Analysis of Waste Production on Building Construction Sites: A Case Study of Public Institutional Projects in Adamawa, Nigeria

*[a]Haruna, A. C., [a]Usman, N. D., [a]Oraegbune, O. M. and [b]Muhammad, U. D. and [c]Bamidele, O.
[a]Department of Building, Modibbo Adama University of Technology Yola, Nigeria
[b]Department of Estate Management, Baze University, Abuja, Nigeria
[c]Department of Building, Federal Polytechnic Auchi, Edo State

*Correspondence email: amoschom@mautech.edu.ng

Abstract

Material waste production on construction sites is related to quantity of building materials leftover and overproduced on-sites during building production process. Material management has been of concern in the building construction industry. Therefore, the study analysed waste production on public institutional project sites and achieved the following objectives: examined the factors responsible for material wastages on site, determined waste minimization and analysed cost of material waste on construction sites. Seven (7) building materials were assessed in 20 public institutional building project sites located in five (5) public higher institutions in Adamawa state selected at random. The materials include timber planks for making formwork and scaffolds used by carpenters; concrete nails used by carpenters; cement used by masons for plaster, mortar and concreting; concretes for casting structural elements; sandcrete blocks for walls construction; reinforcement bars cut to sizes used in beams, slabs and columns by iron benders; and electrical lighting wires installed in buildings by electricians. The left over quantities of each of these materials not utilised after work completion from foundation to roof level were ascertained and constituted the wastages generated on sites. Findings show that concretes for casting structural elements is the most wasted material having the highest relative importance index (RII) of 0.715. The wastage occurs in the area of poorly designed formwork for the various structural elements such as columns, beams, and slabs. With RII of 0.681, timber planks used for preparation of these formworks and scaffolds comes second. The overall total cost value of wasted materials produced by artisans in all the 20 sites is N1, 634,640 with carpenters' contribution of 44.1%, masons' 38.5%, iron benders' 10.5%, and electricians' 6.9%. It is concluded that sound procurement procedures in materials management and adequate training of artisans are vital to waste minimisation on building site.

Keywords: Artisans, Building production, Construction sites, Materials wastage.

INTRODUCTION

Waste is mostly produced during building production, rehabilitation or demolition of buildings (Clark, Jambeck and Townseed, 2006). However, some wastes are produced by human Activities. With the growth in population and increase in demand for housing has necessitated increase in human activities. So the growth of the industry has led to massive increase in waste. Studies have shown that waste generation during building production accounts for 5.05 million tons/year in China, 19.0 million tons in Australia between 2008 – 2009, whereas in UK 77.38 million tons and 170 million tons in USA (EPA, 2014, Ramzy, 2013, Qiu, 2010, US EPA,2009). Akanni (2007) found 13.6% wastage level of materials in Nigerian construction industry.

According to Dania, Kehinde, and Bala (2007), site waste management in Nigeria is very poor based on professional perception. Owing to its significant impact, waste has to be properly managed since it is produced out of the materials used in building production or restructuring.

Material as a general term is used to connote sawn material, spare parts and components that produce goods or services. Materials usually constitute major cost in a building construction project which makes control of this resource important. The cost of material to an overall cost of construction is averagely put at 60% (Navon & Berkovich 2005). The major sources of information for feedback and control of material procurement are requisition bids and quotations, purchase orders and invoices. According to Council of Registered Builders of Nigeria (CORBON, 2011) document on Construction Site Management for Builders, for large-scale projects the use of critical resources such as initiation of procurement procedures might be put in place to avoid shortages and delays. That is, procurement personnel might be appointed by the client to shop for materials with the best price performance characteristics as specified by the designer. This procurement service does not only include purchasing but includes a complete follow-up of every item to ensure that all materials and equipment are in accordance with job specification, and are delivered to the construction site on schedule.

Building Materials Waste Minimization

Material waste during building production operations is inevitable. However, to ensure that the wastes generated in the cause of building production is managed significantly on achieving project objective(s) is of great concern to all parties involved in the project. The significant gains of construction material waste minimization on site during building production can achieve financial, social, and environmental impact on project, leading to higher productivity, construction time saving, safety, and improvement of contractor's image. According to Tam (2002), the construction industry plays a vital role in meeting the needs of the society and enhancing quality of life. However, the responsibility of ensuring that construction activities and products are consistent with environmental policies needs to be defined, and good environmental practices improved (Shen*et al.*, 2002). Compared with other industries, construction generates fairly large amount of pollutants, including solid waste, noise, dust and water (Ballard, 2002).

Since construction has a major and direct influence on many other industries by means of both purchasing the inputs from other industries and providing facilities and products to almost all other industries, eliminating or reducing waste could yield great cost savings to the economy (Ballard, 2004). The provision of these facilities consume great amount of resources which includes labour, material, money and time. The construction industry has been encouraged to re-use built assets, minimize waste, recycle materials, minimize energy in construction and use of buildings, use environmental management systems to reduce pollution, enhance bio-diversity, conserve water, respect people and their local environment, measure performance and set targets for the environment and sustainability (Ofori *et al*., 2000).

The rising level of construction waste has caused serious problem of high cost of construction both locally and globally. Bossink (1996) found out that the level of waste in construction industry globally is between 20 – 30% of the total quantity of the materials on site. According to Ekanayake (2000), Construction waste is any material apart from earth materials which needs to be transported elsewhere to the construction site or used within the construction site itself. Ekanayake (2000) categorized construction waste into three major categories as material, labour and machinery waste. However, materials waste, which is the focus on this research is

more common because the raw materials from which construction inputs are derived come from non-renewable resource.

METHODOLOGY

The study uses descriptive survey method. Oral interviews were conducted on artisans and craftsmen and existing literatures were reviewed in obtaining data on the subject. Two sets of structured questionnaires for data collation were administered to site managers and artisans commonly engaged on construction sites such as Mason, Iron Benders, carpenters and, electricians. The questionnaires were distributed randomly to sites in Adamawa State. The response rates for artisans were 65.45% (see table 1). These indicate an unbiased and higher value of survey as stipulated (Usman, Inuwa & Dantong, 2014). The data collected were analysed to determine percentages of materials wastage by artisans on construction sites and the results were presented on tables and bar chart. The data were analysed using Kendall's coefficient of concordance to establish the level of severity and importance of sample factors and rank them according to their severity and importance index.

Twenty (20) institutional building project sites located in five (5) public higher institutions in Adamawa state were selected at random. Seven (7) building materials were assessed. The materials are timber planks for making formwork and scaffolds used by carpenters; concrete nails used by carpenters; cement used by masons for plaster, mortar and concreting; concretes used for casting structural elements by masons; sandcrete blocks used for walls construction by masons; reinforcement bars cut to sizes and used in beams, slabs and columns by iron benders; and electrical lighting wires installed in buildings by electricians. These building materials were considered because they are the materials commonly employed for building construction on sites in the study area. The left over quantities of each of these materials not utilised at the completion of work from foundation to roof level were ascertained and constituted the wastages generated on sites. These left over quantities (i.e. wastages) were measured by kilogramme (kg), volume (m^3) and length (m) for concrete nails, concretes and reinforcement bars respectively. Timber planks were also measured in length (m). Sandcrete blocks measured in numbers, cements were measured in numbers per 50kg bag, and electrical lighting wires measured per yard. On each building site, the measured quantities of each left over material were multiplied by the prevailing unit cost of purchase of the material so as to obtain the value of cost estimates of the selected materials that were left over, and considered wasted at completion of work by each of the three artisans: carpenters, masons and iron benders. The cost estimates of wasted materials (i.e. left over materials) after completion of work by the artisans from the selected building sites which were presented in figure 2, were calculated from the following equations:

$$W_m = (N_{ct} \times C_{ct}) + (N_{sb} \times C_{sb}) + (V_{cc} \times C_{cc}) \quad (1)$$
$$W_c = (L_{tp} \times C_{tp}) + (K_{cn} \times C_{cn}) \quad (2)$$
$$W_i = (L_{rb} \times C_{rb}) \quad (3)$$
$$W_e = (L_{lw} \times C_{lw}) \quad (4)$$

where,
W_m = cost estimate of wasted material generated by masons on site.
W_c = cost estimate of wasted material generated by carpenters on site.
W_i = cost estimate of wasted material generated by iron benders on site.
W_e = cost estimate of wasted material generated by electricians on site
N_{ct} = number of bags cement left over at completion of work,

and C_{ct} = cost of cement (per bag)
N_{sb} = number of sandcrete blocks left over at completion of work,
and C_{sb} = unit cost (per sandcrete block)
V_{cc} = volume of concrete left over at completion of work (in m^3),
and C_{cc} = cost of concrete (per m^3)
L_{tp} = length of timber planks left over at completion of work,
and C_{tp} = cost of timber planks (per length)
L_{rb} = length of reinforcement bar left over at completion, and
C_{rb} = cost of reinforcement bar (per metre)
L_{lw} = length of lighting wire left over at completion of work,
and C_{lw} = cost of lighting wire (per yard).

Two sets of structured questionnaires were administered to two sets of respondents; site managers and artisans on each of the twenty (20) project sites. Justification for selection of 20 sites out of a population of 35 projects being executed in 5 higher institutions in the state was because works at these sites were at roof level as at the time of data collection. According to Lucey (2002), small samples of $n < 30$ are distributed around the population means in a manner similar to normal distribution. The artisans were divided into 4 groups on each site: masons, carpenters, electricians and iron benders. The questionnaire distribution was randomly done by direct visitation and delivery to the sites. One set of the questionnaire which was on prevalent factors that contributed to materials wastage on building sites was directed to site managers on site. Site managers were chosen because they are responsible for materials purchase, monitoring and control of activities on building sites, while the other set of the questionnaire which sought to identify the relative level of wastage of selected building materials on sites and the areas which these wastages occur was directed to the artisans. Twenty two (22) questionnaires were distributed to each of the 20 sites to achieve uniformity in the administration of questionnaires. Artisans were chosen because they are directly involved in construction of the residential buildings and also play a vital role in building materials handling, placement and transportation within building sites.

Relative Importance Index (RII) was used to determine the relative frequency level of wastage of selected building materials on sites and the activities contributing to wastages. The result was presented in table 2. Structured questionnaire were developed and administered to site managers in two stages. In the first stage, factors contributing to building materials wastage prevalent in a site were identified by each site manager from list of twenty (20) factors identified from literatures. Seven (7) factors were identified out of the twenty (20) factors contributing to building materials wastage on building sites as the common and predominant factors in the 20 project sites. In the second stage, site managers rank the seven (7) identified factors of building materials wastage. The results obtained are presented in figure 2.

RESULTS AND DISCUSSION

Response Rate by Artisans

Two hundred and eighty eight (288) respondents (skilled artisans made up of masons, carpenters, electricians, and iron benders) from 20 building sites completed and returned the administered questionnaire as shown in table 1. This gives an overall percentage returned to be 65.45%. One hundred and forty two (142) of the respondents are masons representing 54.04%; sixty three (63) of the respondents representing 21.88% are carpenters; forty (40) representing 13.89% are carpenters; while iron benders are 38, constituted 13.19% of the respondents. Masons constituted the larger workforce on building sites due to the enormity of their task compare to other artisans on sites. The masons carry out site works involving casting of

concretes, lying of concrete blocks, plastering of walls, beams and columns etc. The maximum response rate recorded from individual construction site is 90.91% and the minimum is 45.45%. The variation in response rate from various sites is due to the sizes of building projects and location of these project sites, as some of these sites are located in remote areas where accessibility is difficult due to the nature of the access roads to some of the sites.

Table 1: Response Rate

Building Sites	No. of Masons	No. of Carpenters	No. of Electricians	No. of Iron Benders	Total No. Returned	Total No Sent	Site's Response Rate (%)
1	8	4	2	2	16	22	72.73
2	8	3	2	2	15	22	68.18
3	8	4	3	3	18	22	81.82
4	6	3	2	2	13	22	59.09
5	6	2	1	2	11	22	50.00
6	7	2	2	1	12	22	54.55
7	6	3	1	2	12	22	54.55
8	8	4	3	2	17	22	77.27
9	8	4	3	2	17	22	77.27
10	10	3	3	3	19	22	86.36
11	6	4	2	2	14	22	63.64
12	8	4	2	2	16	22	72.73
13	6	2	2	1	11	22	50.00
14	6	2	2	2	12	22	54.55
15	10	4	3	3	20	22	90.91
16	8	3	1	1	13	22	59.09
17	8	4	2	2	16	22	72.73
18	6	3	1	1	11	22	50.00
19	6	2	1	1	10	22	45.45
20	8	3	2	2	15	22	68.18
Total No of Response	147	63	40	38	288	440	
Percentage Response by Artisans	51.04	21.88	13.89	13.19	Percentage Returned = 65.45		

Source: Fieldwork, 2017

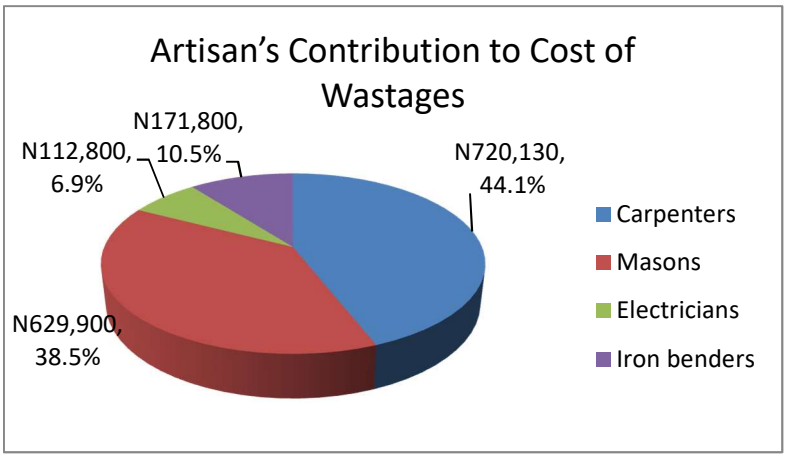

Figure 1: Artisan's Contribution to Cost of Wastages on Sites. Source: Fieldwork, 2017

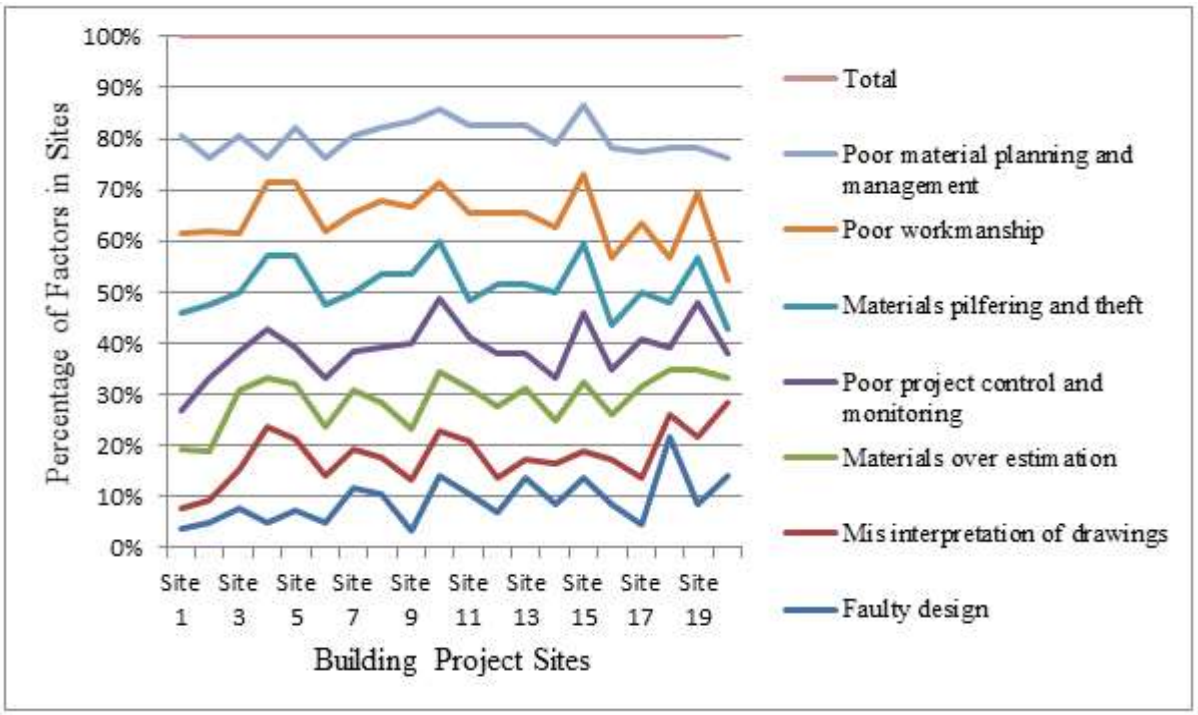

Figure 2: Factors of Material Wastages on Sites. Source: Fieldwork, 2017

Artisans and Materials Wastages on Building Sites

Relative importance index (RII) on frequency of building materials wasted on sites is shown in table 2. The various work carried out by sites artisans in the utilization of these materials shows that concretes for casting structural elements is the most wasted material having the highest frequency index of 0.715 RII. The wastage occurs in the area of poorly designed formwork for the various structural elements such as columns, beams, and slabs. Other materials following concretes as the most wasted material with RII of 0.681 are timber planks used for preparation of these formworks and scaffolds, as well as cement used for plaster, mortar and concreting. The wastages in timber occur during cutting to sizes to achieve the required specifications of the designed structural elements while wastage on cement is due to poor cement mix for concreting, mortar, plaster, handling and placement. Since carpenters are the artisans responsible for the construction of formworks and wooden scaffolds, it means they are the artisans that responsible for these wastages. On the other hand, masons involved in handling cement for concreting, mortar and plaster mix contributed to the wastages in cement.

Table 2 also shows that the materials least wasted on sites are concrete nails with 0.434 RII value due to minimal cases of over purchase of nails for use on building sites. Artisans' training and working experiences on building sites are crucial factors that can mitigate material wastages on construction site.

Cost estimates of materials wastage contributed by each artisan in 20 sites is shown in the appendix). The highest cost of materials wastage achieved is one hundred and twenty one thousand, four hundred naira (N121,400) in Site 15 while the least is forty nine thousand, nine hundred naira (N49,900.00) in Site 19.In general, it can be seen that carpenters have overall highest cost value records of material wastage of seven hundred and twenty thousand, one hundred and thirty naira (N720,130.00) representing 44.1%. Masons contribution is N629,900.00 representing 38.5% shown in Figure 2, while iron benders contribution is N171,800.00 which is 10.5%. The least cost value of wastages is generated by electricians

which is one hundred and twelve thousand, eight hundred naira (N112, 800.00) at 6.9% of wastage. Artisans involved in carpentry work contributed the highest cost record value of wasted materials amounting to N446, 150 as shown in table 3. The masons followed with N394, 850, and lastly the iron benders with N78, 540 in all the 21 sites. The total cost value of wasted materials is N1, 634,640 in all the 20 sites (see Appendix).

Table 2: Relative Importance Index on Frequency of Material Wastages

		Frequency of Area of Wastages							
Building Materials	Wastage Activities	Most Freq (3) A	Freq. (2) B	Less Freq (1) C	Total Number of Respondents N=A+B+C	Total Score (S)	Average Score Index S/N	Relat. Imp. Index S/3N	Rank Order
Timber planks	1.Cutting to size	125	50	113	288	588	2.042	0.681	2nd
	2.Over purchase	62	20	206	288	432	1.500	0.500	13th
	3.Poor storage and deterioration	74	62	152	288	498	1.729	0.576	10th
Cement	1.Pilfering and Theft	122	50	116	288	582	2.021	0.674	3rd
	2.Handling, mortar/plaster mix, and placing	110	60	118	288	568	1.972	0.657	5th
	3.Over purchase	69	48	171	288	474	1.646	0.549	11th
Concrete	1.Over purchase	61	15	212	288	425	1.476	0.492	14th
	2.Loss during Placing/Transport	88	54	146	288	518	1.799	0.600	9th
	3.Poor formwork	130	70	88	288	618	2.146	0.715	1st
Concrete Blocks	1.Cutting on Laying	94	71	123	288	457	1.899	0.633	7th
	2.Breakages during transportation	106	62	120	288	562	1.951	0.650	6th
	3.Over purchase	55	18	215	288	416	1.444	0.481	15th
Rebars	1.Cutting/bending to shape	102	48	138	288	540	1.875	0.625	8th
	2.Pilfering and Theft	118	55	115	288	579	2.010	0.670	4th
	3.Over purchase of Reinforcement	61	38	189	288	448	1.556	0.519	12th
Concrete Nails	1. Pilfering and Theft	50	18	220	288	406	1.410	0.470	17th
	2. Over purchase	30	27	231	288	375	1.302	0.434	21st
	3. Improper Handling	40	40	208	288	408	1.417	0.472	16th
Lighting Wires	1. Pilfering and Theft	41	25	222	288	395	1.372	0.457	19th
	2. Over purchase	45	20	223	288	398	1.382	0.461	18th
	3. Cutting	39	20	229	288	386	1.340	0.447	20th

Source: Fieldwork, 2017

Factors Responsible for Material Wastage on Sites

Findings indicated in Figure 2 that poor material planning and management constituted, poor workmanship, and materials pilfering and theft are the top most factors of wastages on sites. This is confirmed by findings of Haruna, Adole, Anum, and Khalid (2015) that poor material planning and management constituted the highest factor (95.2%) contributing to building

materials wastage. Lack of material purchase and delivery plan makes wastages inevitable in the building sites. Poor workmanship 85.7% is the next highest factors contributing to materials wastage on sites. Training for skilled and unskilled labour is important in addressing issues of poor workmanship on sites.Other factors contributing to building materials wastage are over-estimation of materials required on sites; poor supervision, control, and monitoring; materials pilfering and theft; misinterpretation of drawings; and faulty designs.

CONCLUSION

In conclusion, findings from the twenty public institutional building project sites showed that concretes for casting structural elements is the most wasted material having the highest relative importance index (RII) of 0.715. The wastage occurs in the area of poorly designed formwork for the various structural elements such as columns, beams, and slabs. With RII of 0.681, timber planks used for preparation of these formworks and scaffolds comes second. The overall total cost value of wasted materials produced by artisans in all the 20 sites is N1, 634,640 with carpenters' contribution of 44.1%, masons' 38.5%, iron benders' 10.5%, and electricians' 6.9%. It is therefore recommended that sound procurement procedures in materials management and adequate training of artisans are vital to waste minimisation in building production.

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Appendix: Cost Estimate of Material Waste on Building Sites

Building Sites	**Carpenters**	**Masons**	**Electrician**	**Iron Benders**	**Site's Total Cost**
	(W)	**(X)**	**(Y)**	**(Z)**	
	N'000	**N'000**	**N'000**	**N'000**	**N'000**
Site 1	37.88	29.20	10.80	11.30	89.18
Site 2	27.80	29.80	9.90	13.90	81.40
Site 3	29.50	36.50	11.80	12.70	90.50
Site 4	29.70	23.40	7.40	9.70	70.20
Site 5	40.60	18.20	9.40	13.70	81.90
Site 6	24.40	24.90	5.80	6.60	61.70
Site 7	54.60	38.20	6.40	8.40	107.60
Site 8	19.25	29.80	8.90	12.40	70.35
Site 9	22.40	39.10	3.60	4.90	70.00
Site 10	53.20	26.50	2.70	5.20	87.60
Site 11	25.70	26.60	4.10	7.90	64.30
Site 12	18.60	55.10	3.20	5.50	82.40
Site 13	63.80	26.80	1.90	4.80	97.30
Site 14	22.70	39.80	4.30	6.20	73.00
Site 15	63.60	52.10	1.10	4.60	121.40
Site 16	42.30	30.20	6.10	10.80	89.40
Site 17	45.60	35.50	5.20	10.50	96.80
Site 18	29.50	29.80	3.80	8.20	71.30
Site 19	22.40	18.90	2.70	5.90	49.90
Site 20	46.60	19.50	3.70	8.60	78.40
Artisan's Total Cost	720.13	629.90	112.80	171.80	**1,634.63**

Sourced: Fieldwork (2017)