Examining Sustainable Construction Waste Management Methods for Potential Performance Improvement

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Abstract
Approximately 30 percent of municipal solid waste is typically comprised of construction debris, posing a significant challenge to municipal authorities in almost every city in the world, especially those in developing nations. Adoption of sustainable waste management methods in the Nigerian construction industry is crucial because, as long as man continues to construct, sustainable practices will remain a necessity. Change comes with numerous challenges and the adoption of sustainable waste management practices is not an exception. It is on this note that this study attempts an assessment of sustainable waste management in the Nigerian Construction Industry. Existing methods of waste disposal were outlined, familiarity with sustainable waste management practices was evaluated, challenges hindering the execution of sustainable waste disposal practices were identified as well and it was assessed using mean score. The study revealed that the most familiar waste management methods in the construction industry are Re-Use, Recycling & Landfilling. The most practiced waste management methods are reuse, burning &landfilling. Inadequate government support for green technology and insufficient encouragement and support from the construction industry's various professional organisations were identified as the most significant obstacles to sustainable waste management methods. The study recommends that construction companies should focus more on waste management through reduction of the total amount of construction waste generated and leaving disposal as a last resort. Also, the Government and the Governing bodies of construction professional bodies should put conscious efforts into supporting the execution of construction projects with the aim of using green technologies, sustainable construction methods as well as sustainable methods of waste management.

Keywords: Waste management, Sustainable construction, Construction & Demolition Wastes, Re-Use, Recycling and Landfilling

Introduction
The construction industry is a vital part of the economic backbone in many countries and its activities affects national development [Fei, et al., 2021]. Construction and demolition wastes (C&DW) are the materials that are generated when new buildings and civil engineering structures are being built, and also when existing buildings and civil-engineering structures are being renovated or demolished with deconstruction activities [Erich, 2020; Dajadian & Koch, 2014]. However, waste material generation is a prominent issue in construction projects, and the adverse effect of waste has influenced the management of C&DW in many countries [Ekanayake & Ofori 2004]. C&DW is the major contributor to nearly 15–30% of the volume of wastes disposed in several landfill sites in most countries [Erich, 2020; Duan, et al, 2019].

The construction industry is faced with many challenges among which is waste management, construction waste is already causing safety and environmental concerns around the globe [Babatunde & Low, 2013]. Aside from the fact that wastage contributes to time and cost overrun, it also has environmental implications in the form of pollution [Ogunmakinde, Sher & Maund, 2019]. The majority of this waste has not been well managed, thus causing substantial health and environmental problems which affects the performance of many projects in Nigeria

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[Ogunmakinde, Sher & Maund, 2019]. Studies have shown that waste from the construction industry accounts for a sizable portion of production costs [Povetkin, & Isaac, 2020]. As a result, poor material and waste management raises the overall cost of construction projects. Sustainable waste management is an essential component of a circular economy. It is a systemic approach to economic development that opposes the take-make-waste model and seeks to decouple growth from the consumption of finite resources [Duan et al, 2019]. Sustainable waste management not only addresses the broader issues of a linear consumption society, but it also provides more direct solutions to the numerous problems caused by waste However, the industry has the capacity to effectively manage waste, from generation to disposal. All stages of the management process are important, but scholars and governments have provided the final step, being disposal, unabated attention in order to ensure effective management [Kabirifar, Mojtahedi, Wang & Tam, 2020]. Therefore, this study aims to investigate methods of suitable waste management with a view to securing methods of sustainable waste management.

Literature Review

Construction Waste

Construction waste is a topic that can be discussed broadly and lacks a general definition. The term "construction waste" refers to any material that results from building sites, ripping down structures, or a combination of the two. Construction waste is defined as the difference between the value and quantity of materials purchased and the quantity of materials used appropriately and accurately. Construction waste is a collection of surplus materials created during the building, maintenance, and demolition of new structures, bridges, roads, and other related civil engineering projects (Obaid, Rahman, Idan, & Nagapan, 2019). Various sources of construction waste as well as their causes have been identified in Table 1:

Table 1: Causes of Construction Wastes

Group	Causes of Construction Waste
Design	Last minute client requirements, Frequent design changes, Design errors, Slow drawing distribution, Interaction between various specialists, Error in contract documentation, Lack of design information, Inexperience designer.
Procurement	Congestion of the site, Interference of other crews at site, Poor site condition, Waste resulting from packaging
Management Factors	Late information drift amongst parties, Poor of quality information, Lack of coordination amongst parties, Inappropriate methods of construction, Rework, Lack of environmental information, Lack of influence of contractors, Lack of knowledge about construction, Communication problems, Resources problems, Non-availability of equipment, Out-dated equipment.
Construction Operation/ Project management	Poor workmanship, Improper project planning, Poor supervision, Poor site conditions, Reworks Due to Errors, Leftover from cutting and shaping, Inadequate knowledge, Materials off-cuts
Site Condition	Unforeseen ground conditions, Difficulties accessing construction site, Leftover materials on site, Poor site condition, Waste resulting from packaging, Lighting problem
Handling	Poor Materials Storage, Poor Materials Handling
External factors	Effect of weather, Anti-acceleration, Accidents, Inappropriate use of materials
Workers	Worker's no enthusiasm, Insufficient training for workers, Inventory of materials not well documented, Too much overtime for workers, Workers' mistakes during construction, Lack of experience, Incompetent workers, Poor workmanship.

Adopted from [Duan et al, 2019; Ogunmakinde et al, 2019; Kabirifar et al, 2020; Nagapan, Rahman & Asmi, 2011, Povetkin, & Isaac, 2020]

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Construction Waste Management Methods

Recycling

Recycling is defined as the act of recovering a material's value at the end of its useful life and using it again to create a new product for ongoing use in either its primary or secondary condition. [Ortiz, Pasqualino, & Castells, 2010] Recycling helps to conserve potential resources while reducing the consumption of finite resources. However, its drawbacks include a disregard for product efficiency and quality as well as a dearth of energy recovery. [Tam, & Tam, 2006; Mohammed et al., 2020]

Incineration

Incineration disposes wastes by means of combustion at high temperature, which could be through the central system or on-site. The advantages of incineration are waste reduction, production of electricity, and heat energy [Tam, & Tam, 2006], while the disadvantages include pollution in the form of acid rain and ash production [Cho, Nam, An & Youn, 2020].

Composting

In order to decompose organic waste, composting uses natural microbial organisms [Tam, & Tam, 2006]. Due to its aerobic nature, it contributes to global warming by generating carbon dioxide, glass-like debris, and polymers. [Oliveira et al., 2017].

Landfilling

According to Ortiz, Pasqualino and Castells (2010), landfill is described as a designated space on the earth's surface where waste materials are buried. Usually, landfills are for a specific period of time and comprise two types, which are sanitary and natural attenuation [Ajayi, & Oyedele, 2017; Siddiqua, Hahladakis, & Al-Attiya, 2022]. Its advantages include job opportunities for scavengers and energy generation from the gases produced. Landfills used to be the cheapest and most economical method of waste disposal, but its negative effects on the environment makes it unsustainable.

Open Dumping

Another low-cost disposal practise is known as "open dumping," in which waste is recklessly thrown in public areas such site corners and kerbs along roads [Siddiqua, Hahladakis, & Al-Attiya, 2022]. This approach has no benefits other than the fact that it is inexpensive; nonetheless, there are a number of drawbacks, such as the risk of fire and airborne infections. [Ogunmakinde et al, 2019].

Burning

Similar to open dumping, which involves starting fire to refuse, is burning. This alternative carries some dangers, such as the possibility of fire, explosion, and air pollution. Additionally, the greenhouse gases released during the process contribute to the destruction of the ozone layer. [Ogunmakinde et al, 2019].

Reuse

Reuse is any process that allows for the continued use of non-waste items or components for the original purpose. Reuse as a method of disposal guarantees effective waste reduction, which is made possible through direct or indirect use. In terms of the environment, it lowers waste, energy use, greenhouse gas emissions, and air pollution. It improves interpersonal communication and lowers the price of creating new materials [Mohammed *et al.*, 2020].

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Shredding

Another waste disposal technique is shredding, which uses a mechanical process to reduce the size of the garbage. The fact that these materials are ultimately disposed of via different disposal techniques suggests that shredding serves as a tool rather than an aim in and of itself. Other waste disposal techniques, outside reuse and recycling, are obviously not environmentally friendly, and as a result, it can be inferred that they are not sustainable [Ogunmakinde et al, 2019].

Pyrolysis

In contrast to incineration, pyrolysis ensures that materials thermally decompose at extremely high temperatures and without oxygen [Czajczyska et al., 2017]. It has the capacity to decrease waste volume, decompose harmful substances, and generate fuel-efficient gases. However, it also creates ashes that pollute the air and result in pollution. Similarly, pyrolysis is not economically viable because to its high running costs, particularly in underdeveloped nations [Czajczyńska et al., 2017].

Materials and Methods

Study Area

This research was carried out in the Abuja Metropolis. Abuja is the capital and eighth most populous city in Nigeria, located in the centre of the country. To ensure that adequate and reliable data is collected, the sample is required to be homogenous and comprehensive and should give a true representation of the population. Therefore, this study population included professionals in the construction industry that are involved in waste management, these consist of quantity surveyors, architects, civil engineers, project managers, and builders in construction firms within Abuja, Nigeria.

Population and Sampling Size

For the purpose of this study, 50 construction sites were visited comprising of both public and private projects that have a value above 100 million naira. This project cost was enquired of the project manager who had access to the project BOQ. The rationale for this selection is that building construction projects of this value and above are likely to generate large quantities of material waste and also have more experienced professionals than in smaller-sized projects. The population for this study comprised of all ongoing construction in FCT Abuja being the capital of Nigeria and the fastest growing city. However, it was impossible to determine the total number of ongoing construction and therefore a minimum sample size of 50 was adopted (Mundfrom, Shaw & Ke, 2005), of which 47 were filled, suitable and analysed for this study. This involved identifying and selecting individuals or groups of individuals that are especially knowledgeable about or experienced with a phenomenon of interest [Suri, 2011].

Results and discussions

Nature of construction project sampled

In order to generate robust data for the study, various types of construction projects were visited which include new construction projects, renovations and demolition works. Furthermore, data generated was analysed using descriptive statistics.

From Table 2 below, 45% of the respondents were involved in new construction projects, 34% in renovations and the remaining 21% in demolitions.

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Table 2: Type of construction project involved

S/No	Type of construction project	Frequency	Percentage
1	NEW BUILD	21	45%
2	RENOVATIONS	16	34%
3	DEMOLITION	10	21%
	Total	**47**	100%

Source: Field Survey, (2022)

Familiarity with Sustainable Waste management methods

Level of Familiarity with Sustainable Waste management methods was also analysed in order to assess how familiar professionals involved with waste management were.

Table 3: Respondents Familiarity with Waste management methods

S/No	WASTE MANAGEMENT METHODS	∑Weighted Values	Weighted mean	Rank
1	Recycling	208	4.16	**2**
2	Re – Use	210	4.20	**1**
3	Incineration	207	4.14	**4**
4	Composting	169	3.38	**8**
5	Landfilling	208	4.16	**2**
6	Open dumping	203	4.06	**5**
7	Burning	199	3.98	**6**
8	Shredding	174	3.48	**7**
9	Pyrolysis	124	2.48	**9**

Source: Researchers' Computation

It is observed from table 3 that reuse is the most familiar method of sustainable waste management with a mean score 4.20 while recycling and landfilling ranks 2nd with mean score of 4.16. On the other hand, composting and pyrolysis rank 8th and 9th respectively as the least familiar method of sustainable waste management.

Adopted Waste Management Methods

The method of waste management and disposal adopted by the professional involved was also analysed as shown in Table 4.

Table 4: Respondents Adopted methods of sustainable waste disposal

S/No	WASTE DISPOSAL METHODS	∑Weighted Values	Weighted mean	Rank
1	**Recycling**	30	0.60	4
2	**Re – Use**	37	0.74	1
3	**Incineration**	27	0.54	6
4	**Composting**	21	0.42	8
5	**Landfilling**	31	0.62	3
6	**Open dumping**	30	0.60	4
7	**Burning**	34	0.68	2
8	**Shredding**	26	0.52	7
9	**Pyrolysis**	15	0.30	9

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Ranking 1st and 2nd respectively as the most used form of waste management from the table above are Re-use and Burning with a mean score of 0.74 & 0.68. While composting and pyrolysis rank 8th and 9th as the lease used method of waste management with a mean score of 0.42 & 0.30.

Challenges Hindering the Execution of Sustainable Waste Management Practices

Challenges Hindering the Execution of Sustainable Waste Management Practices were also identified and analysed as shown in Table 5.

Table 5: Challenges Hindering the Execution of Sustainable Waste Management Practices

S/No	Challenges Hindering Sustainable Waste Management Practices	∑Weighted Values	Weighted mean	Rank
1	High cost of recycling	175	3.50	12
2	Quality of recycled materials	172	3.44	14
3	Inadequate government support to green technology	204	4.08	1
4	Inadequate knowledge of sustainable construction principles	190	3.80	5
5	Inadequate expertise in the sustainable construction field	189	3.78	6
6	Lack of interest among project team members	175	3.50	12
7	High cost of implementation of sustainable practices	184	3.68	7
8	Lack of efficient management systems to implement sustainable construction practices	194	3.88	4
9	Inadequate encouragement and support from professional bodies	204	4.08	1
10	Resistance to change from construction professionals	177	3.54	11
11	Lack of government support for sustainable construction	203	4.06	3
12	Inadequate knowledge of the practical application of sustainable construction	184	3.68	7
13	Low demand by clients	178	3.56	9
14	Inadequate knowledge of sustainable materials and building systems	178	3.56	9
15	Lack of credible research on the benefits of sustainable constructions	168	3.36	15
16	Unavailability of locally sourced materials for sustainable construction	163	3.26	16

It is observed from the table 5 above that inadequate encouragement and support from professional bodies & Inadequate government support to green technology both had the highest mean score of 4.08 as the highest challenges hindering the practice of sustainable waste management methods. While Lack of government support for sustainable construction ranks 3rd with a mean score of 4.06. On the other hand, Lack of credible research on the benefits of

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sustainable constructions and Unavailability of locally sourced materials for sustainable construction rank 15th and 16th as the least on reasons why sustainable waste management methods are practiced in Abuja, Nigeria.

Discussion

Generally, the research identified waste management methods with "Re-Use" ranking the highest as the most used/adopted sustainable waste management method while "Pyrolysis" ranked the least. The familiarities with sustainable waste management methods were also assessed, analyzed and from the findings it was gathered that "Pyrolysis" came in lowest therefore, ranked the least and "Re-Use" ranked higher again as the most familiar method of waste disposal.

The research also analyzed the challenges hindering the use of sustainable waste management methods and it was discovered that "Unavailability of locally sourced materials for sustainable construction" is the least among the challenges hindering sustainable waste management methods. "Inadequate government support to green technology" & "Inadequate encouragement and support from professional bodies" are the biggest challenges faced by the construction professionals hindering waste management methods.

The questionnaire respondents identified recommended suitable methods of waste management in Nigeria based on their experiences and majority mentioned "recycling" as the most suitable method of waste management. The study revealed the waste management methods that the construction industry professionals are most familiar with which were, Re-Use, Recycling, Landfilling, Incineration and Open Dumping. With Burning, Shredding and Pyrolysis left as the waste management methods with least familiarity.

The waste management methods that are actively practiced by the construction industry professionals were also researched, they include; reuse, burning, landfilling recycling and open dumping. Leaving incineration, composting, shredding and pyrolysis as the least practiced methods of waste disposal in Nigeria. The research also analysed the challenges hindering the use of sustainable waste management methods and it was found out that, the some of the cause of non-use of sustainable waste disposal methods are Inadequate government support to green technology, Inadequate encouragement and support from the various professional bodies in the construction industry and lack of government support for sustainable construction.

Finally, the study identified recommended suitable methods of waste management in Nigeria. Recycling, Landfilling and compost were the method most recommended by construction industry professionals. This means that for improvement in the management of construction waste, these methods should be developed and advanced for better waste management.

Conclusion

Having carried out a survey on the construction professionals via administered questionnaire, the result of this study shows that there is a lot of work to be done majority of which lies with the Government and the Governing bodies of construction professional bodies. The Government hand in hand with these professional bodies need to work together to a sustainable environment of which sustainable waste management practice is part of. Instead of focusing on waste disposal methods which are not sustainable, construction professionals should focus on waste management which is more concerned about reduction of the total amount of construction waste generated and leaving disposal as a last resort.

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Recommendations

Directives regarding the development of a sustainable waste management plan requires the involvement of experts and professionals who meet the requirements to supervise site operatives, as well as awareness among craftsmen and women to give them concrete information and training in practice. However, this can reduce construction and demolition waste only in a negligible manner. The Government and the Governing bodies of construction professional bodies should put conscious efforts into supporting the execution of construction projects with the aim of using green technologies, sustainable construction methods as well as sustainable methods of waste management.

When the waste management approach is implemented, it can cause a reduction in the construction costs, improvement of output, better storage and handling of materials transported to sites. In addition, the need for the application of proper construction detailing and precise design cannot be overemphasized. A high requirement of expertise should be in place when selecting construction industry professionals as site supervisors in order to ensure the process of design is not marred with errors that could possibly generate huge amounts of construction waste.

To ensure that waste management is sustainable in the Nigerian construction industry, the procurement procedure and policies must focus on ways to eliminate or minimize waste. Site engineers must painstakingly take note of every detail in the drawings provided for the construction projects in Nigeria. In addition, awareness should also be made to promote secondary material sales which thus expand the secondary market.

Recommended Areas for Further Research

Having carried out research on examining sustainable construction waste management methods for potential performance improvement, it is recommended that further research should be made on the assessment of waste reduction practices at the design stage of construction projects.

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