated by the traditional BESMM4-based manual measurement approach, a paired sample test of 30 data sets was used to test the null hypothesis that "there is no significant difference between the BESMMR4-driven measured quantities and the model-generated quantities. Since the results of the hypothesis test shows that the p-value is greater than the alpha protection value of 5%, we conclude that there is no statistically significant difference in the values of quantities generated by the two approaches. Since the model eliminates the hassle of deducting numerous openings from walls, it is recommended for use in quantity surveyor's offices.

Keywords: Internal Walls, Quantification, Regression Model, Residential Buildings, Validating

Introduction

The quantification of construction works from 2-dimensional architectural and engineering drawings is a laborious and time-consuming activities carried out daily by practising quantity surveyors (Abanda,Kamsu-Foreguem and Tah, 2017; Monteiro and Martins, 2013). The need to eliminate this laborious tasks has been one of the drivers of the development and adoption of technologies like Building Information Modelling and computer-aided measurement tools. Despite a global uptake in the use of

these technologies, anecdotal evidence suggests that many practising quantity surveyors still carry out manual quantity take off aided by the use of spreadsheets like Microsoft Excel. A closer look at this semi-automated approach to quantification of construction works shows that one way to reduce the labour and time associated with quantification of works is to develop quantification models that eliminate some of the time-consuming measurement tasks in quantity surveyor's offices. It is against this backdrop that a regression model for quantifying wall quantities in residential buildings was developed.

The model, BOQ wall qty. = -7.643 + 0.89blockwall girth *wall height, was developed by Ibidokun (2018) by regressing the gross wall quantity (the product of block wall girth and wall height) of 60 residential architectural floor plans against their BOQ wall quantities (the dependent variable) using the linear regression algorithms embodied by Statistical Package for the Social Sciences (SPSS Version20). The data was generated by a measurement-oriented analysis of the 60 architectural floor plans and sections of residential duplexes based on the rules of the 4th edition of the Building and Engineering Standard Method of Measurement (BESMM4R) published by the Nigerian Institute of Quantity Surveyors. The coefficient of determination (r^2) of the linear regression model is 98.6%. This implies that 98.6% of the variation in the BOQ wall quantity is accounted for by the block wall girth and the wall sectional height. Since the inputs required by the user of the model are just the blockwork girth and the height of the building, the model eliminates the time taken to deduct numerous openings in walls. However, for the model to be deployed in quantity surveyor's offices, we will need to go beyond reporting the statistical coefficient of the model as presented in Ibidokun (2018). Quantity surveyors would need to see a practical evidence of the applicability of the model.

The current research reported in this paper provides such a practical evidence of applicability of the model using a new data set in a new context. The practical evidence of applicability presented in this paper involves demonstrating using that there is no statistical significant difference in the model-generated quantities of block wall and those quantities generated using the traditional BESMM4R-based measurement approach. While the model was built from residential floors in residential buildings for predicting block wall quantity, our interest in the current research reported here is the assessment of the validity of the model for BOQ quantities for internal walls of residential building floors in both block of flats and residential duplexes. The next section presents the conceptual foundations underpinning the research.

Conceptual Foundations

A conceptual framework shows the relationships that exist between different constructs that a study intends to investigate. The idea presented in this paper are related to three concepts, namely the concept of cost modelling, the practice of MoM-based measurement by quantity surveyors, and the concept of validating models.

Concept of cost modelling

Cost models are technical aids which enable management decisions to be made in the context of building design (Skitmore and Marston, 1999). The primary function of cost models in this context is to provide reliable cost forecasts (Elhag and Boussabaine, 1998), either for the client or the contractor (Ashworth, 1999). Kirkham (2007) defined cost modelling as "the symbolic representation of a system, expressing the content of that system in terms of the factors which influence its cost in a form that will allow analysis and prediction of cost".

Accurate cost modelling is fundamental to the efficiency of the construction industry in general, and the stakeholders within the industry in particular.

Cost modelling is the process of estimating and managing costs within a business. It is used to understand the financial impact of changes to a business operation and to make informed decisions about how to allocate resources. Cost modelling is a critical component of pricing your goods and services – you need to know what your costs are before you can calculate how to price your products to achieve a viable export business. Modelling, according to Darby (2000), is the reduction of a real-world phenomenon of interest into a construct or set of constructs called symbolic models, which captures specific system behaviours. When applied to building project cost models, the model emulates the cost structure system, budget allocation, cost consumption and cost performance review within a project. Hence, it can be concluded that construction cost models can either be predictive models or explanatory models.

Implication: Cost modelling essentially captures the cost structure of a project, and this helps users to organise, analyse and manage the cost consumption (Gosh, 2005). When the cost of internal walls in residential buildings is identified, it will be able to guide the client and help him to plan ahead.

Practice of method of measurement (mom)-based measurement by quantity surveyors

The Bill of Quantities (BOQ) is defined as a document prepared by Quantity Surveyors on behalf of the client in the pre-tender stage of a project, which is used for cost estimating and can be compared with other tender prices. BOQ is one of the crucial elements of construction contract documents because it addresses cost, time and quality, which are the three most essential aspects of any construction projects (Gunathilaka and Senevirathne, 2013). It can be the basis of the success of a project if it has a high accuracy and clear description of works, but at the same time the BOQ can however, lead to a lot of disputes in a project if it is not clear and misleading. Accordingly, the BOQ should be written in a standard format that follows a certain trend and this trend should be guided by what is called "Standard Method of Measurement" (MOM) (Watermeyer, 2008). Effective BOQ should no doubt improve the performance of construction cost.

One of the roles of Quantity Surveyors is doing the measurement. The purpose of measurement is to prepare BOQ. Generally, measurement is a process of transferring the architect drawing, engineer drawing, and specification into the figures or quantities for settlement the payments of the building and civil engineering work (Mayouf, Gerges and Cox, 2019). To get the quantities of the building work, there are two types of measurement one is traditional measurement which is manually measuring quantities of the building while another is using measurement software.

Quantities that are measured by Quantity Surveyors can be in number, length, area, volume, weight and item. All the quantities are measured based on the Building and Engineering Standard Methods of Measurement (BESMM4R) as a referred document that provides rules and guidelines of the measurement that needs to be followed by Quantity Surveyors when measuring the building or Engineering works. The description for the measurement of Masonry is located under part 2, 1.14 where walls are measured on the centre line girth irrespective of construction unless otherwise stated and the unit of measurement is m2 (square metre).

According to Ermiyas (2011), there are different classification of wall depending on the load bearing capability of the material, the

material type it used, joint and connection mechanism it had and manufacturing technique used. Among these the load bearing capabilities of a partition classify partition in-to two major categories.

1. Load bearing Partition Walls and
2. Non-Load bearing Partition Walls

Load bearing Partition Walls – are walls which carry roof and/or upper floor loads in addition to their own self weight and wall lining. Such group of partition wall, most of the time are made from concrete and fibre reinforced concrete and other material. These load bearing materials are expected to have strong stability, integrity and stiffness property and they can be hollow or solid block.

Non-Load bearing Partition Walls -are walls which impart self-weight only to supporting structure and some live loads which are temporary loads due to furniture. Most of the time these groups of partition are prepared in sheet form and they are light in weight and easy to handle. They are usually attached or connected to either timber stud load carrying structure (framework) or metal stud load carrying structure. The later has a better load carrying capability and used most of the time in countries like Japan where earthquake are frequent (Mitek, 2007). This light weight non-load bearing partition walls are made from materials like gypsum, Plywood and composite.

Implication: The principles of measurements using BESMM4R will be applied in the measurement of all the internal walls, taking cognisance of all the rules and guidelines.

Concept of validation of models

Validation represents the action to verify that any process, procedure, activity, material, system or equipment can achieve the desired results. (Pandita, Rana, Seth and Bala., 2012). Validity is defined as the ability of a method to measure what is intended to be measure. According to Pandita *et al.* (2012), validation involves the collection and evaluation of data, throughout process stages, which establishes scientific evidence that a process is capable of consistently delivering quality similar to the one with which the correlation study has been done. The use of validated methods is important for a researcher to demonstrate the qualification and competence of a new product. Its principles can be synthesised in the following words: quality, safety and efficacy in the design and building of a product.

A Model should be developed for a specific purpose (or application) and its validity determined with respect to that purpose (Robert, 2011). If the purpose of a model is to answer a variety of questions, the validity of the model needs to be determined with respect to each question. A model may be valid for one set of experimental conditions and invalid in another. A model is considered valid for a set of experimental conditions if its accuracy is within its acceptable range, which is the amount of accuracy required for the model's intended purpose. This generally requires that the model's output variables of interest are identified and that their required amount of accuracy be specified prior to starting the development of the model or very early in the model development process.

Model validation is usually defined to mean "substantiation that a computerised model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model" (Schlesinger *et al.,* 1979 as cited by Robert, 2011). Model validation processes quantify the accuracy of the model by comparing simulation results to experimental or operational outcomes (Thacker *et.al.,* 2004; Balci, 1997; Riha, *et al.,* 2006). Model Verification and validation cannot guarantee that a model is 100% complete and correct for all possible applications. However, they provide evidence that a given model is

accurate (within an accuracy range) to represent and understand specific research problems.

There are different kinds of model verification and validation methods and each method has distinct characteristics which make them suitable for different real-world simulation purposes and validation criteria. According to Chenggang and Alison (2018), the following are different kinds of model verification and validation methods.

Animation Validation: Simulation model operational behaviour of each element is graphically displayed as the model runs over time.

Model to Model Validation: Outcomes of a simulation model being validated are compared with outcomes from another valid model, related to the same simulation problems.

Event Validation: Event occurrences in the simulation model are compared to those of the real-world system to determine how similar they are.

Extreme Condition Validation: The simulation model architecture and outputs are tested using extreme and unlikely combinations in the real-world.

Face Validation: Asking knowledgeable professionals about the system and whether the simulation model and its behaviours are reasonable.

Historical Data Validation: If historical data exists, some of the data is used to build the simulation model and the remaining data is used to determine whether the model performs as the system does.

Operational Graphics Validation: Observing entities 'operational curves in simulation outputs, to determine whether the model performance is reasonable with respect to the real-world scenario.

Sensitivity Analysis Validation: This method consists of changing the values of the input data and parameters of a simulation model to determine the effect upon the performance of the model and its output. The same relationship should occur in the simulation model as in the real-world system.

Predictive Validation: The simulation model is used to predict the system performance, and comparisons are made between the performance produced from the system and the forecast from the model, in order to determine if they are the same or similar enough.

Traces Validation: The behaviours of different types of specific entities in the simulation model are traced through the simulation model operation to determine whether the model's logic is correct and the necessary accuracy is obtained.

Turing Test Validation: Individuals who are knowledgeable about the real-world operational system are asked whether they can discriminate between outputs from the real-world system and the simulation model.

Implication: The principle of validating models will be applied to validate the regression model for quantifying wall quantities in residential buildings. With respect to this work, traces validation is adopted. This is because it will help to determine whether the model's logic is correct and the necessary accuracy using the behaviours of different types of specific entities in the simulation model.

Research Design

Research design, which is synonmous to research strategy (Groat and Wang, 2013) is an action plan for questioning the research objectives in order to generate knowledge from the research. In other words, it is the vehicle that moves the investigator from his research questions to results or knowledge derived from the research. Research strategy

can be categorised into quantitative and qualitiative. However, a third alternative to quantitative and qualitative research design called mixed method design is also talked about in the research methodology literature (Ostlund, Kidd, Wengstrom, and Rowa-Dewar, 2011; Regnault,Willgoss and Barbic, 2018). These discrete research designs are not as discrete as the typology implies. , Cresswell (2009) sugests that rather than reperenting discrete, clearly delinated types, they are better seen as existing on a continuum with qualitiative and quantitative designs on the ends of the continuum while mixed method design occupies the middle ground.

Cresswell (2009) offers descriptions of the three research design approaches. He defines quantititative research design as an inquiry into a social or human problem, where a focal hypothesis or theory composed of variables are tested using measurement-generated data and statistical tools for analysis with the goal of determining whether the hypothesis or the theory hold true. On the other hand , qualitiative research deigns seeks to understand and explore the meanings that individuals or groups attribute to a social or human problem using emerging questions and procedures targeted at participants in their natural settings culminating in "data analysis inductively building from particulars to general themes" thereby allowing the researcher to interpret the meaning of the accumulated thematic data (Cresswell, 2009). Mixed method research design involves the simultaneous, combinatorial and complementary use of qualitative and quantitative design approaches to investigate a social or human problem.

Of the three research design approaches, the most suitable for questioning the objectives of this study is the quantitative research design. The target population for this study is the population of residential floors internal wall quantities and their associated opening quantities. A sample from this population is accessed via a sampling frame made up of a list of 30 residential floor plans sourced from a number of architects and engineers practicing within Anambra State. Given the sourcing of the blueprints from a sample of accessible professionals, one is constrained to argue that the sampling technique is convenience sampling. However, one can argue that the wall quantitates and associated openings from the 30 residential floor plans are representative of the population of all wall quantities and openings for residential floors in duplexes and block of flats as long as the following condition hold: (i) floor-to-ceiling heights of the floor range from 3.00 metres to 3.30metres.

Table 1: Data derived from the measurement-based analysis (using BESMM4R0 and regression-based quantification of the residential floor blueprints

Project ID	BESMM4R-based Quantity(m2)	Model-generated Quantity(m2)
1	179	174
2	174	174
3	137	125
4	119	121
5	258	264
6	247	256
7	201	200
8	142	139
9	227	235
10	190	188
11	117	117
12	104	98
13	182	175
14	321	336
15	168	290
16	109	105
17	203	164
18	110	108
19	119	114
20	143	146
21	178	153
22	148	139
23	73	74
24	136	124
25	112	110
26	102	101
27	87	97
28	234	201
29	166	181

30	145	115

The data for the study, in the second column of Table 1, was collected via measurement-based analysis of the 30 architectural floor blueprints following the quantification rules embodied by BESMM4R. The measurement was carried out by one of the authors who is a proficient entry-level quantity surveyor. The measurements were then checked by another of the authors who is a registered quantity surveyor. The errors were pointed out and corrected.

Results and Discussion

Table 2: Descriptive Statistics of internal walls quantity gotten from the two measurement approaches.

Method	N	Mean	Std. Deviation	Minimum	Maximum
BESMM4R-BASED QUANTITY	30	161.0460	56.61613	73.38	321.00
MODEL-BASED GENERATED QUANTITY	30	160.8500	63.45255	74.49	335.77
Total	**60**	**160.9480**	**59.61989**	**73.38**	**335.77**

Table 3: ANOVA Test of significant difference

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.576	1	.576	.000	.990
Within Groups	209716.776	58	3615.806		
Total	**209717.352**	**59**			

From Table 3, the ANOVA test shows that the difference between the mean of internal wall quantity gotten using BESMM4 approach and the ones gotten using the regression model approach is not significant with F= 0.000 and significant value = 0.990 at $\alpha = 0.05$. We therefore accept the null hypothesis and conclude that there is no significant difference between the BESMMR4-based quantities and the model-based quantities.

The non-validation of the model: Block wall quantity = -7.643+0.890(Internal Girth * Height**)** by Ibidokun (2018) has restricted its applicability and usage since its development in 2018. This restriction has however been removed by the current research. Our findings show that there is no significant difference between the quantities of block wall generated by the model and those generated using the traditional quantity take-off process. A closer look at the paired sample dataset in Table 1 shows that the model-generated quantities are higher than the traditional quantities in 10 cases of the 30 paired sample cases. The traditional quantities are higher than the model-generated quantities in 18 of the 30 cases. In two cases, the quantities are the same. The difference between the traditional quantities and the model-generated quantities expressed as a percentage of the traditional quantities is less than 10 percent in 24 of the 30 paired cases, ranging from -9.04% to + 8.82.%. The other six cases look like outliers with difference between the quantities expressed as a percentage of the traditional quantities ranging from -72.62% to +20.69%. The negative sign is associated with the 10 cases when the model-generated quantities are higher than the traditional quantities. All in all, on the average the results show that in

most cases, that the model-generated quantities are within +/- 5% of the traditional quantities. Specifically, this is the situation in 20 of the 30 paired cases. But how do these findings compare with similar published findings in scholarly journals?

To answer this question, we searched for scholarly articles on the subject using the population search engine Google. The search results show that very few articles have been published on the subject matter. The closest we found was a COBRA conference paper by Odeyinka *et al.* (2009). While the conference paper was not directly on wall quantification, it provides some information for discussing the findings of this novel paper. Odeyinka *et al.* (2009) examined the reliability of bills of quantities in building procurement and discovered that the percentage difference between quantities in bills and actual construction quantities vary depending on project types. The least deviation was found on housing projects where the deviation varies from -3% to 4%. The deviation on refurbishment projects vary from -11% and 37%. Our discovery that the model-generated quantities are within +/- 5% of the traditional quantities in 20 of the 30 cases is comparable to Odeyinka and Kelly's observable deviation of -3% to 4% on housing projects. But what are the implications of these findings for measurement practices among quantity surveyors? The concluding session of this paper addresses this.

Conclusion

Using a new dataset – 30 paired samples of model-generated quantities and traditionally measured quantities, completely different from the dataset from which Ibidokun (2018) developed the model : **Block wall quantity = -7.643+0.890(Internal Girth * Height);** this paper has shown that there is no statistically significant difference between the quantities of internal block wall generated using the traditional quantity surveyor's approach based on the Building and Engineering Standard Method of Measurement (BESMM4R). The implication of this study for quantity surveying practice is that the validated model is a superior time-saving alternative to the existing traditional quantity take-off approach. The time-saving capability of the model emanates from its elimination of the time-consuming deduction of openings associated with traditional wall quantification. We strongly recommend the use of the model by Quantity Surveyors and estimators.

A limitation of the model that should be born in mind by users is the small sample size of 30 paired dataset of residential floors where the floor-to-ceiling heights ranges from 3.00m to 3.30m. Our findings therefore might not be applicable to institutional buildings or even residential floors of higher floor-to-ceiling heights. Other researchers might want to test this out in such empirical data setting. The findings might also not be applicable to walls where the bonding is different from stretcher bond. The block wall in our samples are built with stretcher bonds.

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