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# Material Waste Minimisation Strategies among Construction Firms in South-South, Nigeria

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## Abstract

Adopting the principles of minimising material waste on a project can demonstrate a firm's commitment to sustainable construction and environmental management. This study examined material waste minimisation strategies practiced by construction firms in the study area, the amount of waste generated and the relationship between them. The data collected were analysed using mean score, Spearman Rank Correlation, Kruskal-Wallis H and Mann-Whitney U tests. It is revealed that the most commonly employed strategies are "ensuring that storage facilities are properly secured before staff leave on a daily basis"; "checking of deliveries for any shortages and/or damages"; and "using materials before expiry date" with mean scores of 4.46, 4.22, 4.20 respectively. There is a significant variation in the level of use of the various strategies among the categories of firms. The amount of waste generated on site are above the estimators' allowance with the least being produced during the installation of asbestos roofing sheets (8.47%) while the highest was found in asphalt concrete (16.61%). A significant variation in the level of material waste generated by different category of firms was confirmed. There is also a significant relationship between the level of minimisation strategies adopted and the waste generated. Based on the $R^2$ values, 18.8% to 49.4% of the material waste generated for all the material types studied could be explained by the material minimisation strategies adopted on site except for stone base with 9.4%. The study recommends that the players in the industry should step up efforts towards training and retraining of personnel on material handling, storage and transportation; introducing incentives to motivate labour to minimise material wastage on site; training and retraining of supervisors on material waste minimisation strategies; and the use of modular design system.

***Keywords:*** *Large, medium and small construction firms; level of use; level of waste; waste minimisation strategies; material waste.*

## 1.0 Introduction

The construction industry in Nigeria, as in many parts of the world, is a vital contributor to National Gross Domestic Product (GDP) as well as a recognised employer of labour: skilled and unskilled [18]. Her contribution to the growth of the Gross Domestic Product (GDP) of Nigeria is steady and improving: from about 5% in 2001 to 13% in 2007 [2]. The construction industry has individuals, corporate bodies, and governmental agencies among its list of clientele. Construction activities, on other hand, utilises materials which contribute significantly to the cost of construction projects. Hence, material wastage has adverse effect on construction cost, contractor's profit margin, construction duration, and can be possible source of disputes among parties to a project [2]. More so, Adewuyi [3] revealed that there is a statistically significant relationship between the level (magnitude) of material waste generated on site and the cost overrun of a project. The cost of material waste generated on sites represents avoidable cost in construction which can either be eliminated or reduced [9].

Construction material waste minimisation, according to Adafin *et al*. [1], is of central importance to the economic health of the construction industry. Greenwood *et al*. [16] defines construction material waste minimisation as a reduction in the amount and environmental effect of material waste generated, by reducing the amount of materials consumed in a project. Poon *et al*. [26] viewed it as a strategy or technique to reduce waste at its source or allow re-use of the waste. On the other hand, Skoyles and Skoyles [28] adjudged material waste minimisation as an integrated process of designing, constructing new structures or re-modelling existing structures, using materials more efficiently with a great opportunity of contributing to construction industry's performance improvement as well as solving material waste management problems.

Therefore, the need for construction firms to explore control measures to minimise these wastages on sites cannot be overemphasised. One immediate and effective way of reducing material waste on site is to implement some minimisation strategies. But the types of minimisation strategies employed and their level of use may vary from one firm to the other, and based on the size of the firm. For instance, in large scale construction firms, the minimisation strategies used at a particular stage of construction and its level of use might differ from other categories of firm and also the level of waste generated may differ invariably.

There is the dearth of local studies available on the measures taken by construction practitioners, either in the study area or in the country, to curb the reported excessive generation of material waste. Furthermore, the few existing studies failed to show the level of material waste generation at firm's category level and the corresponding strategies employed. For example, Dania *et al*. [12]; Akanni [6]; Odusami *et al*. [21] as well as Adewuyi *et al*. [2] did not establish the level of waste on categorical basis of firm's size. Therefore, this research seeks to assess the various strategies adopted by different categories of construction firms, at the construction stage, to minimise material wastages with the following objectives in view:

i. evaluating and comparing the relative level of use of material waste minimisation strategies used by different categories of construction firms
ii. assessing and comparing the relative magnitude of material waste generated by different categories of construction firms
iii. establishing the relationship between the level of use of minimisation strategies and the level of material waste generation.

Three hypotheses, derived from each of the objectives, were posited for the study as stated below:

$H_1$: There is no significant variation in the level of use of waste minimisation strategies among the large, medium and small firms.

$H_2$: There is no significant variation in the level of material waste generated by different category of firms.

$H_3$: There is no significant relationship between material wastes generated and the level of use of waste minimisation strategies on firm's category basis.

## 2.0 Review of Relevant Literature

Adewuyi *et al.* [2] established that the actual material waste generated on site is significantly in excess of the allowable provided in estimate through an empirical study and as such suggested that there is either the need to adjust the allowable value to mitigate its effect on project cost or contractors should explore control measures to minimise waste. The practice of purchasing extra materials to make up for wastage during construction will lead to cost and time overruns, sub-standard works, disputes, and abandonment of projects [30, 1]. Shen and Tam [27] is of the opinion that since additional materials are usually purchased because of lack of consideration given to material waste reduction during planning and design stages, the competitive edge of contractors are usually affected, thus, making their survival more difficult in a competitive environment.

In a study conducted on Turkish construction sites, Polat and Ballard [25] emphasized that minimisation is the best and most effective method of reducing the generation of waste and eliminating many of the waste generation problems. Greenwood et al. [16] noted that the top priority in minimising waste is to avoid waste through designing out or reducing waste at the source and proposed three key project stages where waste minimisation initiative should be introduced; contractual, design and site execution stages. Agapiou *et al*. [4] recommended that waste minimisation should start at the design stage. Greenwood *et al*. [16] noted that waste minimisation is one way of improving the efficiency of the construction industry. Keys *et al*. [19] and Ekanayake and Ofori [13] agreed with Agapiou [4], that waste minimisation should start at the design stage. According to Ene (1997), construction firms must develop or adopt effective waste minimisation strategies in order to solve the problem of material wastage on construction projects.

Ayarkwa *et al*. [8] stated that for wastage to be reduced or eliminated, construction firms should introduce material waste minimisation strategies. Al-Hajj and Hamani [7] found that the main driver of material waste minimisation is the immediate financial benefits and ‘cleaner and safer site conditions’, not legislations or care for the environment, though the latter factors impact some influence. According to Oladiran [22], the dividends of materials waste minimisation in the firms that adopt the techniques are expressed in increased profits, reduced materials shortage, reduced delay on projects’ completion and final cost. Furthermore, a good practice of material waste minimisation, according to WRAP [36] produces a range of benefits which include reduced material and disposal costs, increased competitive differentiation, increased performance against corporate sustainability responsibility (CSR) objectives, lower Carbon IV oxide ($CO_2$) emissions, meeting planning requirements, complementing other aspects of sustainable design; and responding to and pre-empting public policy, in addition to improvements in materials resource efficiency. The drivers for waste minimisation were summarised into four main groups by Osmani, *et al*. [24] which include environmental, industry, economic issues and legislation while the key drivers from these groups were explained by Al-Hajj and Hamani [7] to consist of government policies and contractual terms; environmental standards and assessment tools; and financial benefits. In Spain, a national decree to regulate the production and management of construction and demolition (C&D) waste was promulgated in 2008 and a framework of the Sixth Environment Action Programme advocated for effective management of C&D in the European Union [28]. Waste management plan (WMP) is a standard requirement for most significant development in the majority of Australian local government areas [17]. Dainty and Broke [11] reported that there is an increase use of off-site prefabrication to control waste and damage on site in the UK. While most developed nations and some developing ones have imbibed some of these drivers, Nigerian construction industry is yet to neither adopt any nor come to terms on this issue [12].

The structure of a business firm, including construction industry, is a function of its performance and output. Therefore, the level of waste generated by a construction firm may be the reflection of its organisational structure, culture, practices, policies and size. Basically, industries could be classified on the basis of various parameters -- the scope of operation, ownership, management control and so on. Like other nations of the world, construction firms could be classified as small, medium and large [20]. In Nigeria, large firms are majorly dominated by the expatriates with very few indigenous that could be categorised as medium while most are categorised as small size firms. For example, Olaleye and Abdullahi [23] categorised the construction industry into three (3) layers: small, medium, and large construction firms based on the number of persons employed on a permanent basis but Odediran *et al*. [20] based their classification on the annual turnover, staff strength and equipment capacity. In the UK, construction industry employing 1-59 employees are categorised as small-scale construction firm [34]. This study adopts the categorisation style of Ujene *et al*. [32] regarding construction firms with 1-49, 50-249, and 250 and above permanent employees as small, medium and large construction organisation respectively.

## 3.0 Methodology

The study adopted a quantitative approach for data collection while the samples were stratified into three categories of small, medium and large construction contracting firms. Three States (Akwa Ibom, Cross River and Rivers) among the six States in the South-South geopolitical zone of Nigeria were randomly selected based partly on convenience and partly on the relative high volume of ongoing construction activities in these States. Random sampling approach was adopted for selecting the investigated firms. The inclusion of a construction firm among the ones selected for this study was based on probability sampling, using the stratified random sampling technique. This is because the study used a segment (South-South) of the country's construction firms' population on the one hand and the selected firms were stratified based on their size on the other hand. The sample size was determined based on 95 per cent confidence level for 5% margins of error.

The population of the study includes all small, medium, and large construction firms registered with the Ministries, Departments and Agencies (MDA) in the States covered by the study such as Ministries of Works and Housing and Urban Development (both Federal and States), and Niger Delta Development Commission (NDDC). It was observed that some firms registered with more than one MDA, therefore the list of registered firms obtained from the various MDAs used for the study were screened to ensure that no firm is repeated among the list of firms used for the study. The breakdown of the population size for each category is shown in Table 1.

Forty-eight material waste minimisation strategies identified from the available literature were adopted for the study. The respondents representing each firm namely: project manager, site manager or site engineer, estimators, and designers, were requested to rank the variables of the study in their order of usage.

**Table 1:** Population frame of the Study

| Study Area (States) | Category of Firm | | | |
|---|---|---|---|---|
| | Large | Medium | Small | Total |
| Akwa Ibom | 13 | 23 | 25 | 61 |
| Cross River | 20 | 20 | 28 | 68 |
| Rivers | 24 | 37 | 37 | 98 |
| Total | 57 | 80 | 90 | 227 |

The questionnaire was divided into two sections: A and B. Section A elicited information on the company's and respondent's characteristics while Section B collected data on the level of use of material waste minimisation strategies employed by the investigated firms and the level of waste generated by each firm's category as perceived the respondents of the study. The rating values of 5, 4, 3, 2, and 1 were assigned to the options always, often, sometimes, rarely, and never respectively to obtain the level of use of minimisation strategies, while the rating values of 1-6, 7-12, 13-18, 19-24, and 25-30 (in percentage), represented by 1-5 on a five point Likert scale, were used in obtaining the respondent's perception of the level of material waste generated in their firm. The choice of the percentage of material waste is based on the reports of findings of several studies from different countries [10, 35, 9, 2] that the level of waste for construction materials generally does not exceed thirty (30) percent.

The data analysis techniques used in this study include the Simple Percentages, Mean Score (MS), Spearman Rank Correlation, Kruskal-wallis H Test, and Mann-Whitney U test. The analysis of companies' and respondents' characteristics employed simple percentage method while the Mean Score (MS) method was used to analyse the level of use of material waste minimisation strategies within a particular category of firm. The MS of each variable of material waste minimisation strategies was evaluated by the expression in Equation 1.

$$MS = \frac{\sum_{j=1}^{5} W_i X_i}{\sum_{j=1}^{5} X_i}, \qquad (1 \leq MS \leq 5) \qquad \text{Equation 1}$$

where:

*Wi*, is the rating given to each factor by the respondents ranging from 1 to 5, with 1 representing 'never' and 5 representing 'always';
*Xi* is the level of scoring; and
*i* is the order number of respondents.

To estimate the level of material waste, the scale (Figure 1) adapted from [31] was used to obtain the MS which was then classified into percentage material waste generated by each category of firm as proposed in the methodology on reports of findings from previous studies. The five point rating scale for the levels material waste generated ranged from 1 to 5 representing 1% - 6% and 25% - 30% accordingly. The numbering values calculated by the above were then differently classified as can be seen in Figure 1, because a single point or number changing from 1-5 in questions does not symbolize each verbal scaling expression in the evaluation phase, since the results (MS) are obtained as decimal numbers instead of integers, a specific scale became necessary. Therefore the 5 scale expression was defined by the interval of 0.8 representing 6% of waste generation. This was then used to multiply the MS derived from the respondents' perceptions to determine the percentage of waste generated as expressed in Equation 2. The five-point scale was constructed with 1% and 30% at the extreme left and right respectively as illustrated in Figure 1.

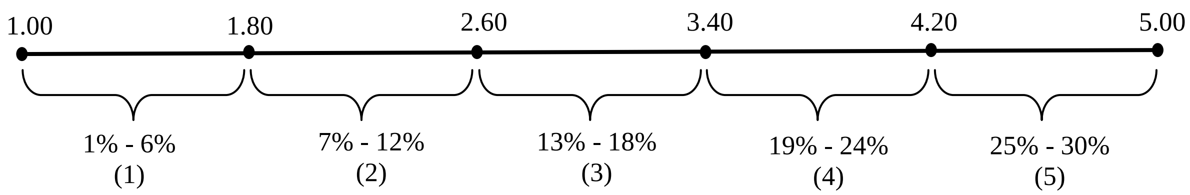


**Figure 1:** Evaluation scale for level of waste generation

MWG = MS * 6% Equation 2

where:

MWG = Material Waste Generated as calculated in Equation 1; and
MS = Mean Score.

Having established the level of material waste generated and the level of use of material waste minimisation strategies in each category of construction firm as perceived by the respondents of the study, there was the need to ascertain if their perceptions were statistically different. This led to the use of Kruskal-Wallis H Test. The decision to accept or reject a null hypothesis is based on the p-value and the significance (2-tailed). If the significance level or the probability value (p) is not less than or equal to 0.05, it implies there is no statistically significant difference in the result, thereby accepting the null hypothesis. Mann-Whitney U test was used for the post hoc test between different pairs of the three categories of firms surveyed.

Lastly, Spearman Rank Correlation was used to establish the relationship between the level of use of minimisation strategies and the level of material waste generated on site. On the one hand, the analysis was carried out on the basis of firm's category while it was based on the overall number of firms evaluated by this study on the other hand.

## 4.0 Results and Discussions

Out of 191 questionnaires distributed to the construction companies, 153 responses were received with 80.1% return rate in this study. The other 38 (19.9%) questionnaires were either not completed properly or not returned as shown in Table 2. Table 2 also shows the response rates among different categories of construction companies.

**Table 2:** Descriptive results of the response to questionnaires administered

| Categories of Companies | No of Questionnaires Distributed | Response Received | Response Rate (%) |
|---|---|---|---|
| Small | 76 | 71 | 93.4 |
| Medium | 65 | 49 | 75.4 |
| Large | 50 | 33 | 66.0 |
| Total | 191 | 153 | |
| | | | |
| Response rate | | | |
| Received | 191 | 153 | 80.1 |
| Not received | | 38 | 19.9 |
| Total | 191 | 191 | 100 |

## 4.1 Characteristics of the Respondents and Firms for the Study

The characteristics of the respondents and organisations that provided the data used for the study were analysed to ascertain the level of reliability of the information provided. The descriptive result of the analysis is presented in Table 3.

The analysis shows that out of 153 firms investigated 46.4%, 32.0% and 21.6% were small, medium and large firms respectively. The breakdown of the assessed firms revealed that about 88.9% have been in existence for over 5years. It implies that the sampled companies have been relatively stable in construction business. The stability of these firms may be as a result of the assertion made by Adewuyi *et al*. [2] that the numerous building construction works on-going for some years in the zone is attributed to a significant increase in revenue from the Federation Account allocated to these States sequel to the nation's wealth derived from the region. It is also indicative that the management of the evaluated firms must have put in place material management and waste minimisation measures to prevent losses and enhance profitability which keeps their business stable over the years. Moreover, about half of the firms (43.1%) had completed more than five large projects during the previous five years while 4.6% had completed more than ten projects within the same period. This gives an indication of high confidence in their responses.

**Table 3:** Characteristics of investigated Firms and Respondents

| Firms' Characteristics | | | | Respondents' Characteristics | | | |
|---|---|---|---|---|---|---|---|
| Characteristics | Frequency | Percent | Cumulative | Characteristics | Frequency | Percent | Cumulative |
| Size of firms | | | | Position of respondent | | | |
| Small | 71 | 46.4 | 46.4 | project manager | 70 | 45.8 | 45.8 |
| Medium | 49 | 32.0 | 78.4 | Estimator | 4 | 2.6 | 48.4 |
| Large | 33 | 21.6 | 100.0 | site engineer | 43 | 28.1 | 76.5 |
| Total | 153 | 100 | | site manager | 36 | 23.5 | 100.0 |
| | | | | Total | 153 | 100.0 | |
| Years of existence | | | | Years of experience | | | |
| 1-5 | 18 | 11.8 | 11.8 | 1-5 | 7 | 4.6 | 4.6 |
| 6-10 | 43 | 28.1 | 39.9 | 6-10 | 98 | 64.1 | 68.6 |
| 11-15 | 64 | 41.8 | 81.7 | 11-15 | 37 | 24.2 | 92.8 |
| 16-20 | 13 | 8.5 | 90.2 | 16-20 | 11 | 7.2 | 100.0 |
| 21-25 | 11 | 7.2 | 97.4 | Total | 153 | 100.0 | |
| above 25 | 4 | 2.6 | 100.0 | | | | |
| Total | 153 | 100.0 | | | | | |
| Location of Firm | | | | Professional Body's Affiliation | | | |
| Akwa Ibom | 37 | 24.2 | 24.2 | NIA | 60 | 39.2 | 39.2 |
| Cross River | 45 | 29.4 | 53.6 | NIOB | 5 | 3.3 | 42.5 |
| Rivers | 71 | 46.4 | 100.0 | NSE | 76 | 49.7 | 92.2 |
| Total | 153 | 100 | | NIQS | 12 | 7.9 | 100.0 |
| | | | | Total | 153 | 100.0 | |
| No. of projects executed in the last 5 years | | | | Membership status | | | |
| Less than 5 | 80 | 52.3 | 52.3 | Graduates | 89 | 58.2 | 58.2 |
| 6 to 10 | 66 | 43.1 | 95.4 | Corporate | 64 | 41.8 | 100 |
| Above 10 | 7 | 4.6 | 100.0 | Total | 153 | 100 | |
| Total | 153 | 100.0 | | | | | |

The distribution of the investigated firms shows that 24.2%, 29.4% and 46.4% are located in Akwa Ibom, Cross River and Rivers States respectively. The analysis presents the picture that the concentration of the assessed firms is in Rivers State signalling the influence of oil exploration companies and the subsequent domination of economic activities in the geo-political zone. Conversely, the least number among construction firms used for the study are located in Akwa Ibom State despite the high volume of construction activities executed in the State as reported by Umoh [33]. The possible explanation may be due to the policy of the administration in power during this research not to patronise indigenous firms for most of the works executed in the last six to eight years meaning that the voluminous construction works referred to by Umoh [33] were executed by few foreign large firms in the State.

The distribution of respondents' position as shown in Table 3 indicates that 45.6% of are project managers belonging to the decision-making (upper management) cadre in the contracting companies, 51.6% are either site engineer or site managers of various professional background representing resident professionals and are in the middle management cadre and also 2.6% being either Quantity surveyors or estimators on site. With all these respondents constituting upper and middle management indicates high interests in the study and high degree of reliability in their responses.

The distribution of respondents' professional affiliation is shown in Table 3 which illustrates that 39.2% are architects; 3.3% builders; 49.7% being structural, mechanical, electrical or any other services engineers and 7.9% being quantity surveyors or estimators. This indicates that respondents' are relevant in the construction industry and professionally qualified which enhances great confidence in their answers.

Table 3 shows the respondents' years of experience, with cumulative of 95.4% of them having more than five years of experience. Thus, the respondents possess considerable experience, and would understand materials waste issues and strategies of curbing waste as practiced by their organisation.

### 4.2 Level of use of material waste minimisation strategies

The assessment of the level of use of material waste minimisation strategies among each category of the construction firms evaluated is presented in Table 4 and ranked accordingly. The analyses show that twenty four among the forty eight waste minimisation strategies examined are rated $\geq 3.03$ which is the overall mean score and regarded as the significant score. The result indicates that, the first five highest ranked strategies among the large firms are "assigning competent contractor's technical staff to construction projects"; "ensuring that storage facilities are properly secured before staff leave on a daily basis"; "preparation of weekly programme of work"; "checking of deliveries for any shortages and/or damages"; and "careful handling of tools and equipment on site" with mean ranks of 4.79, 4.61, 4.52, 4.45, and 4.39 respectively. The values of the mean scores of these variables suggest that they are either always or frequently being used by large firms to reduce the level of material wastage on site.

**Table 4:** Level of use of Material Waste Minimisation Strategies (MWMS)

| Material Waste Minimisation Strategies (MWMS) | Large firms | | Medium firms | | Small firms | | All Firms | |
|---|---|---|---|---|---|---|---|---|
| | MS | R | MS | R | MS | R | MS | R |
| Avoidance of late design variation | 3.48 | 29 | 3.16 | 29 | 2.44 | 28 | 2.90 | 28 |
| Specification of standard sizes and dimensions | 2.91 | 36 | 2.57 | 36 | 2.08 | 33 | 2.42 | 36 |
| Simplification of detailing and dimensioning of material and component | 3.24 | 34 | 2.86 | 34 | 2.37 | 29 | 2.71 | 32 |
| Minimising design changes during construction | 2.82 | 39 | 2.02 | 41 | 1.65 | 45 | 2.02 | 40 |
| Accurate and good specification of materials | 2.88 | 38 | 2.55 | 37 | 2.03 | 34 | 2.38 | 37 |
| Use of modular design system | 2.09 | 45 | 2.02 | 41 | 1.59 | 46 | 1.84 | 44 |
| Use of experienced and sound design team | 3.70 | 24 | 2.59 | 35 | 1.92 | 37 | 2.52 | 35 |
| Reviewing of design by a person or group not involve with the original design before execution | 2.33 | 42 | 2.45 | 38 | 1.24 | 48 | 1.86 | 43 |
| Completion and arrival of contract document before execution | 3.64 | 25 | 3.41 | 21 | 3.14 | 17 | 3.33 | 22 |
| Purchasing raw materials that are just sufficient | 1.79 | 47 | 1.98 | 44 | 1.69 | 44 | 1.80 | 46 |
| Coordination between store and construction personnel to avoid over/under ordering | 3.61 | 26 | 3.57 | 16 | 2.34 | 30 | 3.01 | 25 |
| Access to latest information about types of materials in the market | 2.91 | 36 | 2.35 | 39 | 1.87 | 38 | 2.25 | 38 |
| Ensuring early and prompt scheduling of materials | 3.39 | 32 | 3.20 | 28 | 1.97 | 35 | 2.67 | 34 |
| Verification and authorisation of orders by the site manager before requisition | 4.06 | 14 | 3.88 | 13 | 2.87 | 23 | 3.45 | 14 |
| Submission of detailed description and quantities of items to be ordered by the requisitioner | 3.97 | 17 | 3.90 | 12 | 2.83 | 24 | 3.42 | 17 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Using a sound, experienced resources procurement team with technical backing | 3.52 | 27 | 3.14 | 30 | 2.13 | 32 | 2.75 | 30 |
| Fencing the site (perimeter fencing) | 4.24 | 9 | 4.45 | 1 | 3.94 | 5 | 4.17 | 4 |
| Locking/controlling access to site and prohibiting strangers from entering | 4.27 | 6 | 4.12 | 7 | 3.94 | 5 | 4.07 | 5 |
| Ensuring that there is security during and after work at strategic places | 4.27 | 6 | 3.96 | 11 | 3.37 | 10 | 3.75 | 10 |
| Lighting the site at night | 3.91 | 20 | 3.35 | 22 | 1.76 | 41 | 2.73 | 31 |
| Ensuring that deliveries are supervised and always placed on site | 4.27 | 6 | 4.12 | 7 | 3.82 | 8 | 4.01 | 7 |
| Employing a proper security guard instead of using labour | 4.06 | 14 | 3.27 | 24 | 2.49 | 25 | 3.08 | 24 |
| Ensuring that storage facilities are properly secured before staff leave on a daily basis | 4.61 | 2 | 4.39 | 3 | 4.44 | 1 | 4.46 | 1 |
| Provision of alternative storage for valuable goods | 3.42 | 31 | 3.02 | 32 | 2.14 | 31 | 2.70 | 33 |
| Establishment of on-site procedures for the reception of goods | 3.85 | 23 | 4.27 | 4 | 3.15 | 15 | 3.66 | 11 |
| Using materials before expiry date | 4.03 | 16 | 3.84 | 14 | 4.11 | 3 | 4.01 | 7 |
| Keeping inventory/control of all materials through a well trained employee (store manager) | 4.18 | 11 | 4.45 | 1 | 4.04 | 4 | 4.20 | 3 |
| Checking of deliveries for any shortages and/or damages | 4.45 | 4 | 4.08 | 9 | 4.21 | 2 | 4.22 | 2 |
| Planning for storage of goods in advance | 3.91 | 20 | 4.16 | 5 | 3.20 | 13 | 3.66 | 11 |
| Proper storage of materials on site | 4.12 | 12 | 3.29 | 23 | 3.10 | 19 | 3.38 | 21 |
| Training and retraining of personnel on handling, storage and transportation | 1.76 | 48 | 1.49 | 48 | 1.87 | 38 | 1.73 | 48 |
| Careful handling of tools and equipment on site | 4.39 | 5 | 4.16 | 5 | 3.44 | 9 | 3.88 | 9 |
| Avoiding unnecessary material handling | 3.48 | 29 | 3.24 | 26 | 3.21 | 12 | 3.28 | 23 |
| Provision of access(roads etcetera) to storage | 3.36 | 33 | 2.88 | 33 | 2.92 | 22 | 3.00 | 26 |
| Accurate measurement of materials during operations such batching, mixing, and placing of concrete | 3.91 | 20 | 3.47 | 18 | 3.15 | 15 | 3.42 | 17 |
| Just in time operation | 4.09 | 13 | 3.43 | 20 | 3.13 | 18 | 3.43 | 16 |
| Employing experienced and skilled labour | 4.21 | 10 | 3.47 | 18 | 2.94 | 21 | 3.39 | 19 |
| Training and retraining of operatives | 2.52 | 40 | 2.04 | 40 | 1.79 | 40 | 2.03 | 39 |
| Implementation of tool box talks on a daily basis | 2.30 | 43 | 2.00 | 43 | 1.72 | 43 | 1.93 | 42 |
| Introducing incentives to motivate labour to minimise material wastage on site | 1.94 | 46 | 1.90 | 45 | 1.56 | 47 | 1.75 | 47 |
| Using prefabrication/offsite construction | 2.39 | 41 | 1.84 | 46 | 1.93 | 36 | 2.00 | 41 |
| Inclusion of material waste control policies in the invitation for sub-contractors | 3.52 | 27 | 3.22 | 27 | 2.46 | 26 | 2.93 | 27 |
| Inserting disciplinary clauses in labour only sub-contracts | 3.24 | 34 | 3.06 | 31 | 2.46 | 26 | 2.82 | 29 |
| Effective communication among stakeholders | 3.94 | 18 | 3.49 | 17 | 3.18 | 14 | 3.44 | 15 |
| Effective and frequent site supervision | 3.94 | 18 | 3.27 | 24 | 3.23 | 11 | 3.39 | 19 |
| Assigning competent contractor's technical staff to construction projects | 4.79 | 1 | 3.82 | 15 | 3.86 | 7 | 4.05 | 6 |
| Training and retraining of supervisors on material waste minimisation strategies | 2.15 | 44 | 1.69 | 47 | 1.73 | 42 | 1.81 | 45 |
| Preparation of weekly programme of work | 4.52 | 3 | 3.98 | 10 | 3.04 | 20 | 3.66 | 11 |
| Overall Mean = ΣMS/N | | | | | | | 3.03 | |

MS = Mean Score; R = Rank; Large firm (N = 33); Medium firm (N = 49); and Small firm (N = 71); All firms (N = 153)

It is noted that “training and retraining of supervisors on material waste minimisation strategies”; “use of modular design system”; “introducing incentives to motivate labour to minimise material wastage on site”; “purchasing raw materials that are just sufficient”; and “training and retraining of personnel on handling, storage and transportation” with mean ranks of 2.15, 2.09, 1.94, 1.79, and 1.76 respectively are the five minimisation strategies with the lowest level of use. A critical examination of these strategies with the least mean scores show that they are either never or rarely being used by this category of firms and may explain the reasons, with the combined effects of other minimisation strategies with mean scores less than the overall mean of 3.03, for high level of material waste generated on site as reported by some authors [2, 21, 6].

The analyses indicate that six strategies ranked in the first five positions of commonly practiced strategies among the medium firms namely: “keeping inventory/control of all materials through a well trained employee (store manager)”; “fencing the site (perimeter fencing)”; “ensuring that storage facilities are properly secured before staff leave on a daily basis”; “establishment of on-site procedures for the reception of goods”; “careful handling of tools and equipment on site”; and “planning for storage of goods in advance” with mean ranks of 4.45, 4.45, 4.39, 4.27, 4.16 and 4.16 respectively. The five least practiced strategies employed are “training and retraining of personnel on handling, storage and transportation”; “training and retraining of supervisors on material waste minimisation strategies”; “using prefabrication/offsite construction”; “introducing incentives to motivate labour to minimise material wastage on site”; “purchasing raw materials that are just sufficient” with mean score of 1.49, 1.69 1.84, 1.90, and 1.98 respectively.

Additionally, the result identified the five highest strategies employed among the small firms to include “ensuring that storage facilities are properly secured before staff leave on a daily basis”; “checking of deliveries for any shortages and/or damages”; “using materials before expiry date”; “keeping inventory/control of all materials through a well trained employee (store manager)”; “fencing the site (perimeter fencing)” having a tie rank with “locking/controlling access to site and prohibiting strangers from entering” with mean ranks of 4.44, 4.21, 4.11, 4.04, 3.94 and 3.94 respectively. On the other hand, “reviewing of design by a person or group not involve with the original design before execution”; “introducing incentives to motivate labour to minimise material wastage on site”; “use of modular design system”; “minimising design changes during construction”; “purchasing raw materials that are just sufficient” with mean ranks of 1.24, 1.56 1.59, 1.65, and 1.69 respectively are the five least used waste minimisation strategies by small firms.

Furthermore, it is observed that some strategies are prominently practiced by at least two categories of firms, hence were ranked among the first five in those categories. These include “ensuring that storage facilities are properly secured before staff leave on a daily basis”; “checking of deliveries for any shortages and/or damages”; “careful handling of tools and equipment on site”; “keeping inventory/control of all materials through a well trained employee (store manager)”; and “fencing the site (perimeter fencing)”. Conversely, “introducing incentives to motivate labour to minimise material wastage on site”; “purchasing raw materials that are just sufficient”; “training and retraining of personnel on handling, storage and transportation”; “training and retraining of supervisors on material waste minimisation strategies”; and “use of modular design system” are some practices revealed to be among the five least used waste minimisation strategies among at least two categories of firms.

Nevertheless, considering the results across all categories of construction firms reveals that “ensuring that storage facilities are properly secured before staff leave on a daily basis”; “checking of deliveries for any shortages and/or damages”; “using materials before expiry date”; “keeping inventory/control of all materials through a well trained employee (store manager)”; “fencing the site (perimeter fencing)" and "locking/controlling access to site and prohibiting strangers from entering" with mean score of 4.46, 4.22, 4.20, 4.17 and 4.07 respectively are the five most used waste minimization strategies. It implies that these strategies are always being used by most of the firms irrespective of its category. Conversely, "training and retraining of personnel on handling, storage and transportation"; "introducing incentives to motivate labour to minimise material wastage on site"; "purchasing raw materials that are just sufficient"; "training and retraining of supervisors on material waste minimisation strategies"; "use of modular design system" with corresponding mean scores of 1.73, 1.75, 1.80, 1.81 and 1.84 are the waste minimisation strategies that are generally either rarely used or never used across the different categories of construction firms in the study area. This result supports the assertion made by Adewuyi [3] that the use of modular design system and prefabrication are rarely adopted in Nigeria and by Teoh, Abdelnasar and Abdul [30] that additional materials are usually being purchased because of lack of consideration given to material waste reduction.

The study compares the level of use of waste minimisation strategies across the categories of construction firms investigated to ascertain if there exist peculiarities in the strategies adopted by each category. Kruskal-Wallis H test was used to achieve this. The result of the analysis is portrayed in Table 5. Post-hoc test of difference was carried out between pairs of firm's categories to investigate if variations across all the categories of firms may be attributed to any pair of firm category.

**Table 5:** Comparison of Level of use of MWMS among and between Firms

| Category of firm | N | Mean Rank | df | Z calculated | P-value | Decision |
|---|---|---|---|---|---|---|
| Large | 48 | 91.06 | | | | |
| Medium | 48 | 74.97 | 2 | | 0.001 | Reject |
| Small | 48 | 51.47 | | | | |
| Post Hoc test (using Mann-Whitney U) | | | | | | |
| Large | 48 | 54.43 | 1 | -2.085 | 0.037 | Reject |
| Medium | 48 | 42.57 | | | | |
| Large | 48 | 61.14 | 1 | -4.445 | 0.001 | Reject |
| Small | 48 | 35.86 | | | | |
| Medium | 48 | 56.90 | 1 | -2.953 | 0.003 | Reject |
| Small | 48 | 40.10 | | | | |

The result shows that there is significant variation in the level of use of the material waste minimisation measures among the three categories of firm on the one hand, and significant difference between each pair of the categories of firms on the other hand since the p-values are less than 0.05. This provides the basis for rejecting hypothesis one and the conclusion that there is significant variation in the level of use of waste minimisation strategies among the large, medium and small firms. The source of the variation is not dependent on any pair of the categories of firms but common among them. Therefore, it can be concluded that the material waste minimisation strategies adopted by each category of firms varies.

## 4.3 Level of Material Waste Generation

The level of material waste generation in the different categories of firms investigated was assessed based on their mean scores after which the evaluation scale was applied to determine the actual corresponding percentage of waste. The result is shown in Table 6.

The results shown in Table 6 are comparable with the results obtained by Bekr [9], being the magnitude of material waste generated in Jordanian construction industry. Ten materials assessed by Bekr (2014) include sand, aggregate, timber, cement, concrete block, ceramic tiles, PVC water pipes, steel reinforcement, concrete and facing stones with the level of material waste ranging between 15.14% and 20.98%. Similarly, Aiyetan and Smallwood [5] found the level of concrete waste, without reference to the size of construction firm, to be between 5 -10%, cement (5-7.5%), roof tiles (5-7.5%), mortar (5-7.5%), floor tiles (>10%), paint (>10%), block (5-10%), steel reinforcement (5-7.5%), and timber waste between 2.6-7.5%. Additionally, it is observed that the results of these various authors are above the estimators' allowance for each of the materials assessed as was equally reported by Odusami *et al*. [21] and Adewuyi *et al*. [2].

**Table 6:** Percentage of Material Waste Generation

| Material type | Large Firms | | Medium Firms | | Small Firms | | All Firms | |
|---|---|---|---|---|---|---|---|---|
| | MS | Waste (%) | MS | Waste (%) | MS | Waste (%) | MS | Waste (%) |
| Cement | 1.02 | 6.11 | 1.49 | 8.91 | 1.65 | 9.89 | 1.51 | 9.06 |
| Sand | 1.37 | 8.20 | 1.91 | 11.49 | 1.99 | 11.97 | 1.90 | 11.38 |
| Gravel | 1.32 | 7.90 | 1.91 | 11.49 | 2.01 | 12.07 | 1.89 | 11.36 |
| Timber | 1.74 | 10.44 | 2.34 | 14.06 | 2.37 | 14.20 | 2.30 | 13.81 |
| Reinforcement steel | 1.19 | 7.16 | 1.61 | 9.69 | 2.03 | 12.17 | 1.77 | 10.65 |
| Glass sheets | 1.04 | 6.26 | 1.40 | 8.40 | 1.90 | 11.41 | 1.61 | 9.65 |
| Concrete | 1.74 | 10.44 | 2.30 | 13.80 | 2.50 | 15.01 | 2.35 | 14.12 |
| PVC pipes | 1.99 | 11.93 | 1.49 | 8.91 | 2.27 | 13.64 | 2.04 | 12.25 |
| Mortar | 1.74 | 10.44 | 2.57 | 15.43 | 2.73 | 16.38 | 2.55 | 15.29 |
| Tiles | 1.86 | 11.18 | 1.50 | 9.00 | 2.39 | 14.35 | 2.07 | 12.44 |
| Sandcrete blocks | 2.36 | 14.16 | 2.41 | 14.49 | 2.81 | 16.83 | 2.68 | 16.10 |
| Aluminium roofing sheet | 1.04 | 6.26 | 1.49 | 8.91 | 1.50 | 8.97 | 1.44 | 8.66 |
| Asbestos roofing material | 1.24 | 7.45 | 1.11 | 6.69 | 1.58 | 9.48 | 1.41 | 8.47 |
| Paint | 1.29 | 7.75 | 1.56 | 9.34 | 2.12 | 12.73 | 1.82 | 10.95 |
| Asphalt concrete | 2.34 | 14.01 | 2.34 | 14.06 | 3.04 | 18.25 | 2.77 | 16.61 |
| Facing bricks | 1.17 | 7.01 | 1.34 | 8.06 | 1.53 | 9.18 | 1.44 | 8.66 |
| Ceiling board | 1.04 | 6.26 | 1.30 | 7.80 | 1.64 | 9.84 | 1.45 | 8.71 |
| Boulders | 1.07 | 6.41 | 1.44 | 8.66 | 1.51 | 9.08 | 1.44 | 8.66 |
| Stone base | 1.66 | 9.99 | 1.84 | 11.06 | 1.75 | 10.50 | 1.83 | 10.96 |
| Hydrated lime | 1.09 | 6.56 | 1.41 | 8.49 | 1.50 | 8.97 | 1.43 | 8.59 |

Furtherance to ascertaining the level of material waste generated by the different categories of firm with respect to various material types, comparisons were made of the waste generated among the firm's categories using Kruskal-Wallis H test. The results are presented in Table 7. The results show that the p-values are less than 0.05 for all the twenty material types examined by this study. This implies the rejection of the second hypothesis and the study concludes that there is significant variation in the level of material waste generated across different categories of firms.

**Table 7:** Comparison of Level of material waste generated among Category of Firms

| Material type | Category of firm | Mean Rank | P-value | Decision | Material type | Category of firm | Mean Rank | P-value | Decision |
|---|---|---|---|---|---|---|---|---|---|
| Cement | Small | 99.92 | | | Sandcrete blocks | Small | 100.52 | | |
| | Medium | 73.73 | 0.001 | Reject | | Medium | 65.02 | 0.001 | Reject |
| | Large | 32.53 | | | | Large | 44.18 | | |
| Sand | Small | 96.80 | | | Aluminium roofing sheet | Small | 95.33 | | |
| | Medium | 75.87 | 0.001 | Reject | | Medium | 76.78 | 0.001 | Reject |
| | Large | 36.08 | | | | Large | 37.8]9 | | |
| Gravel | Small | 97.28 | | | Asbestos roofing material | Small | 106.41 | | |
| | Medium | 76.37 | 0.001 | Reject | | Medium | 52.70 | 0.001 | Reject |
| | Large | 34.30 | | | | Large | 49.80 | | |
| Timber | Small | 96.67 | | | Paint | Small | 110.04 | | |
| | Medium | 78.11 | 0.001 | Reject | | Medium | 58.18 | 0.001 | Reject |
| | Large | 33.03 | | | | Large | 33.85 | | |
| Reinforcement steel | Small | 105.92 | | | Asphalt concrete | Small | 106.18 | | |
| | Medium | 64.95 | 0.001 | Reject | | Medium | 57.98 | 0.001 | Reject |
| | Large | 32.68 | | | | Large | 42.45 | | |
| Glass sheets | Small | 107.72 | | | Facing bricks | Small | 96.10 | | |
| | Medium | 61.94 | 0.001 | Reject | | Medium | 70.11 | 0.001 | Reject |
| | Large | 33.27 | | | | Large | 46.14 | | |
| Concrete | Small | 101.08 | | | Ceiling board | Small | 100.46 | | |
| | Medium | 71.98 | 0.001 | Reject | | Medium | 66.61 | 0.001 | Reject |
| | Large | 32.65 | | | | Large | 41.95 | | |
| PVC pipes | Small | 109.72 | | | Boulders | Small | 98.26 | | |
| | Medium | 44.46 | 0.001 | Reject | | Medium | 73.98 | 0.001 | Reject |
| | Large | 54.92 | | | | Large | 35.74 | | |
| Mortar | Small | 98.12 | | | Stone base | Small | 88.69 | | |
| | Medium | 74.66 | 0.001 | Reject | | Medium | 77.52 | 0.001 | Reject |
| | Large | 35.03 | | | | Large | 51.08 | | |
| Tiles | Small | 106.96 | | | Hydrated lime | Small | 97.70 | | |
| | Medium | 49.39 | 0.001 | Reject | | Medium | 73.14 | 0.001 | Reject |
| | Large | 53.55 | | | | Large | 38.18 | | |

N = 33 for Large firms; N = 49 for Medium firms; N = 71 for Small firms; df = 2

### 4.4 Relationship between Level of use of minimisation strategies and waste generation

To determine the existence of relationship between the level of use of minimisation strategies and the level of material waste generation, the two variables were correlated using Spearman's Rank correlation method. The result of the test is presented in Table 8 with the data collected being analysed on the basis of each material assessed by this study. The correlation is adjudged significant at the p-value of $\leq 0.05$. The prevailing rule is that $p \leq 0.05$ rejects the hypothesis while $p > 0.05$ does not reject the hypothesis.

**Table 8:** Results of correlation analysis between Level of use of minimisation strategies and Level of material waste generation

| Material type | Large Firms (N = 33) | | | Medium Firms (N = 49) | | | Small Firms (N = 71) | | | All Categories of Firms (N = 153) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R | p-value | Decision | R | p-value | Decision | R | p-value | Decision | R | $R^2$ | p-value | Decision |
| Cement | -0.197 | 0.271 | Accept | -.342* | 0.016 | Reject | 0.118 | 0.329 | Accept | -.563** | 0.328 | 0.001 | Reject |
| Sand | 0.119 | 0.51 | Accept | -0.064 | 0.663 | Accept | -0.089 | 0.461 | Accept | -.492** | 0.242 | 0.001 | Reject |
| Gravel | -0.044 | 0.807 | Accept | -0.064 | 0.664 | Accept | -0.209 | 0.08 | Accept | -.529** | 0.280 | 0.001 | Reject |
| Timber | -0.154 | 0.391 | Accept | 0.211 | 0.146 | Accept | -.250* | 0.035 | Reject | -.496** | 0.246 | 0.001 | Reject |
| Reinforcement steel | 0.016 | 0.93 | Accept | 0.256 | 0.076 | Accept | 0.035 | 0.775 | Accept | -.591** | 0.349 | 0.001 | Reject |
| Glass sheets | -0.047 | 0.797 | Accept | -0.046 | 0.752 | Accept | 0.004 | 0.973 | Accept | -.665** | 0.442 | 0.001 | Reject |
| Concrete | 0.058 | 0.747 | Accept | .306* | 0.033 | Reject | -0.127 | 0.29 | Accept | -.535** | 0.286 | 0.001 | Reject |
| PVC pipes | 0.091 | 0.616 | Accept | 0.198 | 0.174 | Accept | -0.082 | 0.495 | Accept | -.586** | 0.343 | 0.001 | Reject |
| Mortar | 0.08 | 0.66 | Accept | -0.194 | 0.182 | Accept | -0.068 | 0.576 | Accept | -.525** | 0.276 | 0.001 | Reject |
| Tiles | -0.121 | 0.502 | Accept | 0.138 | 0.344 | Accept | -0.039 | 0.745 | Accept | -.545** | 0.297 | 0.001 | Reject |
| Sandcrete blocks | -0.054 | 0.764 | Accept | 0.147 | 0.313 | Accept | 0.063 | 0.602 | Accept | -.452** | 0.204 | 0.001 | Reject |
| Aluminium roofing sheet | -0.315 | 0.074 | Accept | 0.101 | 0.488 | Accept | -0.137 | 0.255 | Accept | -.487** | 0.237 | 0.001 | Reject |
| Asbestos roofing material | -0.375* | 0.031 | Reject | 0.157 | 0.28 | Accept | 0.034 | 0.777 | Accept | -.580** | 0.336 | 0.001 | Reject |
| Paint | -0.14 | 0.437 | Accept | 0.069 | 0.636 | Accept | -0.136 | 0.256 | Accept | -.703** | 0.494 | 0.001 | Reject |
| Asphalt concrete | 0.147 | 0.413 | Accept | 0.197 | 0.176 | Accept | -0.023 | 0.85 | Accept | -.559** | 0.312 | 0.001 | Reject |
| Facing bricks | 0.061 | 0.735 | Accept | 0.003 | 0.983 | Accept | -0.023 | 0.849 | Accept | -.434** | 0.188 | 0.001 | Reject |
| Ceiling board | -0.047 | 0.797 | Accept | 0.23 | 0.112 | Accept | -0.067 | 0.58 | Accept | -.503** | 0.253 | 0.001 | Reject |
| Boulders | -0.194 | 0.279 | Accept | -0.066 | 0.655 | Accept | -0.085 | 0.482 | Accept | -.548** | 0.300 | 0.001 | Reject |
| Stone base | -0.156 | 0.387 | Accept | -0.039 | 0.792 | Accept | -0.019 | 0.872 | Accept | -.306** | 0.094 | 0.001 | Reject |
| Hydrated lime | -0.207 | 0.248 | Accept | -0.176 | 0.227 | Accept | 0.009 | 0.938 | Accept | -.528** | 0.279 | 0.001 | Reject |

** (*) Correlation is significant at the 0.01 (0.05) level (2 tailed)

The results in the Table 8, based on the analysis carried out on each category of firm, shows that the relationship between the two variables is statistically insignificant since the p-values are greater than 0.05 with the exception of asbestos roofing material wastage in large firms, cement and concrete in medium firms and timber in the small firms. As these values do not satisfy the conditions for rejection, the hypothesis is accepted for most of the materials investigated. The implication of not rejecting the hypothesis is that the relationship between the level of use of material waste minimisation and the level of material waste generation on firm's category basis in the study area is statistically insignificant. Notwithstanding, it is observed that there exist a somewhat negative relationship in about 70% of the materials assessed in large and small size firms while it is about 40% in medium firms. The statistically insignificant output may be traceable to the small number of data set (small number of firms) involved in each category as asserted by Adewuyi *et al*. [2]. This assertion is further proven by carrying out the analysis on the overall number of firms assessed, irrespective of the category, with the results showing a well established negative relationship and being statistically significant at 99% confidence level (2 tailed) as shown in Table 8.

Hence, based on the overall result, the hypothesis of no significant relationship between the level of use of minimisation strategies and the level of material waste generated (hypothesis three) is rejected. From the $R^2$ values, it is indicated that between 18.8% to 49.4% of the material waste generated for all the material types studied could be explained by the material minimisation strategies adopted on site except stone base which only 9.4% of the waste generated could be explained by the strategies adopted. The study also showed that the magnitude of material waste generated varies among the small, medium and large construction firms with the highest waste occurring in small firms. To capture the relationship between the two variables correlated, Figure 2 is produced which portrays the specific relationship between waste minimisation measures and waste generation in cement.

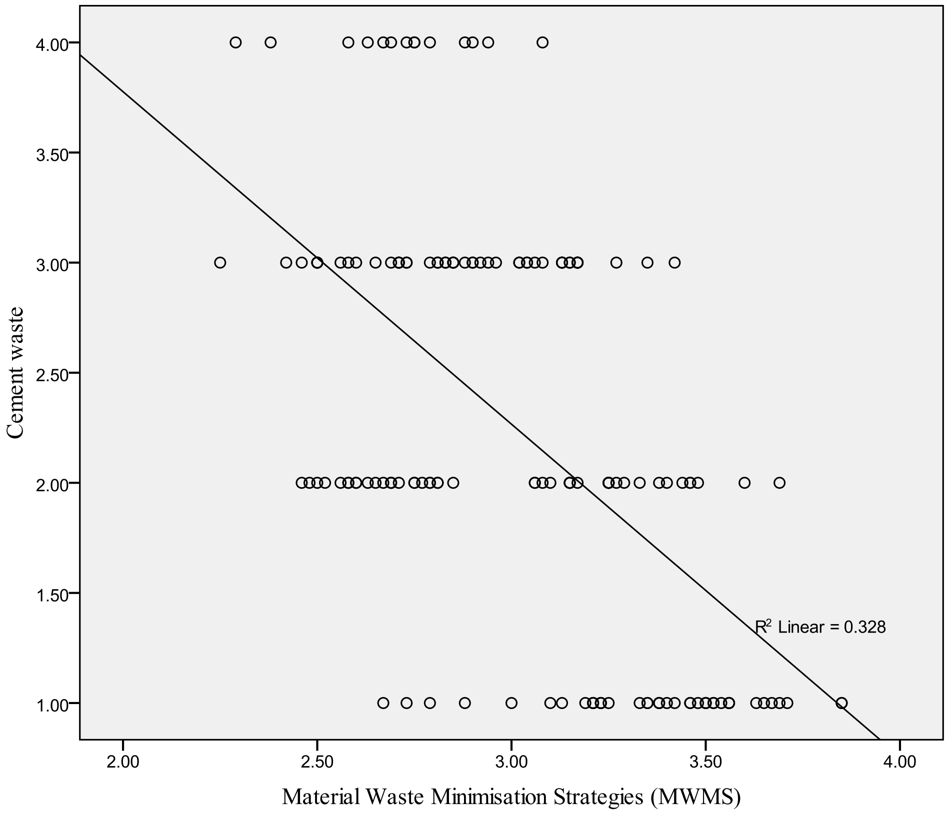


Figure 2: Relationship between Material Waste Minimisation Strategies and Cement waste generation

## 5.0 Conclusions and recommendation

Adopting the principles of minimising material waste on a project can demonstrate a firm's commitment to sustainable construction and environmental management. This study concludes that "ensuring that storage facilities are properly secured before staff leave on a daily basis; checking of deliveries for any shortages and/or damages; using materials before expiry date; keeping inventory/control of all materials through a well trained employee (store manager); fencing the site (perimeter fencing) and locking/controlling access to site and prohibiting strangers from entering" are the first five foremost waste minimisation strategies used among the twenty four waste minimisation strategies having mean score ≥ 3.03 which are accounted being significantly used by construction firms while "training and retraining of personnel on handling, storage and transportation"; "introducing incentives to motivate labour to minimise material wastage on site"; "purchasing raw materials that are just sufficient"; "training and retraining of supervisors on material waste minimisation strategies"; "use of modular design system" strategies, with corresponding mean scores of 1.73, 1.75, 1.80, 1.81 and 1.84, are either never or seldom used. It is also concluded that the level of usage of waste minimisation strategies by small, medium and large firms varies in the study area; hence, the category of construction firm influences the waste minimisation strategies adopted on site.

In addition, the level of waste generated for different construction material types ranged between 8.47% and 16.61% and is in consonance with what obtains in previous studies. The study also showed that the magnitude of waste generated varies among small, medium and large construction firms with the highest waste generation occurring in small construction firms. There is no significant relationship between magnitude of waste generated and the level of use of waste minimisation strategies for most of the construction materials due to the number of firms surveyed under each category. However, considering all categories of construction firms, it is concluded that there is significant relationship between magnitude of waste generated and the level of use of waste minimisation strategies on construction sites.

The study therefore recommends that the players in the industry should consider stepping up efforts towards training and retraining of personnel on handling, storage and transportation; introducing incentives to motivate labour to minimise material wastage on site; training and retraining of supervisors on material waste minimisation strategies; and the use of modular design system which are prominent among least practiced strategies as they are cardinal in achieving reduction of waste on site. The introduction of government policies and contractual terms; and environmental standards and assessment tools are equally recommended due to their potentials in reducing the generation of waste.

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