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Material Resources Optimization for Sustainable Construction in Nigeria

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Abstract

Material waste in construction contributes approximately 30-35% of project cost; thus leading to material loss and project cost overruns. Lack of concern by Governments and developers globally and Nigeria, in particular, is continuously affecting the use of these resource materials. The aim of this paper is to examine the ways by which construction material resources can be optimised towards sustainable material resource preservation. Questionnaire method has been used, and administered among construction consultants in Nigerian. A total of 70 questionnaires were administered to construction practitioners; 53 were returned giving a 75% response rate. This was analysed using descriptive statistics. The findings reveal that selection of low-quality products and inexperience of method are the major sources of material wastage at the design stage. Construction stage major sources of material wastage are design changes during construction and re-working due to incorrect use of material and labour. While at procurement stage the major source of materials waste are the lack of possibility to order small quantity and waste encountered during loading/transportation. Finally, at the handling stage, the major sources of material wastage are theft and inappropriate storage. The study also revealed that lack of adequate security in the country and inadequate knowledge of recycling are the main challenges that occur more frequently in resources management .The study found that the following factors should be considered for sustainable material resources optimisation that include, use of standard space product design, adoption of supply chain management, and developing of material schedule software. It recommends that better utilization of resources through adopting lean production and prefabricated component processes, use of appropriate equipment and specification, recycling/re-using of old materials for new construction projects will assist greatly to reducing visit of the base materials, hence leading to resource optimization and protection of the environment. Lastly, there is the need for policy establishment and implementation for resource optimisation for the Nigeria construction industry

Keywords: Construction, Material management, Resource Optimization, Sustainability, Waste, Nigeria.

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1. Introduction

The world has witnessed significant population development, technological advancement and is equally increasing in the use of its resources following the industrial revolution. It is acknowledged that technological advances have impacted on the utilisation of these resources and causes ozone depletion, deforestation particularly in the developing nations, global warming, flooding etc. These factors are affecting the sustainability of the earth in terms of the resources ability to meet the need of current and future generations (Cartlidge, 2004). Lack of concern by the majority of governments and developers globally and Nigeria, in particular, is continuously affecting the use of construction resource materials.

Various policies related to the construction industry and environmental sustainability in Nigeria have emerged in recent time such as Building Codes, Environmental Impact Assessment (EIA ACT 1992), Federal Environmental Protection Agency (FEPA ACT 1988) etc. All these acts have aims of protecting the environment against damages, the regulation of potentially harmful activities and the punishment of persons deliberately damaging it whenever this occurs (Nwokoro & Onukwube 2011). However, policy on how to deal with sustainable sourcing of construction materials, its waste management and structure for green buildings are not yet in place. This lack of policy encourages uncheck utilisation of natural base material resources in the country.

In Nigerian context, the existing practice has shown that industrial barons, particularly in cement industry use their trucks to transport up to 40 tons of cement as against 30 tons specified by highway codes and road design criteria. This resulted to roads damage before their full lifespan and specified periodic maintenance period. For instance Abuja-Kaduna-Kano dual carriage highway started experiencing significant failures at various sections within the first three years of its usage, this is similar to buildings in the country, property meant to last between 60-70 years lasts between 30-40 years useful lifespan. This assertion is supported by Cartlidge, (2004) that buildings that attracted good tenants and high rents in the 1980s and early1990s are now tending to attract only secondary or tertiary covenants, leading to lower rents and valuations as a result of the deterioration of properties and unsustainable construction practice.

The use of material resources in the construction industry touches areas such as finance, human, and equipment. The optimum use of these resources collectively leads to preservation of the base material resources and more affordable construction works. Hence, this paper aimed to examine ways by which construction material resources can be optimised towards general resource preservation; through these specific objectives identifying the major sources of Material wastage, challenges of resource optimization and lastly the means of material resources optimization.

Construction Materials Wastage

The word waste means loss during usage or decay (Adeagbo & Kunya, 2002). In other words, waste is any activity which does not add value (Slack et al., 2004).

Material wastage is define as the difference between the value of those materials delivered and accepted on the site and those properly used as specified and as accurately measured in the work. This has been recognized as a major problem in the construction industry. There is a concern in recent time on both implications of the efficiency of the industry through materials wastage and the environmental impact of construction projects (Motete et al., 2003). According to Bin Ibrahim etal., (2010) the cost of materials is over 50% of the total construction cost, depending on the construction form. They further stressed that the causes of material wastage were "poor workmanship, setting-out, order not meeting specifications, excessive use of materials, and breakage in handling materials, improper storage, and misdemeanour". This kind of waste typically accounts for 15 - 30% of urban waste (Forsythe and Marsden 1999).

Materials wastage on the construction site has recognizable implication on the stakeholders. To the contractor, it significantly reduces the predictable proceeds from a project, whereas to the client, it escalates the development costs and undermines values. High rates of material wastage on construction site perhaps may be responsible for the project cost overruns reported in the literature. Hence, there is the need for maximizing material wastage management on the construction site to enhance profit maximization, achieving value for money and also reduce the cost of development (Ogunsemi, 2006), and are used as an important criterion for project success (Abdulrahman et al., 2013). Abdulrahman et al. further stressed on the function of material management system in construction projects to be identifying, acquiring, storing, distributing, and disposing of materials. See Table (1) for material wastages identified at various stages of construction projects as generated in the literatures.

Table 1: Major Sources of Materials Wastage at Various Construction Stages

S/N	Design Stage	Operational Stage	Procurement Stage	Material Handling Stage
01.	Design changes while construction	Damages to work done due to subsequent trades	Lack of possibility to order small quantity	Material supplied loose
02	Inexperience of methods/sequence	Errors by trademen/Labourers	Ordering errors (too much or too little)	Inappropriate storage
03	Lack of attention to dimension	Required quantity unclear due to improper planning	Purchase not comply with specification	Damages while transporting
04	Lack of knowledge about standard sizes	Re- working due to incorrect materials/Labour		Theft
05	Complexity of detailing	Delay in passing information to the contractor		Unfriendly attitudes of project team and labourers
06	Lack of information in drawings	Accident due to negligence		Use of materials close to workplace
07	Selection of low quality products	Inclement Weather		
08	Inconclusive contract documentation	Malfunctioning of Equipment		
09	Errors in contract documents			

Minimizing Material Wastage

According to the National Specialist Contractors Council (UK) - over 10% of construction waste (13 million tonnes) in Britain consists of unused materials (i.e. materials delivered to the site but not being used). Al-Hajj and Hamani (2011) opined that it represent 13%. Construction waste is understood in different ways and its accounts for a large percentage of production cost (Viana et al., 2012). The following may be means of minimizing materials wastage and reduce visiting materials base resources for sustainability purpose:

Use with minimal/without waste

Waste minimisation is a process which avoids, eliminates or reduces waste at its source or permits reuse/recycling of the waste for environmental benign purposes (Jaillon et al. 2009). The quality and/or experience of the personnel used in the execution of the works will determine the extent of the non-value activities.

Selection of Alternative Building Materials

The use of alternative building materials will reduce touching of the base materials thereby preserving them for future generations needs and as well as minimizing their impact on the environment (WBDG Sustainable Committee, 2010**)**

Use of Appropriate Equipment

To select appropriate equipment required for a project, it is necessary to first determine machine productivity. To perform such analyses, the planner must consider both machine capability and methods of employment (Peurifoy et al., 2006) with a view to minimise wastage during utilisation.

Appropriate Specification

Choice of appropriate material at both the design and implementation stages of construction will assist construction works to have full life span they were designed for. For instance use of wall tiles/Glass on the toilet walls as against plastering and painting, will assist in preserving the building against early and subsequent maintenance.

Lean Production

This is a process where sizes of the products are optimized to ensuring robustness. This encourage 50% reduction on everything leading to half human effort in the factory, manufacturing space, tools, engineering hours to develop a new products, and produces a greater and ever growing variety of product designed both to eliminate waste and constantly improve production output and quality (Womack et al., 1990; McGivern et. al., 2001).

Supply Chain Management

Approximately 13% of wastes generated in the construction industry are new, unused materials. Solution to the above problem is adoption of supply chain management (SCM) principle, through finding suppliers who accepts returns or exchanges. Exchange materials, which might appear to be of no value to you, may be of value to someone else (Al-Hajj & Hamani 2011). SCM can assist with the delivery that is just-in-time for the required building stage, and it avoid keeping materials in storage for too long as this ties up your funds and may lead to damage, spoilage and pilfering (Begum et al., 2009).

Recycling / Reusing

There are many ways to improving the sustainability of the built environment and include among others using non-toxic and using materials in such a way that they can be re-used or recycled. The use of high recycle content construction materials on prospect projects will reduce frequency of visit to base material resources and this will reduce waste and protect the environment (Cartlidge, 2004; Begum et al., 2006).

Prefabricated Construction

According to Jaillon et al., (2009) "Prefabrication is a manufacturing process, generally taking place at a specialised facility where various materials are joined to form a component part of the final installation". Prefabrication has been recognised as a means to reduce waste arising during design and construction phases. Hence, it is possible to reduce waste level up to approximately 52% through prefabrication. Thus, prefabrication could considerably reduce construction waste generation and alleviate the burdens associated with its management (Jaillon et. al. 2009).

Resource Optimization at Various Stages of Construction

Design Stage

About 5–10 percent of building materials end up as a waste on building sites (Nehru 2009) and laps been an extended joining of materials for increasing their length or width are also between 5-10 % part of item rate (Holm etal., 2006). Waste and laps can be reduced through the design process. Designing to modules will assist in reducing/eliminating waste or eliminate non- standardization.

Costing Stage

It is a standard practice when estimating for any rate of construction item or element to include waste, but in the first instance why inclusion of waste into these items of works during costing?

The following factors could be the reasons: storage waste, transit waste, residue waste, loading waste, application waste, stock pile waste, cutting waste. It is also fair to conclude that lack of coordination between design, construction and costing is also preventing it from identifying opportunities to optimize resource use/minimize waste.

Construction/Implementation Stage

Most of the above explanation can be applied at post contract stage. The most importance factors during construction stage is the purchasing and supplying procedure of the materials (further encourage waste by over estimating and rounding up of purchasing requirements), purchasing not complying with specification and non-challant attitudes of tradesmen/labor force during execution.

Current Challenges to Resources Optimization in Nigeria

Based on the existing practice in Nigeria, the following challenges are affecting sustainable construction and include:

Untraceable Income

Inordinate income stream in Nigeria encourages economic vulgarism, which leads to wasteful spending and minimum attention to resource optimization. Because of the poor policy framework and implementation capacity, income(s) are not properly monitored generally and specifically during construction process.

Ambiguous Bills Items

Items that serve as cover in the contract that is usually used as decoy/ conduit to siphon money from the project such as provisional sum; prime cost sum and sometimes contingency sum need to be avoided for sustainable construction purpose.

Status Symbol / Cultural Attitude

The tendency of Nigerians to define their economic status by making a statement with bogey structures, this tend to make the spending on such structures very high without adding functional values: for e.g. is the case of concrete fascia that is currently in vogue in Nigeria. When comparing concrete facial with timber/wooden facial board; the cost of concrete fascia is eight times the cost of timber type.

Seeming Abundance of Resources

Make up call to the realization that the seeming limitless materials can actually get exhausted. For e.g. sand can get exhausted through weathering effect, which is related to volcanic/ rock formation activities.

Lack of Security

Inadequate security has led to excessive protection of the structures (high fencing, burglar proofing, concrete fascia, double roofing among others). This waste form is avoidable if the overall security of the country is improved. The idea is paradoxical if actually does not.

Inadequate Knowledge of Recycling

The internalization of the benefits of recycling within some projects is insufficient because a good link has not been established between the understanding of recycling and resource optimization. A typical case in Nigeria is when a client bought a building, instead of re-using or recycling part of the building, they will prefer to demolish the whole structure and redesign and reconstruct from the beginning.

Lack of Political Will on the Part of Government

Adherence to rule of law in entrenching policy frame work aimed at ensuring advancement in the methods of resource utilization, sourcing, development, production and manufacture; within the context of optimizing resources for the benefit of all and the environment is not in place. Hence, there is the need for policy establishment and implementation for resource optimisation in the Nigeria construction industry by the government; giving rooms for new ideas or concepts such as "Rethinking Construction".

Methodology

Optimizing resources for sustainable construction was considered a necessary foundation for this study. To achieve this, secondary data were generated from literature and pilot interviews was conducted with Construction Practitioners (Architects, Contractors, Builders, Engineers and Quantity Surveyors) on material wastage with a view to developing questionnaire content. The data collection process consisted of a questionnaire survey developed by the researchers. The questionnaires were personally administered by the researchers. A survey design was used because it is effective in seeking the views of people about a particular issue that concerns them and can be used to generalize.

A survey design is one in which a group of people or items is studied by collecting and analysing that data from only a few people or items considered to be representative of the entire population (Naoum 2007). The questionnaire aimed to establish the major sources of construction, the challenges of resource optimization and the means of resource optimization in the Nigerian Construction Industry. A summary of the analysis of the data collected are presented in Figures 1 to 3.

Firstly, the research assessed the major sources of material wastage. The questionnaire identified 27 major causes of material wastage under four headings representing four stages (Design, Construction, Procurement and Handling).

Secondly, the research also identified challenges to resource optimization in Nigeria; prior to this, a pilot study was conducted to identify the challenges. The challenges were classified into two sections: the frequency of occurrence of the challenges and the impact of each challenge identified. Each of the sections had eight questions.

Lastly, the questionnaire identified the means of material resource optimization. The questionnaire had twelve questions in this section. The questionnaire consisted of a total of 55 questions. The 55 questions formed the basis of the questionnaire which was developed to sample the opinion of Construction Practitioners. The respondent's views were sought using 5 points likert scale method "1" is the lowest score and "5"represent the highest score. The ranking of the factors was based on the means calculated, the higher the mean, the higher the ranking. The questionnaire was constructed in simple clear language to enhance the respondents' exercise of sound judgment. The majority of the respondents are practitioners based in the Federal capital Territory and Kaduna City. A total of 70 questionnaires were administered and 53 were correctly completed and returned representing a response rate of 75%. This was considered adequate for the analysis based on the assertion by Moser and Kalton (1971). No questionnaire was discarded. Thus 53 number were used for the analysis

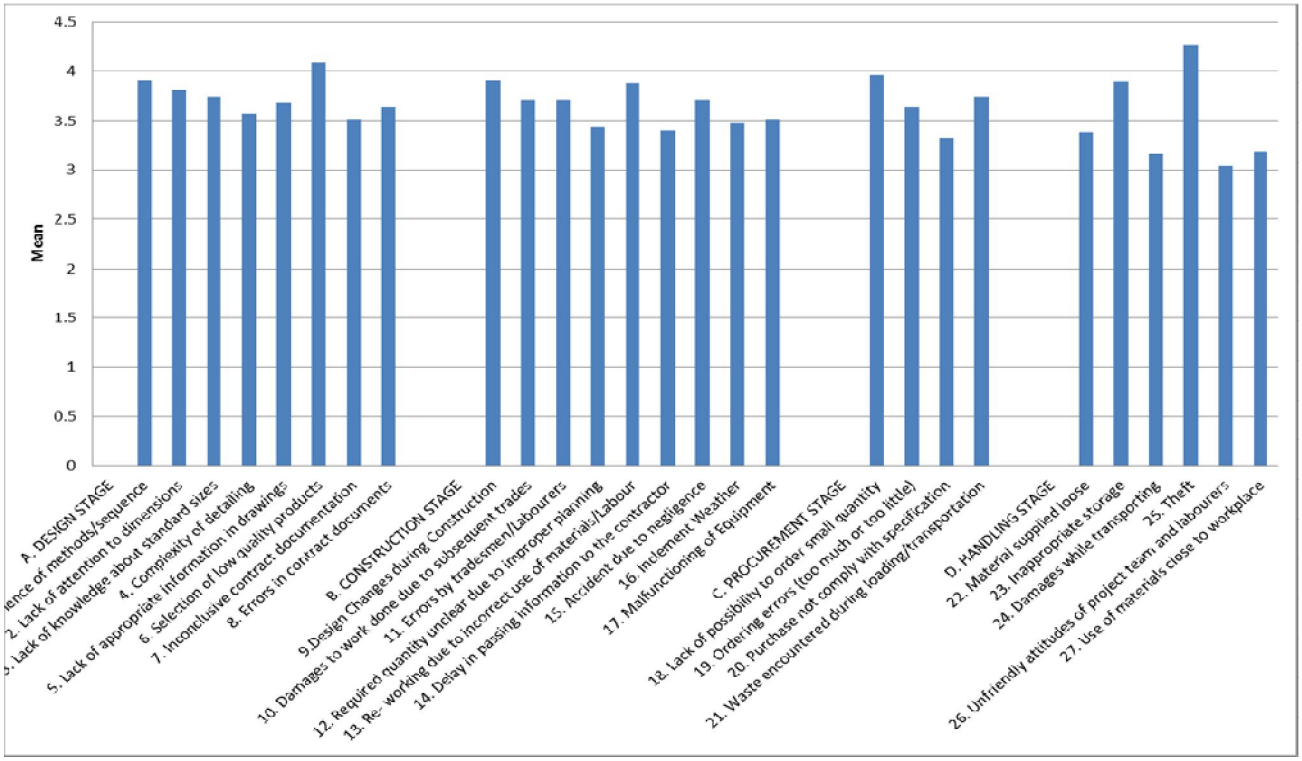

Figure 1: Major Sources of Construction waste

Figure 1 shows the various factors responsible for material wastage in the Nigerian Construction Industry. The major sources of Material wastage at the design stage is the selection of low- quality material with a mean of 4.08 while inconclusive contract documentation has the least impact with a mean of 3.51.

At the construction stage, a design change during construction is the major source of material wastage with a mean of 3.91, while unclear required quantity due to improper planning is the least with a mean of 3.43. At the procurement stage, the major source is the lack of possibility to order small quantities with a mean of 3.96 while the least is purchase not comply with specification with a mean of 3.32. Finally, at the handling stage, the major sources of material wastage are theft and inappropriate storage with a mean of 4.26 and 3.89 respectively; while damages during transportation are the least with a mean of 3.17.

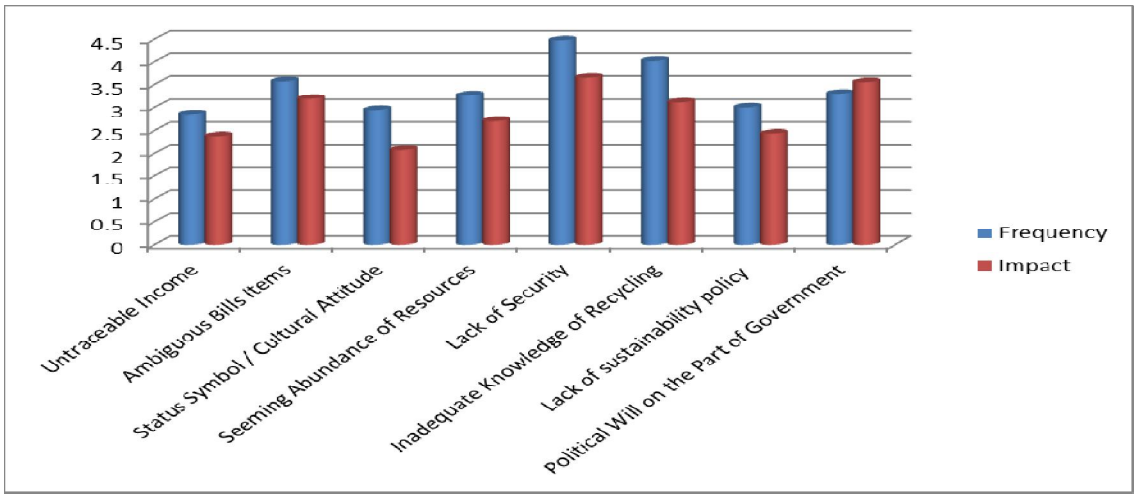

Figure 2: Challenges to resource optimization in the Nigerian Construction Industry

Figure 2 shows the challenges to resource optimization in the Nigerian Construction Industry. This was achieved by analyzing the impact and the frequency of occurrence of the challenges. The result shows that lack of security has the highest frequency with a mean of 4.47, while untraceable income has the least frequency with a mean of 2.85. On the other side, lack of security similarly, has the highest impact with a mean of 3.64 while status symbol/cultural attitude has the least impact with a mean of approximately 2.00.

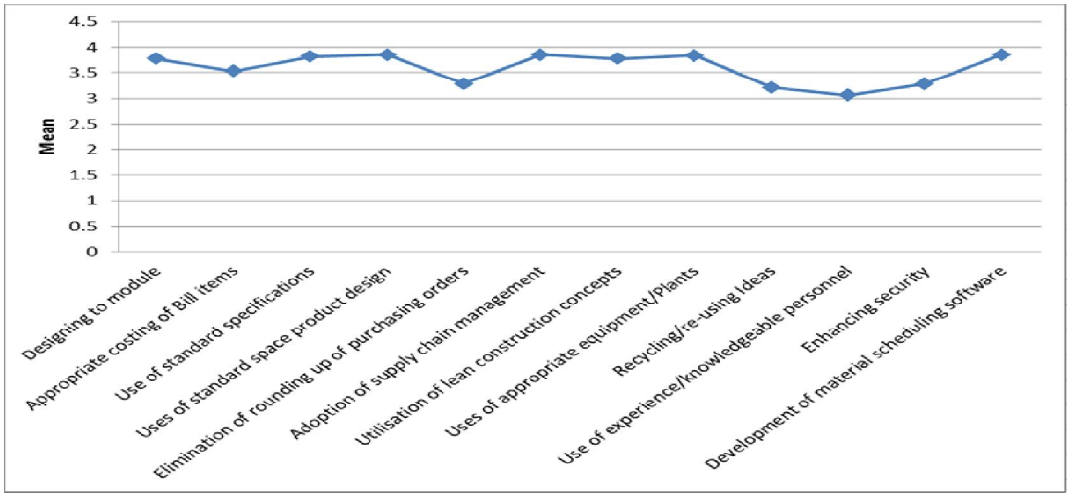

Figure 3: Means of material resources optimization at various stages of construction

Figure 3 shows the means of material resource optimization strategies at various stages of construction. The findings reveal that use of standard space design and adoption of supply chain management are the major means of resource optimization with a mean of 3.85; while use of experience/knowledgeable personnel is the least with a mean of approximately 3.10.

Analysis of Findings and Discussion

This study set out to achieve Material Resources Optimisation for sustainable construction in Nigeria. Resource materials optimization can be achieved at the various stages of construction. The first objective meant to identify the major sources of material wastage at various construction stages (see Figure1). The figure shows the various factors responsible for material wastage in the Nigerian Construction Industry. The findings reveal that selection of low-quality products and inexperience of method and sequence by the labour force are the major sources of material wastage at the design stage. Currently a large number of sub-standard products influxes into the Nigerian Market, most don't fit or are damaged and have to be replaced thus generating more waste. More so, experience practice have shown that using experienced and competent personnel in manning construction works will significantly reduce waste generation; although hiring them could impact on the total cost of the project. More so, at the construction stage, the major sources of material wastage are design changes during construction and re-working due to incorrect use of material and labour.

The way construction activities are carried out also impacts on the quantity of waste produced. Design changes during construction can and should be avoided wherever possible. Design changes while construction is in progress can result in waste in different ways. Firstly if the construction materials have already been purchased based on the original design, waste will result if the materials cannot be resold or returned to the supplier (considering supply chain principle utilisation is limited). Also, if a structure has already been constructed, a change in design may result in partial demolition, thus resulting in material wastage (Bekr, 2014). At the procurement stage, the major sources of waste are the lack of possibility to order a small quantity, and waste encountered during loading/transportation. The solution is the adoption of a robust system that enables the production of accurate estimates of material requirements at the start of a project that then links to real waste figures on completion. Only by focusing upon these material quantities will sub-contractors be able to understand what their wastage rates are and subsequently, be able to take action to reduce them. Finally, at the handling stage, the major sources of material wastage are theft and inappropriate storage.

The second objective investigated the challenges of resource optimization in the Nigerian construction industry. The study revealed that lack of adequate security in the country and inadequate knowledge of recycling strategy are the challenges that occur more frequently in resource management. Also, lack of security (burglar proofing, high fencing, double roofing) has the highest impact on resource management and over utilization of resources without value. This is in accordance with the study by Oladiran (2009). Efficient Material Management is an important criterion for the success of any project considering the portion of material resources in the overall constructions project cost.

More so, adoption of recycling/re-using principle will help significantly in reducing project cost and visiting of the natural base material resource. Chui (2007) agrees with the above "Reuse/Recycling program has assisted Hong Kong to reduce approximately 30% of construction waste to be disposed of in landfills and achieved the economic benefit of around US$7 million from the construction waste disposal charging scheme".

In line with the last objective investigated, the study found that the following factors should be considered for sustainable material resources optimisation and include, use of standard space product design, designing to module and supply chain management. Designing to a module is one of the major strategies and will assist in reducing/eliminating waste and/or eliminate non- standardization. For instance doors and windows are usually design to standard modules and this usually assists manufacturers minimize wastage during production, hence assisted in reducing selling cost to consumers. Lack of standard space allocations is another problem which can cause cutting materials to different sizes in building projects and the materials usually affected by this include among others floor tiles, ceiling board, block work, roofing trusses, roof covering; this is in agreement with Holm et al., (2006). Also, adoption of supply chain management principle and development of material schedule software will help in achieving sustainable material optimization. This is in agreement with the study by Saka and Mudi (2007). There is an obvious case of lack of comprehensive and value enhancing approach to supply chain issues in Nigeria.

Conclusion

Following all of the above mentioned, material resources optimization can be achieved at the various stages of construction. In line with the first objective (identify the major sources of material wastage at various construction stages) - the findings reveal that, selection of low quality products and inexperience of method and sequence by the labour force are the major sources of material wastage at the design stage. At the Construction stage, the major sources of material wastage are design changes during construction and re-working due to incorrect use of material and labour. While at the procurement stage, the major sources of waste are lack of possibility to order small quantity, and waste encountered during loading/transportation. The solution is the adoption of a robust system that enables the production of accurate estimates of material requirements at the start of a project that then links to real waste figures on completion.

Finally, at the handling stage, the major sources of material wastage are theft and inappropriate storage. The paper also found that lack of adequate security in the country and inadequate knowledge of recycling are the challenges that occur more frequently in resource management. Also, lack of security has the highest impact on resource optimisation and over utilization of resources without value. Lastly, the following factors should be considered for sustainable material resources optimisation and include, use of standard space design, designing to module and adoption of supply chain principle; also, will assist in reducing or eliminate waste and/ or eliminate non-standardization.

This research work will benefit the decision makers in identifying where the wastage in respect of construction activities is coming and it will helps in raising concern on depleting of natural base resource with a view to strengthening the existing policies on environmental protection. In addition, it will helps in sensitizing construction practitioners in reducing material wastages. This study is limited to data collection and analyzing the data and finding; hence further research would include testing and validating the results outcomes. Lastly, the study is recommending the need for policy establishment and implementation for resource optimisation for the Nigeria construction industry.

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