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Waste-efficient materials procurement for construction projects: A structural equation modelling of critical success factors

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ABSTRACT

Albeit the understanding that construction waste is caused by activities ranging from all stages of project delivery process, research efforts have been concentrated on design and construction stages, while the possibility of reducing waste through materials procurement process is widely neglected. This study aims at exploring and confirming strategies for achieving waste-efficient materials procurement in construction activities. The study employs sequential exploratory mixed method approach as its methodological framework, using focus group discussion, statistical analysis and structural equation modelling.

The study suggests that for materials procurement to enhance waste minimisation in construction projects, the procurement process would be characterised by four features. These include suppliers' commitment to low waste measures, low waste purchase management, effective materials delivery management and waste-efficient Bill of Quantity, all of which have significant impacts on waste minimisation. This implies that commitment of materials suppliers to such measures as take back scheme and flexibility in supplying small materials quantity, among others, are expected of materials procurement. While low waste purchase management stipulates the need for such measures as reduced packaging and consideration of pre-assembled/pre-cut materials, efficient delivery management entails effective delivery and storage system as well as adequate protection of materials during the delivery process, among others. Waste-efficient specification and bill of quantity, on the other hand, requires accurate materials take-off and ordering of materials based on accurately prepared design documents and bill of quantity.

Findings of this study could assist in understanding a set of measures that should be taken during materials procurement process, thereby corroborating waste management practices at other stages of project delivery process.

1. Introduction

The construction industry accounts for about 13% of the global economy and serves as a key driver for other industries as a result of its infrastructural and facilities development (HM Government, 2008). Despite its significance to the global economy (Ajayi et al., 2015), it has remained a major target for environmental sustainability (Anderson and Thornback, 2012). This is due to its consumption of the largest portion of materials resources, water and energy, while also contributing largest waste to landfill sites (Bilal et al., 2016b; Edwards, 2014). It has also been argued that continuous sustainability of the industry depends on how well it manages waste generation (Ajayi et al., 2016; Udawatta et al., 2015); especially as waste minimisation is requisite to preventing materials depletion (Oyedele et al., 2014; Akinade et al., 2015). Although the waste generated by the construction industry is contributed by both construction and demolition activities, reducing waste during the construction process is not only good for environmental reasons, it could also reduce the overall cost of projects. This is especially as a substantial proportion of construction cost overrun is due to waste generation (Ameh and Itodo, 2013). Due to an understanding of the needs to minimise waste generated by construction activities, various studies have been carried out to determine both causative factors and preventive measures. This has led to an understanding that construction waste is caused by various activities at design, procurement and construction stages of project lifecycle (Faniran and Caban, 1998, Ekanayake and Ofori, 2004; Dainty and Brookes, 2004).

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Despite the consensus that other stages and processes of project delivery are important for reducing waste generated during construction processes (Osmani et al., 2008, Akinade et al., 2016), research and legislative efforts have been concentrated on the actual construction activities (Al-Hajj and Hamani, 2011). Within the UK for instance, site waste management plan, landfill tax and aggregate tax are legislative and fiscal measures that target the construction stage of project delivery process. Construction waste management studies have also largely focussed on the actual construction stage of project delivery process (Osmani et al., 2008; Bilal et al., 2016a). Other sets of studies have also been carried out to determine design factors and strategies capable of mitigating waste generated by the construction industry (Wang et al., 2015; Osmani et al., 2008). However, unlike design and, specifically, construction-related activities that are widely investigated for waste efficiency, a little effort has been made to investigate how material procurement process could be optimised to improve the waste efficiency of construction projects.

Notwithstanding the knowledge that wasted materials are purchased through the procurement process, the relevance of the process in reducing construction waste has not been adequately considered. Few procurement strategies that have been identified are subjects of studies that specifically focussed on design or construction activities. This is albeit the fact that substantial percentages of waste generated in construction activities have been traced to ineffective coordination of materials procurement activities (Faniran and Caban, 1998). Thus, it is important that waste-effective measures be taken while purchasing materials for construction activities. This has the tendency of reducing waste as well as the cost of construction materials, which is about 50% of total project cost (Kong et al., 2001).

Based on the paucity of literature that specifically focussed on materials procurement measures for waste mitigation, this study aims at investigating the waste preventive measures that should be taken during the construction materials procurement process. The study explores a set of requisite measures capable of minimising waste generated as of result of ineffective materials purchase, delivery, handling and storage. In order to achieve this goal, the study fulfils the following research objectives:

1. To explore waste-efficient measures that could be taken during procurement of construction materials.
2. To confirm key strategies for engendering construction waste minimisation through materials procurement process.

In order to gain an in-depth understanding of the materials procurement measures for mitigating construction waste, the first phase of the study employs a qualitative approach to enquiry, using focus group discussions as means of data collection. The approach was followed by a quantitative approach where pilot-tested questionnaires were used for eliciting broader practitioners' opinion before the use of Structural Equation Modelling (SEM) for confirmatory factor analysis. As a theoretical insight for this study, the next section provides a review of extant literature in construction waste management. Methodological approach employed in the first phase of the study, which includes sampling, data collection and analytical procedures are then justified and described. Qualitative findings of the study are then presented before the design, research processes, findings and discussions of further quantitative studies and SEM are presented.

The paper offers insights into factors and strategies to be considered during materials schedule, purchase and delivery process so as to achieve effective waste management. The relationship between various measured and latent factors are also presented. The study would assist construction professionals, materials suppliers and other stakeholders in understanding how well the procurement processes could be coordinated for construction waste mitigation. It also offers new theoretical insights into the importance of materials procurement in construction waste management.

2. Construction materials logistics and supply chain management

The construction industry is arguably one of the least integrated sectors of the global economy, notwithstanding its significance in driving other sectors (Fulford and Standing, 2014). Due to the project-based nature of the industry and the transient nature of the project team, long-term relationship between the parties is often non-existent. This affects the multi-dimensional relationships that exist between various parties involved in project delivery process. While many industries have adopted various innovative concepts such as the Lean approach and assemble to order, among others, in their materials supply process, there has been little success in integrating these sets of concepts in the construction industry. This is notwithstanding the existence of strong relationships between supply chain management and organisational performance (Tan et al., 1998). According to Vrijhoef and Koskela (2000), the fragmented nature of the construction activities, as well as unique nature of every project, is partly responsible for the one-off approach to materials procurement, with the repeated reconfiguration of materials supply team and project organisation. This has resulted in a large quantity of waste, and several other problems, that characterised the materials supply chain in the construction industry (Vrijhoef and Koskela, 2000).

Construction materials supply chain management is a complex process that combines people, technology, process and parties involved in the planning, estimation, suppliers' identification, purchasing, transportation and stocking of the materials for construction activities (Bell and Stukhart, 1986). Effective coordination of the whole process is capable of engendering cost savings, safety, quality and improved productivity in construction activities (Thomas et al., 1989). As represented in Fig. 1, traditional construction materials management process usually involves a number of stages including materials take-off, bill of materials, warehousing and the actual use of the materials. At the early stage, an effort is required to ensure that the materials take-off is accurately made from project specification in order to prevent error in ordering (Bell and Stukhart, 1986). The increasing use of Computer Aided Design (CAD), and specifically the use of BIM tools for materials take-off, is continuously facilitating efficient estimation of materials required for building activities. Nonetheless, this largely depends on the accuracy of the drawing documents and adequate coordination of drawings between various professional parties involved in modern-day designs (Monteiro and Martins, 2013).

In the case of new project teams, and where there is no pre-selected vendor as in several cases, vendor inquiry and assessment usually precede the actual materials purchase. The capacity inquiry is submitted by vendors whose commercial and technical capacities are further evaluated in terms of previous performance and ability to cater for specific project needs. Depending on the project types and construction techniques, evaluation of the vendor could be based on several criteria. This includes the tendency of participating in a pull or push delivery system, volume capacity, the supply of prefabricated materials, location, responsible sourcing, among others (Aretoulis et al., 2010). The purchasing function is largely influenced by the types of project procurement routes, which determines whether the role is played by the owner's team, contractor, sub-contractor or other delegated team (Bell and Stukhart, 1986). This function includes raising of a purchase order, which incorporates item stock number, quantity, date needed,

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