Construction material waste causes and their contribution levels: A case study of construction projects in Abuja, Nigeria

IBE, Chukwumaobi Ndukwe

Construction Material Waste Causes and their Contribution Levels: A Case Study of Construction Projects in Abuja, Nigeria.

Chukwumaobi Ndukwe Ibe
Social and Economic Research Institute
Department of Natural and Built Environment
Sheffield Hallam University
Sheffield, England
c.ibe@shu.ac.uk

Abstract

With a population of 211 million, Nigeria's construction industry generates about 3 million tons of C&D waste per year. Recovering, recycling, or reusing over 75% of C&D waste is possible. It's widely accepted that waste management methods, technologies, rating systems, and policies must be comprehensive and integrated. Prevention, minimization, reuse, recycling, energy recovery, and disposal are waste management steps. Recycling is unplanned in Nigeria. This study analyses construction project MWG and predetermined materials waste causes. Abuja construction professionals comprise the study. The targeted population was surveyed using convenience sampling and analyzed using frequency, mean score, and Mann–Whitney U test. The study confirms Nigeria's construction waste causes. "Adjustments done without following the agreed-upon blueprints," "Revisions and alterations to the design," and "Spent resources on inefficient forms" are the main causes of construction material waste on Abuja building sites. It also shows that these factors affect MWG at different levels on Nigerian construction projects. Poor supervision is the most responsible for material waste generation, while inappropriate tools are the least responsible. To optimize building projects in Abuja, Nigeria, construction industry players should consider all investigated variables at each stage of their construction processes and waste management strategies.

Keywords
Construction and Demolition (C&D), Material waste generation (MWG), Waste Management, Construction Materials, Design Alterations

1. Introduction
The world population was 7.6 billion in 2017, and it is expected to reach 9.8 billion by 2050 according to Luangcharoenrat C et al. (2019) . Currently, 55% of the world's population lives in cities, and this figure is expected to rise to 68% by 2050. To meet the demands for transportation, housing and energy supply, infrastructure, and waste management, urbanization will be required. The construction industry is a major source of building infrastructure to support city growth and contributes to environmental degradation.

Adewuyi and Odesola (2015) defined construction waste as 'construction materials that are lost in transit on or off site, discarded without adding value to the project for which it was procured including overproduction or left over from newly constructed facility'. According to Ikau et al. (2016), inexperience in construction waste, non-conformance of materials with requirements, poor storage, and rework are the primary sources of material waste in construction projects. Mishandling and improper usage of some products, such as tiles, ceramics, and plastering materials, can cause them to break, as discovered by Poon (2007).

In order to determine what factors, contribute most to construction waste in Thailand, Luangcharoenrat et al. (2019) did a study. They reasoned that design revisions made at the last minute, sloppy scheduling, and improper material storage were to blame. Researchers have been collecting data regarding waste from construction projects to gain insight into the status of the issues and find solutions. As seen in Table 1, In each country, the proportion of construction debris (by weight) landfilled ranges between 13% and 60% of total waste.

Table 1. Construction and Demolition Waste as Percentages of all Solid Waste entering Landfills

Country	Weight of Construction and Demolition Waste (%)
United States	26
Austrialia	20-30
Netherlands	20-29
Germany	19
Finland	13 -15
United Kingdom	26

Source: Bossink and Brouwers (1996) & UK statistics on Waste (2015)

There are many advantages to reducing construction waste, including protecting natural resources and using fewer virgin materials to make building materials, lowering costs by using fewer building materials, and lowering disposal costs. Additionally, Ling, and Lim, (2002) noted that cutting waste gives construction industry participants a competitive edge, particularly subcontractors, general contractors, and real estate developers.

1.1 Objectives

Using Abuja, Nigeria as a case study and the data generated from construction professionals working on building projects in Abuja, Nigeria, the purpose of this research is to investigate the causes of material waste and how they contribute to material waste generation on construction projects. The data for this research was generated from construction professionals working on building projects in Abuja, Nigeria.

2. Literature Review

Efficient Waste in Construction

Construction waste differs from municipal waste in that it is generated during the renovation, construction, modification, and demolition of roads, buildings, and other constructed facilities.[7]. Debris generated during the building, remodeling, or demolition of a structure is referred to as construction and demolition (C & D) debris. When compared to other types of waste, construction and demolition waste has a high volume and causes environmental and social problems.

Construction waste frequently has a distinct composition because it varies depending on the building type, construction method, country, and other elements. Concrete, asphalt, wood, metals, gypsum wallboard, and roofing are all components of construction and demolition debris. Similar to this, given how much waste is recyclable, determining the composition of waste is important for an effective waste management process.

Based on the work of Ferguson (1995), the construction waste management hierarchy is the best framework for organizing one's first waste management plan. Avoiding, eliminating, or drastically reducing waste at its source, and reusing or recycling waste materials were identified as the most effective solutions for building waste minimization by Faniran and Caban (1998).

Several authors have proposed methods and approaches for cutting down on waste in the building industry. Sustainability-wise, the most common and, arguably, best options for construction waste management are the three Rs (reduce, reuse, and recycle; 3R's) proposed by Patty et al. (2021). Information management platforms for construction waste can benefit from real-time monitoring, intelligent management, and control using popular building information modelling and geographic information system technology (Wang et al. 2021). Legislative reform is Australia's best bet for cutting down on construction waste, but this must be accompanied by new rules and procedures that prioritize prevention measures (Doust et al. 2021).

The use of waste management officers, off-site production of components, prefabrication, proper on-site waste management, and the implementation of a policy of material waste minimization plan are just a few of the methods for reducing construction waste that have been identified by Tafesse (2021) in the Ethiopian context. Ajayi and Oyedele (2017) suggest several key factors to limit the waste production threshold in a construction project contract, including effective transportation management in the material transportation process, strict adherence to the project drawing design during the construction process, and reduction of design changes.

According to Porwal et al (2020) .'s research, clients can cut down on waste by as much as 25% if they use BIM in their pre-project planning. Although construction waste generation is triggered in a variety of ways across industries, much of it originates in the building trades. Even so, authors from a wide range of nations have proposed various approaches to reducing waste in the construction industry. It is crucial to understand the construction waste production scenario and the root causes of construction waste generation within the context of the Nigerian construction sector due to the varying waste production scenarios across construction industries.

3. Methods

To gather the information needed to complete the study's goals, a questionnaire was created. Construction industry experts working for construction companies in Nigeria's capital city Abuja make up the study's population. The factors influencing the development of waste from construction materials on building construction sites in Abuja, Nigeria, were uncovered through in-depth questionnaires and interviews.

From the available literature, several variables that influence the accumulation of construction material waste on construction sites were discovered, and a total of 75 were chosen. Key players in the construction business (consultants and contractors), in the ratio of 100:50, were systematically given a total of 150 questionnaires.

It was asked of the respondents to rate these elements in terms of importance. The options for extremely important, very important, moderately important, slightly important, and not important were given the rating values of 5, 4, 3, 2, and 1 in order to determine how the respondents felt about the variables influencing the generation of construction material waste on construction sites in Abuja, Nigeria. The questionnaire served as the basis for the analysis of these parameters.)

4. Data Collection (12 font)

Methods of data analysis such as the Mean Score method, the Ranking method, and the Mann-Whitney U test were used during this research. In order to determine the degree of relevance and importance of the variables that impact the creation of material waste on construction sites in Abuja, Nigeria, the Mean Score technique was utilized.
The responses of the respondents were collected and turned into real scores.
The following mathematical example may be used to explain this point:

$$Rank\ Sum\ (S) = \sum_n W \qquad \text{Equation 1}$$
$$Mean\ Score\ (MS) = \sum_n \frac{W}{|N|} \qquad \text{Equation 2}$$

Where S = Rank sum, n = the highest attainable rating and W = corresponding weight of rank category, N = total number of respondents, MS = Mean score

A factor is considered "not important" if its mean falls between 0.5 and 1.49, "somewhat important" if it falls between 1.5 and 2.49, "moderately important" if it falls between 2.5 and 3.49, "quite important" if it falls between 3.5 and 4.49, and "very important" if it falls between 4.5 and 5.0.

It was necessary to further determine if consultants' opinions were statistically different from contractors' perceptions after establishing that consultants and contractors had distinct perspectives. Because of this, the Mann-Whitney U test became popular. The t-test is a parametric test; however, this alternative is a nonparametric test (Ho, 2006). The Z value and the significance level are taken into consideration in this test before a judgement is made on whether to accept a null hypothesis (2-tailed).

If the coefficient of determination or the probability value (p) is not less than or equal to 0.05, it indicates that there is not a statistically significant variation in the outcome, which means that the null hypothesis has been accepted.

5. Results and Discussion

Table 2 displays the results of an examination of how consultants see several elements influencing waste generation on construction sites. According to Table 2, out of a total of 75 considerations, experts rated 54 as somewhat important, while 21 were rated as very important. It is clear from Table 2 that all of these characteristics are significant, although to varying degrees.

As can be seen in Table 2, the average ratings of the elements responsible for waste accumulation on Abuja, Nigeria construction sites fall between 2.88 and 4.14. The average score for rework that deviates from drawings and specifications is 4.14 out of 5, with improper equipment receiving the lowest score (2.88) on average. This indicates that alterations made without following the agreed-upon blueprints is the consultant's top consideration when identifying causes of waste on Abuja, Nigeria construction sites, while inappropriate tools is the consultant's bottom concern. The data also revealed the extent to which consultants in the study area made use of and were familiar with construction equipment.

Table 2. The Perspectives of Consultants Regarding Selected Factors Contributing to the Generation of Waste in Abuja, Nigeria

Table 3 shows the results of a statistical analysis of the contractors' perceptions. It demonstrates that the contractors in Abuja, Nigeria, regarded 14 of the 75 characteristics as extremely significant, while 61 were seen as fairly important. Table 3 further reveals that all 75 criteria were deemed relevant by contractors, despite the fact that their value or contribution to waste generation varied, as demonstrated by the analysis. According to contractors, the mean scores of the elements contributing to waste generation on construction site in Abuja Nigeria range between 2.90 and 4.13.

Alterations made without following the agreed-upon blueprints has the highest mean score of 4.08 while difficulties in obtaining work permits has the least mean score of 2.86. This suggests that issues acquiring a work permit were viewed as the least essential element leading to waste generation on construction sites by contractors in Abuja, Nigeria, as opposed to Alterations made without following the agreed-upon blueprints

Table 3. The Perspectives of Contractors Regarding Selected Factors Contributing to the Generation of Waste in Abuja, Nigeria

Factors	1	2	3	4	5	Sum	MS	Rank
Alterations made without following the agreed-upon blueprints	1	1	25	21	37	347	4.08	1
Using excessive quantities of materials more than the required	2	11	14	32	26	321	3.78	2
Impossibility to order small quantities	1	5	25	34	20	320	3.76	3
Using untrained labour		6	24	33	22	320	3.76	3
Manufacturing defects	5	5	21	28	25	313	3.73	5
Slow response from the consultant engineer to contractor inquiries	4	7	13	48	13	313	3.68	5
Ambiguities, mistakes, and changes in specifications	7	9	19	22	28	309	3.64	7
Poor schedule of materials procurement	5	12	19	28	21	301	3.54	8
Theft and vandalism	4	11	22	28	20	301	3.54	8
Incomplete contract documents at commencement of project	1	10	27	34	13	299	3.52	10
Overproduction	3	10	29	24	19	296	3.48	11
Site conditions significantly different from contract documents	4	18	14	27	22	296	3.48	11
Severe weather conditions	4	13	29	14	25	295	3.47	13
Restiveness	4	17	14	34	16	294	3.46	14
Use of incorrect material	3	11	30	26	15	293	3.45	15

Errors in contract documents	5	14	18	32	16	293	3.45	15
Design changes and revisions	3	16	22	26	18	292	3.45	17
Lack of on-site materials control	4	10	26	32	14	291	3.38	18
Double handling of materials	2	14	28	23	18	291	3.42	18
Inadequate supervision	2	16	32	14	21	290	3.41	20
Effects of subsurface conditions	3	8	33	29	12	290	3.41	20
Manufacturer's non-involvement	3	12	19	44	7	290	3.41	20
Substitution of a material by a more expensive one	4	13	28	20	19	289	3.44	23
Accidents due to negligence	4	8	30	32	10	288	3.43	24
Selection of low-quality product	1	15	34	15	19	288	3.43	24
Breakdown of equipment	3	13	28	27	14	288	3.39	24
Unnecessary inventories on site	1	18	33	12	21	287	3.38	27
Interaction between various specialists	2	13	29	29	12	287	3.38	27
Poor site layout	2	21	15	33	14	286	3.36	29
Wrong handling of materials	5	10	28	31	11	286	3.36	29
Accident	8	12	22	24	19	286	3.36	29
Lack of attention paid to dimensions of product	2	14	33	19	17	286	3.36	29
Poor storage of materials		10	36	35	4	283	3.33	33
Lack of waste management plan	5	15	27	22	16	283	3.33	33
Over-sized of building elements during execution	4	13	31	23	14	283	3.33	33
Ambiguities, mistakes, and inconsistencies in drawings	6	19	14	30	16	283	3.33	33
Incompetent consultant engineer's staff	3	16	29	20	17	282	3.32	37
Bad road condition	2	12	37	21	13	282	3.32	37
Season of the Year	7	9	26	33	10	282	3.32	37
Unnecessary material handling	3	20	23	24	15	281	3.31	40
Inappropriate storage	4	22	20	21	18	281	3.31	40
Damage to work done caused by subsequent trades	1	13	39	21	11	280	3.29	42
Poor and wrong storage of materials	4	15	30	19	17	280	3.29	42
Incompetent contractor's technical staff	4	13	37	15	16	278	3.27	44
Lack of coordination among crews	4	24	20	19	18	277	3.26	45
Damage of materials on site	2	16	33	23	11	277	3.26	45
Damage during transportation	4	10	40	18	13	276	3.25	47
Purchase of material contrary to specification	3	13	37	19	12	276	3.29	47
Government authority	2	24	24	22	14	276	3.21	47
Poor workmanship	4	24	17	28	12	274	3.22	50
Inappropriate equipment	4	20	22	29	10	273	3.21	51
Over ordering or under ordering	1	27	14	37	6	271	3.19	52
Poor technology/malfunction of equipment	2	19	36	16	12	269	3.16	53
Waste from uneconomical shapes	4	15	33	29	4	268	3.15	54
Change orders	5	17	34	17	12	265	3.12	55

Lack of skilled subcontractors	4	24	21	27	9	264	3.12	56
Purchase of materials contrary to specification	3	18	40	13	11	264	3.11	56
Poor quality of materials	4	14	42	19	6	263	3.09	58
Insufficient instructions about storage and stacking	4	25	24	21	11	262	3.08	59
Insufficient instructions about handling	3	16	43	13	10	262	3.08	59
Contractor's non-involvement	2	17	40	19	7	262	3.08	59
Rework due to workers' mistakes	2	23	32	20	8	260	3.06	62
Inadequate stacking and insufficient storage on site	3	25	31	15	11	259	3.05	63
Difficulty in performance and professional work	5	18	34	22	6	257	3.02	64
Complexity of detailing in the drawings	5	20	36	13	11	255	3	65
Choice of wrong construction method	4	13	52	8	8	254	2.99	66
Over ordering or under ordering due to incorrect estimate	3	22	38	14	8	254	2.99	66
Lack of a quality management system	3	25	32	19	6	253	2.98	68
Waiting for design documents and drawings	2	21	44	10	8	253	2.98	68
Labour unrest	4	25	33	15	8	252	2.96	70
Specifying materials and dimensions without considering waste	8	25	20	22	10	251	2.95	71
Supplier's non-involvement	3	16	53	7	6	249	2.93	72
Lack of strategy to waste minimization	9	15	44	9	8	245	2.88	73
Lack of information about types and sizes of materials on design documents	6	32	23	14	10	244	2.87	74
Difficulties in obtaining work permits	5	33	23	14	10	243	2.86	75

5.1 Consultants and Contractors' Perceptions of Construction Site Waste Generation Causes

The first three elements are regarded equally by consultants and contractors, which accounts for their level of significance. These include rework that deviates from plans and specifications, design modifications, and waste from unprofitable shapes.

The hypothesis that there is no major difference in the perception of consultants and contractors about the variables contributing to waste creation on building sites in Abuja was hypothesized in order to determine further if there is a significant variation in their overall perception.

A Mann–Whitney U test at the 5% significance level (p 0.05) was used to examine the hypothesis. If the p value is greater than 0.05, then the hypothesis cannot be rejected by the test; but, if the p value is less than 0.05, then the hypothesis is rejected. Table 3 displays the results of the hypothesis test.
Table 4 displays the p-value from a Mann Whitney U test, which comes out to be 0.880. The significance level for this test has been exceeded by this value. This indicates that consultants and contractors in Abuja, Nigeria do not significantly differ in their opinion of the variables leading to waste generation on construction sites. Consultants' and contractors' shared understanding of the impact of construction waste on project outcomes is indicative of this awareness and knowledge.

There may be opportunities to improve construction project efficiency and save money by identifying the causes of waste production on construction sites, assessing those causes, and calculating each cause's relative importance and contribution to waste production. This will help to alleviate Nigeria's problem of construction cost overruns.

Table 4. The results of the Mann-Whitney U test to compare how consultants and contractors see things.

Rank group	N	Mean Rank	Sum of Ranks
Consultants	75	74	5475.50
Contractors	75	75	5554.50
Total	150		
Consultants'/Contractors' Perception			
Mann-Whitney U	60		
Wilcoxon W	125		
Z	−.15		
Asymp. Sig. (2-tailed)	.896		

For the purpose of this research, consultants and contractors were selected as representative major players in the building industry with the expertise to pinpoint the issues of waste generation. The contractors are responsible for managing resources and waste on-site and implementing waste minimization strategies and processes, while consultants are involved in planning and controlling costs from the beginning of a project to its conclusion. In addition, the variables that were included for the research were derived from the direct participation of these two groups in the building process.

Therefore, the dependability of the results is demonstrated by the fact that they agreed on how to rate the many elements that were stated. The same phenomena is shown in this research as well as in other studies that are similar in nature, where rework that is not in accordance with the specifications appears to be a major component contributing to the formation of material waste.

The findings of this study are beneficial to all parties involved in the building industry in terms of their costs, waste management, and control approaches.

6 Conclusion

This study's objective was to determine the elements that contribute to the development of waste from construction materials on building sites in Abuja, which is the capital city of Nigeria.

Based on the findings of the research, it was determined that " Alterations made without following the agreed-upon blueprints," " Revisions and alterations to the design," and " Spent resources on inefficient forms " are, in order, the three most important factors that contribute to the generation of construction material waste on building sites in the Abuja, Nigeria. It was also determined that all of the elements investigated in this study were seen as relevant by consultants and contractors as being involved in the generation of waste on site. The findings suggest that building sites in Abuja, Nigeria, make effective use of the construction equipment that is available to them.

Moreover, it was found that consultants and contractors do not have vastly divergent perceptions of the causes of waste generation on construction sites, and that contractors have few difficulties acquiring work permits in Nigeria's capital city.

This study advises that construction industry stakeholders take into account all the researched aspects at each stage of their construction processes and waste management plans to effectively optimize the performance of building projects in Abuja, Nigeria.

References

Adewuyi, T. O., & Odesola, I. A., Factors affecting material waste on construction sites in Nigeria. Journal of Engineering and Technology (JET), 6(1), 82-99,2015.

A. Imam, B. Mohammed, D.C. Wilson, C.R. Cheeseman, Solid waste management in Abuja, Nigeria, Waste Management, Volume 28, Issue 2, 2008, Pages 468-472, ISSN 0956-053X, https://doi.org/10.1016/j.wasman.2007.01.006

Ajayi SO, Oyedele LO., Policy imperatives for diverting construction waste from landfill: experts' recommendations for UK policy expansion. J Cleaner Prod. 147:57–65,2017..

Coventry, S., Patel, V., & Woolveridge, C. (1999). Waste minimisation and recycling in construction-Boardroom handbook. Ciria.

Doust K, Battista G, Rundle P., Front-end construction waste minimization strategies. Aust J Civ Eng. 19(1):1–11,2021.

Ekanayake, L., & Ofori, G. (2000). Construction material waste source evaluation.

Ho, R., Handbook of Univariate and Multivariate Data Analysis and Interpretation with SPSS. Florida: Taylor and Francis Group, pp. 226-228, 2006.

Ikau, R., Joseph, C., & Tawie, R., Factors influencing waste generation in the construction industry in Malaysia. Procedia-social and behavioral sciences, 234, 11-18,2016.

Ling, F. Y., & Lim, M. C., Implementation of a waste management plan for construction projects in Singapore. Architectural Science Review, 45(2), 73-81,2002.

Luangcharoenrat C, Intrachooto S, Peansupap V, Sutthinarakorn W. Factors Influencing Construction Waste Generation in Building Construction: Thailand's Perspective. Sustainability. 2019; 11(13):3638. https://doi.org/10.3390/su11133638

Patty R, Bera DK, Rath AK. 2021. Strategies for construction and destruction (C&D) waste management. Paper presented at the Recent Developments in Sustainable Infrastructure, Singapore.

Poon, C. S. (2007). Reducing construction waste. Waste management, (12), 1715-1716, 2007.

Porwal A, Parsamehr M, Szostopal D, Ruparathna R, Hewage K. 2020. The integration of building information modeling (BIM) and system dynamic modeling to minimize construction waste generation from change orders. *International Journal of Construction Management* https://doi.org/10.1080/15623599.2020.1854930.

Tafesse S., Material waste minimization techniques in building construction projects. Eth J Sci Technol. 14(1):1–19, 2021.

Thailand Pollution Control Department. Study of the Guideline for Construction and Demolition Waste Management in Thailand. Available online: http://www.pcd.go.th/public/publications/print_waste.cfm?task=wastemana50_1 (accessed on 19 September 2022).

Wang A, Wang N, Li K, Ren F. 2021. Preliminary study on the integration control platform of construction waste based on "BIM&GIS" technology. E3S Web Conf. 237:01034.

Yi CJ, Seow TW, Chen GK, Shafii H., Waste minimization in construction using building information modeling (BIM) approach. Res Manage Technol Bus. 2(1):999–1020, 2021.

Biography

Chukwumaobi Ibe is a doctoral researcher and graduate teaching assistant at Sheffield Hallam University's Social and Economic Research Institute (SERI) under the department of Natural and Built Environment England UK. He is an interdisciplinary scholar with a bachelor's degree in mechanical engineering from the University of Nigeria Nsukka and a Master's degree in Industrial Design from the department of Civil Engineering and Architecture sciences at Polytechnic University of Bari Italy. An Erasmus scholar and graduating top of his class with a Distinction, his research interests are in Natural and built environment, sustainable production and consumption, product and packaging design, design for public space and particularly drawn to researching and designing novel methodologies that would reduce the environmental impact of construction materials and adoption of a circular economy within the building sector.