LIFE CYCLE ASSESSMENT OF MATERIAL WASTE GENERATION FROM BUILDING CONSTRUCTION PROJECTS IN SOUTHWEST NIGERIA

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ABSTRACT: Studies recognized that construction waste constitutes about 30-40% of the overall solid waste deposited at the landfill sites worldwide, and to have impact on our personal lives and the entire world around us. This research studied building life cycle and waste generation by building projects in southwest Nigeria by the use of structured questionnaire applied to representatives of professionally registered firms of the Nigerian construction industry in the region. A total of four hundred and three (403) questionnaires were randomly administered to the professionally registered firms within the study area, out of which only two hundred and sixty-one (261) of those returned were considered valid and usable. The retrieved data was profiled and rank using the 5 points Likert scale. The study found that post-construction stage activities had the greatest affinity for material waste generation with the highest mean score of 3.5172 and followed by the construction stage activities with the mean score of 3.0672 indicating that waste generation at this stage is moderate. Based on this, the study concludes that there is a need to develop incentives that will encourage the industry professionals to imbibe waste prevention and minimization strategies that will help limit waste generation by the different building life cycle stages.

1. Introduction

Today the world is overwhelmed with threatening information related to the rate of waste generation, environmental degradation, sanitation-related problems and public health. For example, some previous studies reported that construction waste constitutes about 40% of total urban waste in mainland China, 26% of total solid waste in the U.S., and 34% of all industrial waste within Europe [1], [2], and [3]. Globally, the construction industry growth has continued in unabated generating about 3 billion Tons of C&D waste annually majorly due to the strong need for building and infrastructural development following increased growth in population and urbanization activities [4]. The C&D waste generated over the past decades have risen astronomically to reach crisis levels causing severe damage to the environment [5].

Building construction activities entails a step-by-step process that involves putting together large quantities of resources and a large number of people over a period of time to create a physical structure that is called a building [6], [7]. This developmental activity consists of many parts that interrelate with one another and with the environment, leaving both physical and non-physical impacts as a result of its direct and indirect actions. [8], sees building construction activities globally consuming about three trillion kilogrammes of raw materials annually with a large portion of them ending up as waste, and the wastes are generated at all the stages of the building life cycle [8], [9], [10]. Also, these group of researchers 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/or indirect costs without adding value to the finished product.

A review of some old and recent studies like [11], [12], [13], [14], [15], [16], [17], [18], and [19], showed that they all carried out studies on the nature, cause and impact of wastes from building and construction 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 construction activities while a very small group of them concerned themselves with the economic aspect of waste in construction. In all, majority of the studies reviewed tend to focus on the generation of material wastes during the implementation/construction stage of the building life cycle management process in neglect of the other stages.

During the activities at the construction stage, the physical material bye-products generated are considered to be synonymous to waste [20]. Generally, the studies established that building life cycle activities lead to the production of wastages and are subsequently grouped into off-site and on-site operational activities. The on-site activities of building construction related to the development of a physical facility. This consists of the substructure and superstructure 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. The review of literature also established that prefabrication reduces waste and ensures timely delivery, but, it comes with a financial premium, as it could be slightly more expensive than onsite/in-situ construction [21].

From the various studies reviewed here, it was observed that the generation of material waste is an inevitable by-product from the process of procuring a building project; hence the quantity surveyors allow factors for waste in the preparation/pricing of a bill of quantities [22]. Additionally, the activities of the implementation stage of the building life cycle process generate the largest amount of waste streams in the EU, accounting for between 25% and 30% of all waste generated. In the U.S., reports have it that the construction industry generates over 100 million tons of waste per year from its activities and this amounts to approximately 30% of the entire solid waste stream, while in Brazil, it is between 20% and 30% by weight of the total materials delivered on-site and in the United Kingdom, it is reported to be between 55% and 65% of the total material used for projects [23].

[24], reported that material wastage from the implementation stage of the building procurement process has come to stay since it has become a norm in the construction industry. That study further reported that about 5% of the total budget for a building project is usually allowed for in the bill of quantities (BoQ). In some later studies by [24], [25], it was discovered that building materials alone accounts for over 50% of the total cost of a building project in Nigeria, at least 20% of the building materials purchased for the works are left unused at the end of the project and these unused materials end up as waste in most cases. Observations further showed that these left-overs may remain on the project sites unused and treated as waste that may not 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 as design, tendering, construction and occupancy which generates direct and/or indirect costs and adds no value to the finished building project. Over the last couple of years, the increase in the rate of building construction activities in Nigeria and many of the other developing countries following population increase which result in needs and insufficiencies has inevitably created huge amounts of building waste from the different stages of the life cycle process. The generation of these wastes has reached a critical mass such that it has become a growing problem/burden to the environment and the socio-economic conditions of many nations [4], Table 1.1. shows the summary of findings on the generation of physical waste from different countries and by the various researchers in terms of percentage of what is generated and/or of what is delivered to the different landfill sites.
The rate at which the waste is generated has been on the high reaching several billion tonnes globally and averaging above 30% of the total wastes received at the landfill sites all over the world [26]. The physical waste generation per the total weight received at the landfills in the industrialised nations is about 31% in the [27]. It is 33% in the UK, 30% in the US, 35% in Canada, 42%-44% in Australia and China, it is about 29% of the total municipal waste in the world, and 40% of it falls within the Construction and Demolition waste category and that around 30% - 40% of building materials purchased for the works end up as waste on project sites. The situation in the developing nations is slightly different, about 5 and 10% of the building materials end up as waste on project sites in Hong Kong and about 23% of the total waste is deposited at the landfill (EPD, 2010; Kofoworola & Gheewala, 2009; Poon, Ann, & Jaillon, 2004; Shen, Tam & Tam, 2002b; Yu et al., 2012). About 15% and 30% of the solid waste in Kuwait is from building construction-related activities, 75% in UAE and 55% generally in the Gulf Cooperation Council (GCC) countries. It is also reported that about 5% and 27% of the total materials purchased in construction projects in Ghana is waste [28], [29] and 5% in Nigeria [24]. In response to this, the study assesses construction life cycle stages of a building project that are associated with waste generation in Southwest Nigeria.

Table 1.1: Summary of Research Work on Building and Construction Waste Burden

| Author & Date | Building Material Waste Generation | Country |
|---------------|-----------------------------------|---------|
| Begun, Siwar, Pereira and Jaafar (2006) | About 10-30% of the wastes received at the landfill sites are Construction and Demolition (C&D) wastes. | All over the world |
| DEFRA, (2008) | About 31% of the total waste disposed of in the landfills is C&D waste. | European Union |
| DEFRA (2009); Keys et al. (2000); Kofoworola and Gheewala (2009); Lu and Yuan (2010); Poon et al. (2004) | At least 10-15% of all raw materials delivered to most 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. | United Kingdom |
| Al-Hajj and Iskandarani (2012); USA EPA (2004); US Green Council Building (2001); | In the US, C&D waste makes up about 30% of the volume of material in the landfill yearly. | United States of America |
| Begum et al. (2009); Kofoworola and Gheewala (2009) | About 35% of the volume disposed at the landfill is C&D waste. | Canada |
| Japan Ministry of Environment, 2005 | 10-30% of the total waste received at the landfill sites. 70% of all illegally dumped waste comes from construction activities in 2004. | Japan |
| Hao, Mi and Ding (2011); Lu and Yuan (2010); Yuan and Shen (2011); | About 29% of the world’s total municipal. 40% of this falls within the C&D category, and around 30% - 40% of building materials used on construction projects end up as | China |
waste on building sites.

### Table 1.1 Cont’d: Summary of Research Work on Building and Construction Waste Burden

| Author & Date | Building Material Waste Generation | Country |
|---------------|-----------------------------------|---------|
| Mariluce (2004) | The average material wastage is between 20%-30%, depending on the building technology | Brazil |
| EPD (2010); Kofoworola and Gheewala (2009); Poon, Ann, and Jaillon. (2004); Shen, Tam and Tam (2002b); Yu et al. (2012) | 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. | Hong Kong |
| Australian Bureau of Statistics (ABS, 2013); Kofoworola and Gheewala (2009) | 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. | Australia |
| Kartam, Al-Mutairi, Al-Ghusain, and Al-Humoud, (2004) | The country produces 15-30% of solid waste through construction activities. | Kuwait |
| Al-Hajj and Iskandarani (2012) citing Construction Week (2009) Gulf News (2018) | About 55% of the total waste stream is from construction activities. | GCC Countries |
| Al-Qaydi (2006); UAE Interact (2007) | About 75% of the total waste generated is from construction. | United Arab Emirates |
| Agyarkwa, Agyekum and Adinyira (2012) | 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. | Ghana |
| Akinkurolere and Franklin (2005) | About 5% of the total budget for a building project is usually allowed for in the bill of quantities (BoQ) as waste factors in Nigeria. | Nigeria |
| Datta (2000) | About 20-25% of materials are wasted on construction sites. | Tanzania, Zambia, Zimbabwe and Botswana |

**Source:** Adapted from [4} unpublished Ph.D. thesis, 2020

## 2. Materials And Method

In this study, primary and secondary data were used. The primary data was attained through field survey, while secondary data were derived from published texts. To collect data and to meet the set objectives of this study, a total of four hundred and three (403) questionnaires were randomly administered to a study population made up of consultant architects, consultant engineers and consultant quantity surveyors working in ARCON, COREN and QSRBN registered firms across the six (6) states (that is, Ekiti State, Lagos State, Ogun State, Ondo State, Oyo State and Osun State) that make-up the Southwest geopolitical region of Nigeria on their perception on building
life cycle and material waste generation. Out of the administered questionnaires, only two hundred and sixty-one (261) were returned and considered valid and usable to give a response rate of 64.76%. The remaining one hundred and forty-two (142) copies were considered invalid and deemed unusable.

All the respondents answered questions on; sex, age, nationality, profession, academic qualifications, professional qualification, and years of experience. Similarly, the respondents answered additional questions on the characteristics of the consultancy firms that they represent which include; type of organization, registration status, year of registration, number of staff in the organization, project types handled in the past, the preferred building procurement method, the scope and complexity of previously executed projects, contract duration, the company’s annual turn-over. Lastly, the respondents in a similar manner answered questions concerning their perception of building procurement systems, building life cycle stages and waste generation from building construction activities.

To assess the construction life cycle stages of a building project that is associated with waste generation in Southwest Nigeria, this was achieved through the use of Likert scale for raking professionals' perception on the level of waste generated at each stage of building life cycle process. 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 stage 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, recorded as 4 (Great) and 4.50 to 5.00, recoded as 5 (extreme).

3. Results And Discussion

The result of the findings on Table 3.1 represents the outcome of the demographic characteristics which were obtained from the two hundred and sixty-one (261) questionnaires used for the analysis in this study.

3.1 Individual Demographics

Based on the findings, the result (Table 3.1) showed that most (84.3%) of the professionals sampled were male, while the remaining 15.7% were female which indicates that the Nigerian construction industry is a male dominated one. Also, Table 3.1 shows that most (99.6%) of the respondents were Nigerians. This suggests that the respondents are those who are aware of the environment in which they live and work, as such will give satisfactory responses enough to conclude with. Further findings on the respondents’ socioeconomic attributes established that over half (59.4%) of the respondents’ were between 31 and 45 years old, followed by those between 46-60 years (27.7%) and those below 30 years (14.4%). This result suggests the predominance of a fairly young workforce in the industry who will be willing to embrace/adoption the implementation of relatively new work concepts.

Analysis of the individual professional characteristics of the respondents (Table 3.1), show that majority (98.9%) of the respondents’ were corporate and affiliated members of their respective professional bodies which included (MNIA- 41%, MNIQS- 37.2% and MNSE- 20.7%). The other professional affiliations though not specified in the questionnaires administered but were listed by the respondents are the Member, Nigerian Institute of Builders (MNIOB); Member, Nigerian Institute of Town Planners (MNITP) and Member, Nigerian Institution of Surveyors (MNIS); which together make up the remaining (1.1%) of the surveyed population. This result shows that these groups of respondents are experts who are fully registered with both their respective professional and regulatory bodies, and are fully involved in the practice of their various professions in the study area. This implies and/or suggests that the respondents/firms enlisted for the study are qualified through training, experience and practice and would give responses that are reliable and capable of impacting the study outcome.
Table 3.1: Analysis of the Respondents Demographics

|         | Frequency | Percent |
|---------|-----------|---------|
| **Sex** |           |         |
| Male    | 220       | 84.3    |
| Female  | 41        | 15.7    |
| Total   | 261       | 100     |
| **Age** |           |         |
| Less than 30 | 12 | 4.6     |
| 31 - 45 Years | 155 | 59.4   |
| 46 - 60 Years | 87  | 33.3    |
| Above 60 Years | 7  | 2.7     |
| Total   | 261       | 100     |

Table 3.1 Cont’d: Analysis of the Respondents Demographics

| Respondents’ Nationality | Frequency | Percent |
|-------------------------|-----------|---------|
| Nigerians               | 260       | 99.6    |
| Ghanaians               | 1         | 0.4     |
| **Profession**          |           |         |
| Architect               | 107       | 41.0    |
| Engineer                | 52        | 19.9    |
| Quantity Surveyor       | 100       | 38.3    |
| Others (Builders and Surveyors) | 2 | 0.8 |
| Total                   | 261       | 100     |
| **Level of Education of the Respondent** | Frequency | Percent |
| HND                     | 26        | 10.0    |
| BSc/BTech               | 61        | 23.3    |
| MSc/MTech               | 160       | 61.3    |
| Others (PhD, PGD, etc.) | 14        | 5.4     |
| Total                   | 261       | 100     |
| **Professional Qualification** | Frequency | Percent |
| MNIQS                   | 97        | 37.2    |
| MNSE                    | 54        | 20.7    |
| MNIA                    | 107       | 41      |
| Others (MNIOB, MNITP and MNIS) | 3 | 1.1 |
| Total                   | 261       | 100     |

**Source:** Adapted from [4] unpublished Ph.D. thesis, 2020

Looking at Figure 3.1, the result for the respondents’ years of experience shows that 71.7% of the respondents have experiences of over 10 years. About 30.7% of the respondents had practiced for 11-15 years, 24.1% had practiced for 6-10 years, while 24.5% had practiced for 20 years and above. The remaining groups are the respondents with practice experience of less than 5 years with 4.2% and those of between 16-20 years with 16.5%. This suggests that the result of the study may be satisfactory and relevant based on the fact that the respondents are experienced enough to give reliable responses on the building procurement waste management strategies adopted by their firms and the reasons for their choices.
Demographic Characteristics of Participating Firms

The study examined the corporate characteristics of the firms wherein the surveyed respondents work. The populations of the respondents were computed based on the information contained in the registers of corporate membership of the various regulatory bodies that they belonged to. The firms’ characteristics studied included: registration with CAC, registration with the professional regulatory bodies, capacity and size, ownership structure and the economic profiles of the participating firms.

As shown in Table 3.2, majority (42.52%) of respondents indicated that their firms are registered with the Architects Registration Council of Nigeria (ARCON). About 17.62% of the respondents indicated that their firms are registered with the Council of Registered Engineers of Nigeria (COREN), while 26.82% of the respondents sampled worked with firms that are registered with Quantity Surveyors Registration Board of Nigeria (QSRBN). Table 4.5 also shows that a number (13.03%) of the respondents were engaged by contracting firms, client agencies and some other firms who are registered with other professional organizations which were not listed such as, Council of Registered Builders (CORBON), Town Planners Registration Council (TOPREC), and Surveyors Registration Council (SURCON).

The results (Table 3.2) further indicated that 86.97% of the respondents were employed by professionally registered consulting firms operating in the study while the remaining 13.03% of the respondents were jointly employed by the contracting firms, and some client agencies operating in the study area, but individually are registered professionals with other regulatory
bodies not listed by the study. This suggests that the respondents are qualified through training, experience and the expertise which they have garnered from practice over the years to give responses that will impact the study outcome, and may thereby confer authenticity and originality on the study.

It was also observed from the field that some of the respondents who are professionally registered to practice work for firms that are yet to be register with the professional regulatory bodies while others who are yet to be registered to practice work with firms that are registered with the professional regulatory bodies hence their non-inclusion in the data analysis. Additionally, it was seen that many of the registered consulting firms were practicing also as building contractors in the study area hence the large number of contracting firms.

Table 3.2: Analysis of Firm Registration by Professional Organizations

| Registration with Professional Organization | Frequency (N) | Valid Percentages (%) |
|---------------------------------------------|---------------|-----------------------|
| ARCON/Consulting                            | 111           | 42.52                 |
| COREN/Consulting                            | 46            | 17.62                 |
| QSRBN/Consulting                            | 70            | 26.82                 |
| Others (Contractors, Client Agencies and others who are registered with CORBON, COREN/M&E Engineers, SURCON and TOPREC) | 34 | 13.03 |
| Total                                       | 261           | 100                   |

Source: Adapted from [4] unpublished Ph.D. dissertation, 2020

3.3 Construction Life Cycle Stages of Building Projects Associated With Waste Generation

According to the results (Table 3.3) on the professional perception of life cycle assessment of material waste generation from building construction activities, it was seen that the post-construction stage activities was surprisingly ranked 1st with the mean score of 3.5172. This indicates that in this study, the respondents’ perception listed the post-construction stage activities as having the greatest affinity for waste generation. Closely following the post-construction stage is the construction stage activities and, with a mean score of 3.0672 is ranked 2nd. This suggests that the respondents perceive waste generation at this stage to be moderate. Together, the post-construction and construction stages account for the majority of the wastes (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 design stage and pre-design stage activities with mean values of 2.9070 and 2.8077 respectively and are ranked 3rd and 4th suggesting that the activities of procuring a building project at these stages generate wastes mildly. Lastly the pre-construction stage activities came 5th with a mean score of 2.3591, hence; stage only contributes minimally to waste generation.

Table 3.3: 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   | 3.51 | 1    |
| Construction                  | 0.4  | 17.0   | 58.1     | 24.0  | 0.0     | 100   | 3.06 | 2    |
| Design                        | 4.7  | 27.0   | 41.5     | 26.0  | 4.0     | 100   | 2.90 | 3    |
| Pre-Design                    | 3.1  | 23.0   | 63.8     | 10.0  | 0.0     | 100   | 2.80 | 4    |
4.0 Conclusion
This study developed an analytical method for assessing the construction life cycle stages of building projects that are associated with waste generation in Southwest Nigeria. The study found that the activities of building construction across the five (5) life cycle management stages listed by the study (that is, pre-design stage, design stage, pre-construction stage, construction stage and post-construction stage) contribute to waste generation, albeit in varying proportions. Also, the perceptions of burdens for wastes generation are greatest at the post-construction and construction stages and the most common waste types listed in this study that are considered to have the most significant and critical contributions to the overall waste stream are; PVC pipe wastes, paint/resin wastes, POP wastes, wood wastes, glass wastes, ferrous metal wastes and concrete wastes.

4.1 Implications
Based on the findings, the following conclusion was necessary:

i. Enact and enforce policies that can regulate material waste generation and management on building construction projects.

ii. The government should come up with incentives that can motivate/encourage the industry professionals to fashion out ways of how to prevent/limit waste generation from building construction activities as much as possible from the pre-design stage and through the design, pre-construction, construction and the post-construction stages of building construction.

4.2 Recommendations
Based on the result of the study, it is recommended that:

i. Industry practitioners should partner the government in the provision of the needed infrastructure to stimulate motivation to manage material waste from building projects.

ii. Both the industry professionals and policy makers should work together to provide management support for the management of wastes on every building project.

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