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Analysis of Trends of Building Construction Worldwide and The Global Implications

K.B. FAGBEMI
Federal Polytechnic, Ile-Oluji, Ondo State, Nigeria

S.O. TONGO
Olabisi Onabanjo University, Ogun State, Nigeria

Y.O. HASSAN
University of Lagos, Nigeria

Abstract. In every period to date, wastages in construction have remained a burden to all stakeholders in the built environment. Today, there is a modification in the construction process globally and this emphasizes the need for a healthier and more sustainable built human environment. This change in emphasis is noticeable partly because construction site waste management and minimization have rarely been planned for in the past few decades and ultimately may eliminate waste in the construction process. It has dramatically changed the urban landscape in recent times, especially in major cities in developed countries. Waste in construction occurs in a variety of ways, in a variety of forms, and in great magnitudes/degrees. For example, there are very few building operations that are absolutely waste-free. Contemporarily, reducing wastage across the building construction process has been discussed broadly in the scientific community by professionals in the built environment and of course by the general public. With the growing construction activities worldwide, it raises a swirl of questions, how did we get to this point, and are the alternatives more desirable? In answering this question, this paper identified and discussed extensively fifteen major distinct trends that are responsible for the wastage in building construction in most cities

Keywords: Trends, Construction, Construction Wastage, Worldwide, Global Implications

1. Introduction

Waste is an inevitable by-product of most human activity. Debris from construction sites ends up in landfills, uncontrolled sites or in other inappropriate places (Tongo, et al, 2020). Construction waste is a universal issue that matters to every single person in the world. This common practice causes a number of impacts on the environment, including pollution of air, surface water and underground water, risks to public health and loss of natural resources. This has geared the attention of scholars and policymakers in order to obtain long-running protection of the environment so that future generations can also make use of natural resources (Sustainable Industrial Design and Waste Management, 2007).

Throughout the world, the strongest demand for resources comes from construction projects, and the single largest waste stream is found in construction, waste generated largely by intensive construction activities, which account for 82.7% of all waste produced by economic activities globally (Eurostat, 2009). As a result of urbanization, construction activities are set to increase, and one of the greatest challenges facing the entire world is to become a "recycling society". From now on, all will have to take the necessary measures to ensure that, in years coming, 70% by weight of all non-hazardous waste from construction (with the exclusion of noncontaminated soil and rocks from excavation) are intended for reuse, recycling, and material recovery operations, including filling operations using waste to replace other materials.

The construction industry is labelled as one of the largest and most important industries; and at the same time the major consumer of natural resources and one of the largest polluters (Tongo, et al, 2020). Globally, studies have confirmed that waste production is inevitable on a construction site even a modest site can produce huge volumes of waste (Environmental Recovery Corporation (ERC), 2021). These activities of the industry generate increasing magnitudes of waste which has created a bad image for the industry and also depletes the limited natural resources. The wastes generated by the industry have not been successfully managed, thus triggering significant health and environmental problems. Wastage on construction sites has become a scourge in the Nigerian construction industry (Adewuyi & Otali, Evaluation of causes of construction material waste - Case of Rivers State, Nigeria, 2013). In construction, 4-M (Material, Manpower, Money Machine) plays a crucial role.

Depending on the type of housing project, building materials account for 60 to 70% of the project cost. Through the material waste management function, we can reduce the overall project cost by waste minimization or maximum utilization of resources (Material) (Meghani, Bhavsar, Vyas, & Hingu, 2011). This delinquent has adversely affected the performance of many projects in Nigeria. A study by Adewuyi et al, (2013) cited Obiegbu (2002) perceived that wastage in construction firms has come to stay considering the fact that at least 5% is achieved when preparing the estimate for a project which is usually not adequate. Wastage can be seen in many ways in the particularity of construction works. In light of this, a very high level of waste is assumed to exist in construction. Although it is difficult to systematically measure all wastes in construction, partial studies from various countries have confirmed that waste represents a relatively large percentage of production costs. A wide range of measures have been used for monitoring waste, such as excess consumption of materials (Skoyles 1976; Bossink and Brouwers 1996), quality failure costs (Cnudde 1991), and maintenance and repair costs, accidents, and nonproductive time (Oglesby et al. 1989). There have been different descriptions of materials wastage in buildings projects by different authors.

Adewuyi et al, (2013) and Shen and Tam, (2002), defined materials wastage in buildings projects as the difference between the value of materials delivered and accepted on-site and those properly used as specified and accurately measured in the work after deducting the cost-saving of substituted materials transferred elsewhere in which unnecessary cost, building material wastage can be defined as the difference between the value of materials delivered and accepted on-site and those properly used as specified and accurately measured in the work after deducting the cost-saving of substituted materials transferred elsewhere in which unnecessary cost and time may be incurred by the material wastage.

Despite disparities in the construction projects, potential material waste is caused by similar inefficiencies in design, procurement, material handling, operation, or residual on-site waste such as packaging (Adeagbo, et al, 2016; Wahab & Lawal, 2011; Formoso et al., 1993; Gavilan and Bernold, 1994). However, this study will examine the causes or factors affecting construction material waste generation on building construction projects, and similarly considered and analyzed these factors statistically.

Poorly managed construction waste is contaminating the world's oceans, clogging drains and causing flooding, transmitting diseases, increasing respiratory problems from burning, harming animals that consume waste unknowingly, and affecting economic development, such as through tourism. The question often asked is how we get to this point of resilience and overreliance mode of construction. To answer this question therefore this paper identified and discussed extensively fifteen major distinct trends that are responsible for construction wastage in most cities of the world.

2. Literature Reviews

The activities in the building life cycle management entail a step-by-step development process. This involves putting together large quantities of resources and the employment of many people over some time to create a physical structure that is called a building (Farida et al. 2018). This consists of many parts that interrelate with one another and with the environment, leaving both physical and non-physical impacts due to its direct and indirect actions. According to Dahlbo, Bacher, Lahtinen, Jouttijarvi, Suoheimo, Mattila, Sirone, Myllymaa & Saramaki (2015), building construction activities globally consume about three trillion kilogrammes of raw materials annually with a large portion of them ending up as waste. The wastes from these activities are generated across the building life cycle stages (Dahlbo et al., 2015; Odusami, Oladiran & Ibrahim, 2012). Also, these researches reported that the system of procuring a building project generates wastes from all its processes which take time to realise and use (that is, both material and non-material resources) to generate direct and indirect costs without added value.

In recent years, different scholars around the world (Wang et al., 2014; Osmani, 2011; Kofoworola & Gheewala, 2009) have carried out several studies into the nature, cause, and impact of wastes from building procurement activities. Some of these studies aimed at the causes of waste and the environmental damage resulting from a large amount of waste generated. Others simply aimed at identifying measures for preventing and reducing material waste generation from procurement activities while a very small group of researchers concerned themselves with the cost implications of waste in building projects. In all, most of the studies reviewed in this study tended towards wastes emanating during the implementation/construction phase of the building process with little or nothing during the other stages. During the activities at the construction stage, the physical material bye-products generated are synonymous to waste. Generally, these studies established that building life cycle activities lead to the production of wastages. These activities are for simplicity referred to as off-site and on-site operational activities. The on-site activities of building construction are related to the development of a building. It includes the substructure and superstructure works of the building, while the off-site activities include the prefabrication of some components of the building to be delivered, project design (architectural and engineering designs) manufacturing as well as transporting of materials and components. According to Won and Cheng (2017), prefabrication of building components can reduce waste and ensures timely delivery of building projects, but it can lead to an increase in the cost of a building.

Wahab & Lawal (2011) described material waste generation as an inevitable by-product of the process of procuring a building project and that this is one reason why the quantity surveyors allow factors for waste in the pricing of the bill of quantities. Similarly, many studies across the globe report that the implementation stage activities of the life cycle of a building process generate the largest waste streams in the EU, accounting for between 25% and 30% of all waste generated. In the U.S., reports have it that over 100 million tons of waste are generated every year from construction activities and this amounts to approximately 30% of the entire solid waste stream, while in Brazil, it is between 20% and 30% when computed by weight of the total materials delivered on-site. In the United Kingdom, it is reported to be between 55% and 65% of the total material used for projects (Aleksanin, 2019; Pakhare, More & Bhalerao, 2017).

According to Obiegbu cited in Adewuyi & Otali, (2013), the material wastage from the implementation stage of the building procurement process has come to stay a norm in the construction industry. The study further reported that in principle about a 5% allowance is made for waste when pricing the bill of quantities (BoQ) for a building project. In some later study by Dajadian and Koch (2014), it was reported that in Nigeria the cost of only the materials used for constructing a building measures up to over 50% of the estimated total cost of the building and at least 20% of the building materials purchased for the works that are leftover at the end of the project. These leftovers may remain on the project sites unused and treated as waste that may never be accounted for. Building waste therefore in this study is referred to as any loss and/or inefficiencies originating directly or indirectly from building procurement and development activities. Such include design, tendering, construction, and habitation generating both direct and/or indirect costs and adding no value to the finished building project.

In conclusion, the rising rate of building development activities in Nigeria and many of the other developing countries following the population increase has resulted in an additional need for housing and other forms of building projects and insufficiencies in infrastructure provisions. These increases have inevitably led to the creation of huge amounts of building waste across the entire life cycle stages. Building waste generation has risen to reach a critical level to become a burden to the environment and the socio-economic conditions of many nations.

Table 2.1 shows the summary of findings on physical waste generation from the rest of the world by different researchers stating what is generated and/or what is delivered to the different landfill sites in percentages. From Table 2.4, it is seen that several (about 4 billion) tonnes of building waste which translates to about 40% of the municipal waste are generated and deposited at the various landfills globally (Kupusamy, Nagapan & Abdullah, 2019; Crawford, Mathur & Gerritsen, 2017; Becqué, Mackres, Layke, Aden, Liu, Managan, … Graham, 2016; Begun et al., 2006). Likewise, between 30%-40% of the building materials purchased for the works are seen to end up as waste on project sites (Kupusamy et al., 2019; Crawford et al., 2017). The building waste generation per the total weight of municipal waste received at the landfills in the industrialised nations is between 31-35% of all industrial waste within Europe (Aleksanin, 2019; Pakare et al., 2017; Eurostat, 2016; Department for

Environment, Food, and Rural Affairs (DEFRA, 2008).

Similarly, it is seen from Table 2.4 that, the building waste per the total weight of municipal waste received at the landfills is about 33% in the UK, 26-30% in the U.S., 35% in Canada, 42%-44% in Australia, and about 40% in mainland China (Aleksanin, 2019; Pakare et al., 2017; DEFRA, 2009; Kofoworola & Gheewala 2009. In Hong Kong, it is seen to have reached about 23% of the things deposited at the landfill (HKEPD, 2019), and between 15% and 30% in Kuwait, 75% in UAE, and 55% in the other Gulf countries (Gulf News, 2018). Additionally, Agyarkwa et al. (2012) reported that in Ghana between 5% and 27% of the total materials purchased in building projects are wasted, while Oladiran (2018); Adewuyi & Otali, 2013; Odusami et al., 2012 reported that in Nigeria, about 5% is allowed in the build-up of the unit rates used in pricing a bill of quantities (BoQ) as waste. Also, between 5% and 7.5% of the total materials purchased for a building project end up as waste on project sites in Nigeria depending on the type of work to be undertaken (Adewuyi & Otali, 2013; Odusami et al., 2012).

Table 2.1: Building and Construction Waste Burden

COUNTRY	BUILDING MATERIAL WASTE GENERATION	REFERENCES
All over the world	About 40% of the wastes received at the landfill sites are Construction and Demolition (C&D) wastes. And, 30-40% of building materials purchased.	Kupusamy et al. (2019); Crawford et al. (2017); Becque et al. (2016); Begun et al. (2006)
European Union	About 31-34% of the total waste disposed of in landfills is C&D waste.	Aleksnin (2019); Pakare et al. (2017); DEFRA (2012)
United Kingdom	At least 10-15% of all the raw materials purchased and delivered to most construction sites are wasted through damage, loss, and over-ordering. 33% of the total waste generated is C&D in nature and more than 50% of the total waste deposited at the landfill is C&D waste.	Aleksnin (2019); Pakare et al. (2017); DEFRA (2012); Kofoworola and Gheewala (2009); Keys et al. (2000)
United States of America	In the US, C&D waste makes up about 26-30% of the volume of material in the landfill yearly.	Aleksnin, 2019; Pakare et al. (2017); Al-Hajj and Iskandarani (2012)
Canada	About 35% of the volume disposed at the landfill is C&D waste.	Aleksnin (2019); Pakare et al. (2017); DEFRA (2009) ; Begum et al. (2009); Kofoworola and Gheewala (2009)
Japan	10-30% of the total waste received at the landfill sites, and 70% of all illegally dumped waste comes from construction activities since 2004.	Polat et al, 2017
China	About 29% of the world's total municipal. 40% of this fall within the C&D category, and around 30% - 40% of building materials used on construction projects end up as waste on building sites.	Aleksnin (2019); Pakare et al. (2017)
Hong Kong	About 5-10% of building materials end up as waste on building sites; this amounts to about 65% of the total waste generated, and 23% of this is deposited at the landfill.	HKEPD (2019); EPD (2016); Kofoworola and Gheewala (2009)
Australia	About 42-44% of the total waste generated is C&D in nature which translates to about 20-30% of the waste deposited at the landfill.	Kofoworola and Gheewala (2009)
Brasil	The average material wastage is between 20%-30%, depending on the building technology	Lafayette, Fernandes da Paz, Holanda & Costa (2018)
Kuwait	The country produces 15-30% of solid waste through construction activities.	Kartam, Al-Mutairi, Al-Ghusain and Al-Humoud, (2004)
GCC Countries	About 55% of the total waste stream is from construction activities.	Gulf News (2018)
United Arab Emirates	About 75% of the total waste stream generated in UAE is from construction projects.	Gulf News (2018)
Ghana	It is reported that about 5-27% of the total materials purchased in construction projects in Ghana end up as waste at the end of a project.	Agyarkwa, Agyekum and Adinyira (2012)
Nigeria	About 5% of the unit rates are for in the pricing of a bill of quantities (BoQ) as waste in Nigeria. Also, between 5-7.5% of the total materials purchased for the project end up as waste on projects sites in Nigeria depending on the type of work to be undertaken.	Oladiran (2018); Adewuyi and Otali (2013); Odusami (2013) Oladiran (2018)
Tanzania, Zambia, Zimbabwe, and Botswana	About 20-25% of building materials are wasted on construction sites.	Datta (2000)

Source: Adapted from Nagapan et al. (2011).

3. Materials and Methods

This study was conducted with a review of literature, and the use of a structured questionnaire and a field survey to practically identify the common trends shaping construction wastage in Nigeria and determine the implications of this globally according to construction phases. A achieved this, a total of 96 building sites located in different 6 regions that made up Nigeria were visited. Some typical figures for the waste of some key construction materials are provided, and the main causes of waste in the sector are discussed.

4. Discussion and findings

To achieve the objective of common trends shaping construction wastage on a building project that is associated with waste generation, information from the respondents' responses to the questions on the sources of building material waste and the enormity of their contributions was analysed. The options ranged from none (1) to extreme (5), on a 5-point Likert scale and the mean scores were computed to rank the life cycle stages of building projects with the highest burden of waste. The means of the perceived burden of waste for each of the stages were recorded. The scores from 0 to 1.49, were recorded as 1 (none); 1.50 to 2.49 as 2 (little). The mean scores from 2.50 to 3.49 were recorded as 3 (moderate), 3.50 to 4.49, recoded as 4 (Great) and 4.50 to 5.00, recoded as 5 (extreme)

As shown in Table 4.1, the post-construction stage activities ranked 1st with the highest mean item score of 3.5172 implying that it is the stage associated with the highest amount of waste generation. The construction stage activities had moderate contribution and ranked 2nd with a mean score of 3.0672. Together, the post-construction and construction stages were perceived to account for many of the waste types (wires/cables wastes, ceiling wastes, PVC pipe wastes, paint/resin wastes, POP wastes, glass wastes, concrete wastes ferrous metal wastes, and wood wastes) generated in the study area. The relative contributions of the other stages are shown in Table 4.1. As many as 91.5% of the respondents rated the severity of waste contribution as moderate to extreme at the post-construction stage of the building life cycle process. At the construction stage, 82.6% of the respondents rated waste as moderate to extreme, while pre-design stage waste was rated the same by 73.8% of the respondents.

Table 4.1: Analysis of the Stages of Building Procurement Activities That Contribute to Waste Generation

Stages of Building Procurement	**The burden of Waste in Percentage (%)**							
	None	**Little**	**Moderate**	**Great**	**Extreme**	**Total**	**Mean**	**Rank**
Post-Construction	0.4	8.0	36.8	49.0	5.7	100	3.5172	1
Construction	0.4	17.0	58.1	24.5	0.0	100	3.0672	2
Design	4.7	27.1	41.5	26.4	0.4	100	2.9070	3
Pre-Design	3.1	23.1	63.8	10.0	0.0	100	2.8077	4
Pre-Construction	16.6	35.1	44.0	4.2	0.0	100	2.3591	5

The findings from the analysis of the stages of building procurement processes that contribute to building waste generation in the study area. By ranks the post-construction stage activities have the highest index of 0.784, hence, showing the highest affinity for waste generation. This is closely followed by the construction stage and the design stage with index values of 0.759 and 0.738 respectively.

5. Fifteen Most Common Trends Shaping Construction Wastage

The fourteen (14) variables in the research instrument relating to the factors affecting building material waste generation from the pre-design stage of the building life cycle process were factor analysed with varimax rotation. The analysis yielded five (5) extracted factors which altogether accounted for a total of 64.187% of the total variance explained for the entire set of variables (Table 4.2). Factor 1 was labelled **project constraints** due to the high loadings by the following items: time constraint; cost constraint; choice of procurement method; choice of consultant. This first factor explained 29.350% of the variance in the data.

The second factor derived was labelled **lack of clarity** due to the high loadings by the following items: undefined project scope; unclear brief/project definition; lack of early collaboration. The total variance explained by this factor is 11.307%. The third factor derived was labelled **non-inclusive project process** due to the high loadings by the following items: lack of contractors' early involvement; waste management not a design directive; expected very high standards. The variance explained by this factor is 8.479%. The fourth factor derived was labelled **unrestrained design process** due to the high loadings by the following items: last-minute client requirement; no specific waste minimisation directive given.

The variance explained by this factor is7.846%. The fifth factor derived was labelled **other pre-design factors** due to the high loadings by the following items: other pre-design factors. These include a lack of interest from the client and feasibility studies not able to identify waste. The variance explained by this factor is 7.205%. The commonalities, which can be regarded as indicators of the importance of the variables in the analysis are generally high (above 50%) across all datasets hence, the variables selected for this study are appropriate and relevant. The relative importance of the factors affecting waste generation from pre-design stage activities of the building construction process is shown by their Eigenvalues, which indicated that the time constraint variable is the most important factor that affects waste generation from pre-design stage activities.

Table 4.2: Rotated Factor Matrix to Determine the Factors Affecting Waste Generation from Pre-Design Stage Activities

Rotated Component Matrix

Factors / % Variance Rotation Sums of Squared Loadings	**Variables**	**Component**					
		Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Communalities**
Factor 1: Project constraints (16.755%)	Time Constraint	**0.811**	0.038	0.054	-.0200	-0.007	0.663
	Cost Constraint	**0.697**	0.277	0.067	0.188	0.112	0.616
	Choice of Procurement Method	**0.541**	0.129	0.419	-0.046	-0.385	0.635
	Choice of Consultant	**0.432**	0.384	0.061	0.350	-0.234	0.515
Factor 2: Lack of clarity (Unclear Project Process) (14.860%)	Undefined Project Scope	0.044	**0.863**	0.079	0.185	-0.029	0.788
	Unclear Brief / Project Definition	0.372	**0.725**	0.011	0.104	0.055	0.678
	Lack of Early Collaborative Engagement	-0.068	**0.634**	0.514	-0.113	0.032	0.684
Factor 3: Non-inclusive Project Process (12.558%)	Lack of Contractors Early Involvement	0.037	0.146	**0.741**	0.075	0.181	0.610
	Waste Management, not Design Directive	0.306	0.091	**0.608**	0.271	0.016	0.545
	Expected very High Standards Procurement Process, not Client Driven	0.170	-0.157	**0.490**	0.306	-0.472	0.611
Factor 4: Unrestrained design process (12.067%)	Last-Minute Client Requirement	0.037	0.331	0.014	**0.775**	0.175	0.742
	No Specific Waste Minimisation Directives Given by the Client	0.235	-0.027	0.269	**0.754**	-0.140	0.545
Factor 5: Other pre-design factors (7.946%)	Other pre-design factors	0.109	-0.015	0.194	0.064	**0.761**	0.633
	Eigen Initial Values	4.109	1.583	1.187	1.098	1.009	
	% of Variance	29.350	11.307	8.479	7.846	7.205	
	Cumulative %	29.350	40.657	49.136	56.981	64.187	

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 9 iterations.

6. Global Implications and Recommendations

6.1 Global Implications

The construction sector contributes to 23% of air pollution, 50% of climatic change, 40% of drinking water pollution, and 50% of landfill wastes. This sector accounts for 40% of worldwide energy usage, with estimations that by 2030 emissions from commercial buildings will grow by 1.8%. Construction activity can "significantly change the surface of a land" due in large part to "clearing of vegetation and excavating" which is common on many construction projects. This means that the surrounding environments will be heavily polluted, particularly surrounding water pools, which have experienced an increase in pollution as a result of various construction projects in recent years.

Additionally, research by Kleiwerks says that building materials, such as concrete, aluminum, and steel, are directly responsible for "large quantities of CO2 emissions" due to high contents of "embodied energy content", with 9.8 million tons of CO2 generated from the production of "76 million tons of finished concrete in the US." Although the construction sector's current practices at reducing pollutants, or omissions, are massively ineffective and may even "generate high levels of greenhouse gas pollution." Worryingly enough, construction activities consume "half of all the resources" extracted from nature, and account for one-sixth of global freshwater consumption, one-quarter of wood consumption, and one-quarter of global waste,"

Globally, these numbers have not gone unnoticed, with different publications such as the Green Guide, the work of Oxford Brookes, and the UK construction industry, which lays out how construction firms can use materials in order to help the environment. Also, there are over 230, 000, publication guides on construction projects and waste minimization, and over a million construction firms awaiting certification worldwide. On countries basis, EPA oversees the protection of the environment and has a number of rules and regulations in place to ensure the construction industry can reduce its negative impact on the climate.

7. Recommendations

In order to ensure a sustainable, and healthy built environment, there should be a management directive regarding waste management plan development and engagement of experienced and qualified professionals. Site operatives and craft men should be aware, and proper training on how to reduce building waste should be done towards achieving a sustainable built environment.

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