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Comparison of the Wastage of Selected Materials on Building Sites with Estimators' Allowances

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ABSTRACT: Evaluation of sites' material wastages is crucial for its minimization. It has been opined that estimators' allowances for materials on construction sites are inadequate. This study therefore compares sites' waste quantity of selected materials with the estimators' allowances. The selected materials are concrete, blocks, tiles, aluminium profiles and glass. The objectives are to evaluate the waste quantity of selected materials on sites, to establish their estimators' allowances and develop models that can be used to predict the waste quantity of the selected materials on projects. The study area was Lagos state, Nigeria. Site measurement was used to evaluate the site waste generation of the selected materials, while the estimators were asked for their allowances. The projects used for the study were identified by purposive sampling technique. A total of 97 projects under construction were used for the study. Data were analyzed using mean, frequency, percentage, t-test and factor analysis, while regression analysis was used for the development of models. The study reveals that estimators allowance for material waste ranges between 8.36% and 10.06% contrary to the current opinion of 5% and glass showed the greatest level of underestimation by estimators. It is concluded that glass has the highest wastage quantity on building sites while the least is aluminium profiles. It is recommended that the site waste quantity determined in this study should be used as benchmarks for the materials. The waste models should also be used to predict waste quantity of the materials on projects, so as to make adequate provision for them before construction commences.

Keywords: Allowances, estimators, models, sites, waste quantity.

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INTRODUCTION

The knowledge of the quantity of material waste that is generated on building sites is pertinent for diverse reasons. First, it serves as a driver for its minimization. Baytan (2007) posit that waste measurement is a precursor to waste minimization. Secondly, it could stimulate attitudinal change toward generating waste. Teo and Loosemore (2001) observed that material wastage is attitudinal and the knowledge of the quantity could foster its minimization. Inspite of these good reasons, evaluation of material waste quantity is a rarity on Nigerian sites. This culminates to high waste generation and minimizing it is an uphill task, which is not an option in most cases. Additionally, knowing site waste quantity could be the basis for comparing it with the estimators' allowances. Estimators allow a certain percentage for waste of materials on projects prior to commencement of the site construction. The general opinion is that 5% waste allowance is made for materials in Nigerian projects. On the other hand, it is opined that estimators cannot allow the same percentage for all materials and in different project types. It is therefore necessary to find out actual estimators' allowances and determine site quantity so that

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comparison can also be made between the two. Due to the complexity of construction materials, it is difficult to evaluate the waste quantity of all materials. Thus, this study selects five most-used construction materials, namely: concrete, block, tile, aluminum profile and glass, to compare between estimators' allowance for waste and site quantity. This study also seeks to develop models to predict the waste quantity of the selected materials on construction projects. The significance of this study lies in the prediction of site material waste quantity, so as to minimize it.

Hypothesis of the Study

Comparison of site waste quantity and estimators' allowances can not be adequately investigated descriptively by comparing their mean scores alone. Thus, to further establish the relationship between the two variables, a null hypothesis (H_0) is postulated for this study, which states that: *there is no significant difference between actual material waste generated on building sites and estimators' allowances*.

LITERATURE REVIEW

Evaluation of Construction Material Waste on Sites

Earlier researches have attempted to assess the wastage of construction materials in many nations. Swinburne, Udeaja and Tait (2010) conducted a study on a local authority highway projects in the United Kingdom. The study measured on-site wastages of sand, cement, concrete with tarmac and compared them against the 5% material wastage allowance included within the tendering and estimating process. Actual material quantities (i.e. actual material usage) were retrieved weekly from the site managers' diaries. "Microrate" software was employed to get the theoretical material quantities (i.e. theoretical material usage). The software permits input of quantities of construction items culled from the final valuation of the project. It then breaks these items into detailed quantities of different construction materials theoretically used on site (i.e. theoretical material usage). The actual material usage and theoretical material usage were compared to establish the amount of wastages occurring. The study reveals that there are significant differences between the theoretical and actual quantities of sand, cement, concrete and tarmac used within the 20 projects used. The quantities used on sites for sand, cement, and tarmac differ greatly from the theoretical quantities while the two quantities are close for concrete. Concrete had an average wastage of +10.9%, cement had +79.7%, tarmac had + 2.2% while only sand had -5.7% (positive % shows actual materials usage > theoretical usage, while negative % is the reverse case). The negative wastages of sand were attributed to misrecording and possible wrong mixing ratio.

Souza and Andrade (1999) also conducted a study on three 15-floor towers and four 17-floor towers in Brazil. Block waste evaluation was done by sampling approach. The approach involves setting aside specific number of blocks marked in the stock pile (A) .After a week, the amount of blocks used (B) in the wall were counted and the remaining blocks in the stock pile (C) were also counted and recorded.

Waste is calculated as Material Loss in

$$\text{Percentage (MLP)} = \frac{A - (B + C) \times 100}{A}$$

The sites presented MLP values of blocks ranging from 3% to 48%. However, the study achieved a considerable reduction in material waste in blocks on a site using a strategy called "setting target to reach a MLP smaller than 3% and continuous evaluation".

In addition, Urio and Brent (2006) conducted a study on 12 building sites in Botswana, which included assessing wastage from sand, cement, concrete stone, concrete, steel, timber and general debris. The data were gathered by observations at building sites, site measurements, contractors' records of delivery, contract and other project documentation, specifications and bills of quantities and interviews. The study shows that sand has the highest waste average of 13%, this is followed in descending order by stone and mortar in plasterwork (11% each), cement (10.3%), common bricks (7.4%), mortar in brickworks (7.2%), facebricks (6.9%) and concrete (5.7%).

Similarly, Shen, Tam, Tam and Ho (2000) investigated seven types of projects in China by interviewing contractors to gather information on wastage of concrete, reinforcement, formwork and brick/block. It reveals that the percentage wastage of these materials vary with the projects' types. All the project types investigated show unavoidable or natural waste and necessitate setting minimum wastage levels for all materials and projects. Formwork has the highest average wastage of 11.11% from monastery's project while concrete is least with 2% from industrial projects. Reduction of wastage of materials (i.e. potential wastage) is calculated as |Max. – Min| wastage. However, Poon *et al.* (2001) cited in Shen, Tam, Tam and Ho (2000) show that the wastage in formwork for private housing projects (15%) is much higher than that for public projects (5%). The difference between the two studies could be attributed to the methodologies used and the type of projects.

Moreover, NAHB Research Centre (1995) conducted material waste assessment for new, single family residential projects using the following methods:

- Obtain a securable and watertight roll-off container.
- Careful selection of container's location.
- Establishment of a good working relationship with site manager.
- Monitoring the job site at least twice weekly.
- Conducting the waste assessment.

Conducting a singular waste assessment after construction is complete are more cost effective than multiple in-progress assessments due to the time required to arrange and coordinate all of the involved parties. Furthermore, assessments done before construction is complete may result in workers being more conscious of their waste generation, and modifying their normal construction technique. This involves five steps, namely: site selection - the assessment is best performed indoors or under roof to ensure that materials remain dry before being weighed; site logistics - the proximity of the sorting area to the scale and the ultimate disposal site largely determine the time required to weigh the individual materials; measurements - scales were used to measure the waste; and records - the wastes were recorded in a standardized format, with mass and volume measurement checks by comparing summed individual totals with the overall totals.

Similarly, Baytan (2007) determines the wastages of ready-mix concrete, rebar, brick and floor block using a material data. It measures the wastage by taking into account the material quantities in the bill of quantities (b), progress payment report (c) and invoices (d).

$$\text{Waste percentage value} = \frac{d-c}{c} \times 100$$

$$\text{Similarly, Waste/m}^2 = \frac{d-c}{a} \times 100$$

Where a = construction floor area; c = material quantity in progress payment; d = material quantity in invoices.

The highest average waste percentage was recorded in floor block (14.6080%) while the least was recorded in ready-mixed concrete (6.1229%). However, the total average waste percentage for the four materials was 9.8568%.

In the same vein, Bossink, Brouwers and Kessel (1996) sorted and weighed the material wastage at five building sites in Netherlands, which resulted to various waste fractions. The fractions were used to calculate the cost of construction waste per house, which include purchase losses, collection costs, transportation costs, recycling costs and dumping costs. The study revealed that the largest origin of waste was the use of stone tablets (29%).This is followed in descending order by piles (17%), concrete (13%), sand-lime elements (11%), roof tiles (10%), mortar (8%), packaging materials (7%), sand-lime bricks (3%) and small fractions of metal and wood (2%). The outcome of waste evaluation of some materials differs from the various studies reviewed. This is largely due to difference in the type of projects, method of construction, site documentations, countries and methods of measurement. For instance, Poon, Yu and Jaillon (2004a) reveals different percentage wastage of the same set of material on public housing and private residential buildings in Hong Kong. Similarly, Guthrie, Woolveridge and Patel (1999) cited in Poon *et.al.* (2004a) reveals different estimated wastage in UK and Hong Kong for the same set of material. In the same vein, the result of Swiburne *et.al.* (2010) shows improper recording and documentation by the site personnel that was used for the study. It resulted to negative value in the wastage of sand. In all, the methodology of Souza and Andrade (1999) is the most appropriate for material waste evaluation for the Nigerian situation. It involves physical counting or measurement of material or work done before and after an operation. Hence, the methodology of Souza and Andrade (1999) with some sort of modification was used for the evaluation of wastage of the selected materials in this present study.

RESEARCH METHOD

This study is a survey research, which involved the usage of a cross sectional survey design with use of site measurement and questionnaire. The study area was Lagos State, Nigeria. The population of this study is projects under construction with their site managers and estimators. The projects used for the study were identified by purposive sampling technique. This is because there is no list of ongoing projects in Lagos State, so an initial scouting was done to identify ongoing building projects that were at the stage of operations that involved the materials investigated. A total of 97 projects under construction were identified from the initial scouting and used to determine the site wastage and estimators' allowance of five selected materials - 29 sites for block, 32 sites for concrete, 36 sites for glass, 23 sites for aluminium profiles and 12 sites for tile. More than one of the five materials was measured in some of the sites, depending on the stage of work and activities on the sites. Site measurement was used to evaluate the site waste generation of the selected materials, while the estimators were asked for their allowances. The procedures for measurement of the various materials on sites are highlighted as follows:

i. Finding out when the operations that require the materials to be measured will be carried out.

ii. Obtaining the total material quantity (A) used for an operation. This quantity was obtained by deducting the left over quantity at the end of an operation from the initial material quantity at the onset. Blocks were counted in numbers, aluminium profiles were measured in meters (m), tiles and glasses were measured in m^2 and concrete in m^3. The total quantity of concrete (A_c) produced on sites with small mixers was determined from the number of bags of cement used in three steps. First, the number of bags of cement (a) in $1m^3$ concrete for different mixes was determined using a 'concrete estimating package'. Secondly, the total number of cement bags (b) and the mix used for concrete operation on sites were obtained by observation. Thirdly, A_c is determined as $A_c = \frac{b}{a}$.

iii. Measurement of the area or volume of the job where the materials were used to get the actual material quantity (B) used. Blocks were counted in numbers, aluminium profiles were measured in meters (m), tiles and glasses were measured in m^2 and concrete in m^3

iv. Calculation of the percentage wastage as (A-B) over A multiplied by 100.

Material waste measurement tools were used for the site measurement. Additionally, a questionnaire was designed for the site managers of the projects to elicit their opinion on the occurrence and impact of some 55 causes to the generation of the wastage of these materials. The occurrence of these causes on the building projects were measured on a 5-point Likert scale. In the scale, 1 implied no occurrence, 2 implied low occurrence, 3 implied average occurrence, 4 implied high occurrence and 5 implied very high occurrence. The impacts were also measured on a 5-point Likert scale. In the scale 1 implied nil, 2 implied very low, 3 implied low, 4 implied average, 5 implied high and 6 implied very high. The severity (S) of the causes was calculated as the product of the mean of occurrence and contribution. S is indexed as: "no severity" from 0.00 – 3.99; "low severity" from 4.00 – 8.99; "medium severity" from 9.00 – 25.00; "high severity" from above 25.00. Data were analyzed using mean, frequency, percentage and t-test. Rankings were done based on mean of severity of variables. Factor analysis was used for data reduction and classification, while regression analysis was used for the development of models.

FINDINGS AND DISCUSSIONS

Evaluation of material wastage on site and comparison with the estimators' allowances

Table 1 shows the descriptive statistics of percentage mean of waste generation for block, tile, aluminium profile, concrete and glass on sites in comparison with the estimators' allowances. It reveals that the highest average percentage wastage on sites for these materials occur in glass with 17.77%. This is followed by tile with 14.8%, block with 12.45%, concrete 8.03% and aluminium profiles 2.95%. It should also be noted that estimators' average allowances for wastage for these materials range from 7.34% to 10.06%. The estimators' allowances are exceeded in tile, block and glass; but are not exceeded in concrete and aluminium profiles.

The test of significance between average sites' waste generation and estimators' allowances for block, tile, concrete, aluminum profile and glass in Nigerian building projects was carried out at 5% level of significance using t test and the results are presented in Table 2. It reveals that there is no significant difference between average sites' waste generation and estimators' allowances in tile, block and concrete; hence the null hypothesis (H_0) is supported for these three materials. However, significant differences exist in aluminium profile and glass, the null hypothesis (H_0) is rejected for these other two materials.

This study confirms the subjective opinion of previous works that material waste in Nigeria is above 5% (Obiegbu, 2002 cited in Adewuyi & Otali, 2013; Olomolaiye, 1995; Odusami, Oladiran and Ibrahim, 2012). One of the implications of this is high cost of construction (Adewuyi and Otali, 2013). Tam, Shen and Tam (2007) discover

Table 1: Comparison of site waste generation and estimators' allowance

Materials	Waste generated on site (mean)	Estimators' allowances (mean)
Block	12.45%	9.84%
Concrete	8.03%	10.06%
Tiles	14.80%	8.39%
Glass	17.77%	8.36%
Aluminium profiles	2.95%	7.34%

Table 2: t-test result of differences between sites' waste generation and estimators' allowances

Pairs Site- Estimators	t-values	df	p-values	Decisions
Tile	1.533	11	0.154	Accept H_0
Block	0.763	28	0.452	Accept H_0
Concrete	0.063	31	0.950	Accept H_0
Glass	3.973	34	0.000	Reject H_0
Aluminium profile	-3.041	22	0.006	Reject H_0

df = degree of freedom

wastage level of 4.48% to 8.99% for concrete, 5.87% to 8.90% for block and 6.62% to 15.58% for tile in Hong Kong, depending on the sub-contracting arrangement. However, Poon, Yu, Wong and Cheung (2004b) discover that material wastage in private residential and public housing are not the same in China, but less than what is recorded for the materials evaluated in this study. Poon *et. al.* (2004b) reveals a lot of variance from the percentage wastage in Nigeria as revealed in this study. For example, concrete is 3 to 5% while it is 8.03% in Nigeria, brick and blocks is 4 to 8% against 12.45% in Nigeria and tiles is 4 to 10% against 14.8% in Nigeria. Similarly, Al-Moghany (2006) assessed mean weight of concrete and block in Gaza Strip to be 5.4 each while tile is 4.4. Again, Poon *et. al.* (2004b) recorded 3% to 5% ready-mixed concrete in 22 sites in Hong Kong where 80% of the concrete are ready-mixed. Concrete waste results from poor formwork, wrong handling and over-ordering or over-production due to improper planning and poor communication (Masudi, Hassan, Mahmood, Mokhtar & Sulaiman, 2011). Block waste occurs from leftover, cutting and bad storage. Tile waste occurs due to poor handling and unstandardized sizes. Lau, Whyte and Law (2008) also discover that the major components of construction waste generated on site are concrete and block. The wastage level of concrete, block and tile in Malaysia are 0% to 10.2%, 3.45% to 5.23% and 3.2% to 8.00% respectively, depending on the type of projects and method of construction (Masudi *et. al.*, 2011). In the same vein, Bossink and Brouwers (1996) reveal overall average waste of 9% in the Netherlands; and 5% to 27% in Ghana by Agyekum (2012) as against 2.95% to 17.77% in this study. Agyekum (2012) opine that concrete and block waste are among the four key materials that are wasted most on sites. Additionally, Bossink and Brouwers (1996) reveal that the material that record highest level of waste is stone tablets (29%). This is followed in descending order by piles (17%), concrete (13%), sand-lime elements (11%), roof tiles (10%), mortar (8%), packing (7%), sand-lime bricks (3%) and remainder (mainly small fractions of metal and wood). It is also stated that in the Brazilian construction industry, 20 to 30% of the purchased materials are not used and end up as waste. It can be observed that the wastage tendency of building materials depend on several factors, but largely on the methodology employed for its evaluation.

Prediction models for materials waste generation

The result of factor analysis of the 55 causes of materials waste presented in Table 3 shows the ten principal causes that are predictors of materials waste generation. The predictors are experience, delays, operations, client, design, planning, purchase/supply, errors, handling and damages.

Linear regression analysis was used to develop six models for predicting the wastages of five selected materials by the causes:

Table 3: Classification of causes of material waste in Nigeria

	Causes of Material Waste	Severity (S)	R	Rotated component matrix	Eigen Values
A	Experience	7.84	7		22.381
1	Inexperienced inspectors	7.54	44	0.868	
2	Lack of subcontractors skills	7.37	46	0.843	
3	Lack of supervision and skillful tradesmen	7.25	49	0.816	
4	Poor material management practices	7.48	45	0.793	
5	Misinterpretation of drawings	7.24	50	0.695	
6	Poor site storage	8.73	20	0.686	
7	Double handling	8.39	21	0.619	
8	Poor site layout and setting out	6.81	54	0.590	
9	Lack of possibilities to order small quantities.	7.96	30	0.510	
10	Over Designing	9.62	11	0.436	
B	Delays	7.50	10		4.405
1	Accidents	7.22	51	0.772	
2	Replacement occasioned by wrong materials	7.09	53	0.761	
3	Wrong ordering by Estimators.	7.28	48	0.740	
4	Delay in transportation and installation of equipment	7.85	35	0.696	
5	Lack of coordination	7.79	37	0.667	
6	Damage caused by subsequent trades.	7.89	34	0.608	
7	Wrong construction methodology	7.17	52	0.599	
8	Unnecessary people move	5.97	55	0.590	
9	Ordering that does not fulfill design	8.28	23	0.565	
10	Improper planning and organization.	7.57	42	0.507	
11	Equipment malfunction /shortage.	8.08	28	0.505	
12	Designers' Inexperience	7.58	41	0.435	
13	Late information	7.79	37	0.358	
C	Operation	7.83	8		3.226
1	Improper sites record	7.57	42	0.746	
2	Poor formwork	7.60	40	0.714	
3	Poor Workmanship	8.30	22	0.673	
4	Too much over time for labour	7.80	36	0.643	
5	Inappropriate /Misuse of materials	7.90	32	0.474	
D	Extraneous factors	9.59	3		2.064
1	Too much material inventories	8.18	25	0.730	
2	Undue interference with project's execution	9.91	9	0.710	
3	Undue pressure to deliver	10.38	4	0.686	
4	Materials and component complexity	10.58	3	0.541	
5	Delay decisions /changes	10.21	7	0.473	
6	Delay in approval of drawings	8.26	24	0.456	

Table 3 (Cont'd): Classification of causes of material waste in Nigeria

	Causes of Material Waste	Severity (S)	R	Rotated component matrix	Eigen Values
E	Error	9.52	4		1.767
1	Design Coordination	9.22	15	0.764	
2	Unfamiliarity with alternative Products	8.17	26	0.586	
3	Expectations of too high standard	10.32	5	0.565	
4	Lack of Contractors' influence	9.24	14	0.545	
5	Ineffective Communication	8.97	17	0.537	
6	Lack of collaboration	11.37	2	0.518	
7	Specifying materials' without considering standard sizes.	9.32	13	0.487	
F	Planning	8.02	6		1.590
1	Poor site documentation	7.92	31	0.617	
2	Incorrect /Inconclusive standard specification	8.16	27	0.557	
3	Uncompleted Design	8.08	28	0.546	
4	Imperfect planning of construction	7.90	32	0.534	
G	Purchase/Supply	9.66	2		1.434
1	Throwaway packaging	9.88	10	0.730	
2	Unpacked supply i.e. loose materials	10.14	8	0.682	
3	Delay in materials supply	8.96	18	0.619	
H	Rework	11.63	1		1.332
1	Lack of or error in information on types and sizes of materials	10.22	6	0.781	
2	Design changes and revisions	13.03	1	0.612	
I	Handling	7.52	9		1.099
1	Unfriendly attitudes from personnel	7.31	47	0.652	
2	Wrong equipment for materials' movement.	7.72	39	0.540	
J	Damages	9.18	5		1.023
1	Inclement weather	9.60	12	0.491	
3	Damage during transportation	8.94	19	0.403	
2	Workers mistake	9.01	16	0.308	

Concrete Waste

The multiple regression equation for concrete waste is presented as:

Concrete Waste = 21.184 – 0.156Ex – 0.169Dl – 0.084Op – 0.118C – 0.125Ds – 0.114P – 0.104Ps – 0.073Er – 0.066H – 0.017Dm.

The model summary shows that R = 0.535, R^2 = 0.287, Adjusted R^2 = -0.053 and Standard error of the estimate = 8.2334

Where: Ex = Experience; Dl = Delays; Op = Operation; C= Client; Ds = Design; P = Planning; Ps = Purchase/Supply; Er = Errors; H =Handling; and Dm = Damages.

The regression analysis shows that the ten predictor variables explain 28.7% of the variance in the model.

Block Waste

The multiple regression equation for block waste is presented as:

Block Waste = 18.659 – 0.191Ex – 0.170Dl – 0.147Op – 0.077C – 0.072Ds – 0.071P – 0.082Ps – 0.050Er – 0.048H – 0.030Dm..

The model summary shows that R = 0.482, R^2 = 0.233, Adjusted R^2 = -0.194 and Standard error of the estimate = 7.99012

Where: Ex = Experience; Dl = Delays; Op = Operation; C= Client; Ds = Design; P = Planning; Ps = Purchase/Supply; Er = Errors; H =Handling; and Dm = Damages.

The regression analysis shows that the ten predictor variables explain 23.3% of the variance in the model.

Tiles Waste

The multiple regression equation for tiles waste is presented as:

Tiles Waste = 46.114 + 0.500Ex + 0.881Dl + 0.707Op + 0.099C – 0.062Ds + 0.103P + 0.360Ps + 0.033Er + 0.167H + 0.162Dm.

The model summary shows that R = 0.999, R^2 = 0.998, Adjusted R^2 = 0.979 and Standard error of the estimate = 2.33570.

Where: Ex = Experience; Dl = Delays; Op = Operation; C= Client; Ds = Design; P = Planning; Ps = Purchase/Supply; Er = Errors; H =Handling; and Dm = Damages.

The regression analysis shows that the ten predictor variables explain 99.8% of the variance in the model.

Aluminium Profile Waste

The multiple regression equation for aluminium profile waste is presented as:

Aluminium Profile Waste = 7.655 – 0.084Ex – 0.059Dl – 0.041Op – 0.063C – 0.051Ds – 0.035P – 0.048Ps – 0.036Er – 0.038H – 0.005Dm.

The model summary shows that R = 0.413, R^2 = 0.171, Adjusted R^2 = -0.520 and Standard error of the estimate = 6.36394.

Where: Ex = Experience; Dl = Delays; Op = Operation; C= Client; Ds = Design; P = Planning; Ps = Purchase/Supply; Er = Errors; H =Handling; and Dm = Damages.

The regression analysis shows that the ten predictor variables explain 17.1% of the variance in the model.

Glass Waste

The multiple regression equation for glass waste is presented as:

Glass Waste = 41.269 – 0.394Ex – 0.340Dl – 0.291Op – 0.247C – 0.253Ds – 0.213P – 0.175Ps – 0.195Er – 0.162H – 0.037Dm.

The model summary shows that R = 0.539, R^2 = 0.291, Adjusted R^2 = 0.007 and Standard error of the estimate = 14.06512.

Where: Ex = Experience; Dl = Delays; Op = Operation; C= Client; Ds = Design; P = Planning; Ps = Purchase/Supply; Er = Errors; H =Handling; and Dm = Damages.

The regression analysis shows that the ten predictor variables explain 29.1% of the variance in the model.

Materials Waste

The multiple regression equation for the five materials waste (i.e. concrete, blocks, tiles aluminium profile and glass) is presented as:

Materials Waste = 4.686 – 0.218Ex + 0.211Dl + 0.008C – 0.016Dm.

The model summary shows that R = 1.000, R^2 = 1.000, Adjusted R^2 = 0 and Standard error of the estimate = 0.

Where: Ex = Experience; Dl = Delays; Op = Operation; C= Client; Ds = Design; P = Planning; Ps = Purchase/Supply; Er = Errors; H =Handling; and Dm = Damages.

The regression analysis shows that there are only four predictor variables and they explain 100% of the variance in the model.

CONCLUSION

The study posits that the quantity of materials waste generated on sites is unknown and there is also a need to establish estimators' allowance to examine the two for similarities and differences. The scenario in Nigerian projects is that estimators' allowances vary for different materials and it ranges between 7.34% to 10.06% for concrete, block, tile, aluminum profile and glass. The implication of this is that there is no standard allowance for waste and estimators' allowance is by the "rule of thumb". This could have adverse effect on the contractors' margin, because most of the time, the percentage allowed is not known by the contractors. Similarly, aluminum profile has the least quantity of 2.93% waste on site, while the highest is glass 17.77%. Consequently, estimators' allowances are exceed in some materials, that is, block, tile and glass, but are not exceeded in others, like concrete and aluminum profile. However, the developed models possess the ability to predict the waste quantity of the materials on project, so that adequate measure can be introduced to minimize them.

RECOMMENDATIONS

The study makes the following recommendations based on the findings:

1. The site waste quantity determined in this study should be used as benchmarks for the materials. This can be done by estimators consulting the findings of this study and other related empirical studies in the determination of waste allowances.
2. The waste models should be used to predict waste quantity of the materials on projects, so as to make adequate provision for them before construction commences. This can be done by mandating contractors at tendering to indicate possible wastage percentage of materials.
3. Estimators should have standard allowances for materials and make them known to contractors or be included in the national building codes. This can be achieved by including standard waste allowances in national code.

CONTRIBUTIONS TO KNOWLEDGE

The study makes the following contributions to the body of knowledge:

1. The study developed models that can be used to predict the waste quantity of selected materials in project delivery.
2. It established the percentage of waste in selected construction materials and showed that glass has the highest wastage quantity on building sites.
3. It established that estimators allowance for material waste ranges between 8.36% and 10.06% contrary to the current opinion of 5% and glass showed the greatest level of underestimation by estimators.

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