NZAAR-SGER-18-06

EXPLORING THE RELATIONSHIP BETWEEN MATERIALS PROCUREMENT AND WASTE MINIMIZATION IN THE CONSTRUCTION INDUSTRY: THE CASE OF EGYPT

Ahmed Osama Daoud[1,2], Ayman Ahmed Othman[3], Herbert Robinson[4], and Ali Bayyati[5]

[1]*Assistant Lecturer, Civil Engineering Department, Faculty of Engineering, the British University in Egypt (BUE), Room 104 Building A, Cairo-Suez Desert Road, Al-Shorouk, 11837, Cairo, Egypt.*

[2]*PhD Researcher, School of Built Environment and Architecture, London South Bank University (LSBU), 103 Borough Road, London SE1 0AA, Room 315.*

[3]*Professor of Construction and Project Management, Head of Architectural Engineering Department, Faculty of Engineering, the British University in Egypt (BUE), Room 208 Building A, Cairo-Suez Desert Road, Al-Shorouk, 11837, Cairo, Egypt.*

[4]*Professor of Project Management and Strategy, School of Built Environment and Architecture, London South Bank University (LSBU), 103 Borough Road, London SE1 0AA, Room 510.*

[5]*Senior Lecturer, School of Built Environment and Architecture, London South Bank University (LSBU), 103 Borough Road, London SE1 0AA, Room 520.*

*ahmed.daoud@bue.edu.eg

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Abstract

Construction projects suffer from materials waste generated at different stages. This does not only lead to financial loss to construction companies but also lead to negative impacts on the environment. In Egypt, many megaprojects are currently being constructed as one of the main pillars of Egypt's sustainable development strategy (SDS) 2030. This means that significant amount of construction materials are likely to be generated as waste during their execution. There is very limited research exploring waste minimization during the materials procurement stage. Ineffective materials procurement strategies can generate waste due to poor planning and management. For example, materials procurement contributes 11.12% of materials waste in the UK and contributes up to 50% towards total project cost. This paper examines the relationship between materials procurement and materials waste reduction in the construction industry to develop an effective materials procurement framework drawing on the specific challenges and experiences in Egypt.

Keywords: *Materials waste, Waste minimization, Materials procurement, Sustainable development, Egypt.*

1. Introduction

The Construction industry is one of the most significant industries which lead to social and economic development of countries. It provides the citizens with high living standards through socio-economic infrastructure such as roads, hospitals, schools, etc. In Egypt, the construction industry contributes 5% of GDP and employs about 11% of the total population [10]. However, the construction industry is blamed for its negative impact on the environment as 40% of generated waste worldwide is caused by the construction industry [27]. In 2012, 89.03 million tons of solid waste was generated in Egypt in which 4 million tons were generated as construction and demolition (C&D) waste [29]. This means that C&D waste contributes about 4.5% of the total solid waste generated in Egypt. This problem could be attributed to traditional practices in the Egyptian construction industry and the inability to handle the different challenges regarding waste generation and pollution of the environment. Materials waste is affecting both the environment and the economy, because materials waste means financial loss for construction companies. This is because the share of materials cost may be up to 40 and 70% of the total project cost [6].

Despite the efforts exerted by the Egyptian government to solve the solid waste management crisis (including C&D waste), inefficient waste management practices still present hazardous effects on the

environment and public health of citizens. C&D waste arises from the increase of construction activities which consequently lead to increase of construction materials waste generated. Due to the fact that the lifetime spans of buildings in Egypt are short because construction materials are not highly durable, and due to the fact that demolition follows construction, it is worth mentioning that the amount of waste that arises from demolition also increases [29]. In Egypt, only large construction companies are capable of properly collecting and disposing such waste. However, small contractors and the public tend to dump C&D waste on highways, public roads, undeveloped land and other sites near residential areas which causes serious hazards to public health and the environment as shown in Figure 1 [29]. Unfortunately, the recycling industry of C&D waste in Egypt is limited and is able to utilize a small amount of the total generated waste. Also, there is an extreme shortage of reliable data on C&D waste management in Egypt. It is worth mentioning that managing this waste properly would lead to cleaner sites, reduced air pollution, and reduced disposal sites. To solve C&D waste problem in Egypt, effective solutions have to be introduced in the Egyptian society [29]. Unfortunately, the Egyptian construction industry still relies on a traditional practice of dealing with materials waste by dumping it [1].

Recently, Egypt, in an attempt to improve the current environmental conditions, has introduced the Egypt's SDS 2030. The environment is one of the main pillars of the SDS in Egypt. The strategic vision of Egypt's SDS 2030 clearly states that "environment is integrated in all economic sectors to preserve natural resources and support their efficient use and investment, while ensuring the next generations' rights. A clean, safe and healthy environment is leading to diversified production, resources, and economic activities,

Figure 1. Construction Materials Waste Dumped on an Egyptian Public Road [4]

supporting competitiveness, providing new jobs, eliminating poverty, and achieving social justice." [23, p.236]. This vision also coincides with the UN sustainable development goals (SDGs) after 2015, which clearly states that environment is one of the main pillars of sustainable development. It is worth mentioning that C&D waste management is very important for sustainable development, which is about environmental, economic, and social development.

In recent decades, construction materials waste management research has explored different waste minimization approaches during design and construction stages, but very few researchers have exerted effort to explore or focus on minimizing waste during materials procurement stage [2], a critical interface between design and construction stages. Materials procurement process is one of the main causes of waste generation and it significantly affects the total project cost [3, 14].

This paper starts with a literature review to provide an overview of the meaning of C&D waste, different types of materials waste and the causes of materials waste generation. Also, it investigates different approaches of materials waste management, procurement management and materials procurement models, and materials procurement as an approach to minimize materials waste in construction projects. The need for a new approach in materials procurement to reduce waste in

the context of Egypt's vision 2030 will be explored drawing from the lessons learnt in developed countries. Finally, conclusion and recommendations for future research on the development of materials procurement framework for waste minimization in Egypt are also presented.

2. Literature Review

2.1. Definition of C&D Waste

C&D waste has been defined in many different ways in construction literature and there is no absolute definition for it. For instance, the Environment Protection Agency (EPA) in the US defined C&D waste as "waste that is generated from the construction, renovation, repair, and demolition of structures such as residential and commercial buildings, roads, and bridges" [8, p.2]. Alternatively, C&D waste was defined by Tchobanoglous *et al.* (1977) as "wastes from razed buildings and other structures are classified as demolition wastes. Wastes from the construction, remodeling, and repairing of individual residences, commercial buildings, and other structures are classified as construction wastes" [8, p.2]. Furthermore, Roche and Hegarty [25, p.1] defined C&D waste as "surplus and damaged products and materials arising in the course of construction work or used temporarily during the process of onsite activities". It is clear that each study defines C&D waste based on the addressed research question. Any study of C&D waste management will have a clear vision and meaning by specifically defining C&D waste from its own perspective [21].

Lu and Yuan [21] stated that "C&D waste" term has been used extensively in the literature as an integral term to represent materials waste generated by construction activities without restricting it to a specific stage of construction or demolition. The term wastage refers to the variance, if any between the estimated and actual consumption of materials. Following the definition of waste stated by Koskela [20], materials waste can be described as any inefficiency that results in the use of materials in larger quantities than those considered as necessary in the production of a building. In Egypt, Garas *et al.* [15] demonstrated in their study that materials waste during construction is the most frequent waste in Egyptian construction sites which leads to major financial loss and high impact on environmental pollution. Materials waste rates differ from one material to another [15]. For example, timber frameworks with an average waste of 13% and sand with an average waste of 9% showed the highest percentages of waste among all materials. While other materials such as reinforcing steel with an average 5%, cement 5%, and concrete 4% were within the acceptable waste rates of 7% steel and 5% cement.

2.2. Different Types and Main Causes of Materials Waste

Elgizawy *et al.* [8] identified a list of materials which could be wasted in most construction sites as follows: concrete, wood, metal ferrous (Steel) and metal non-ferrous (Copper and Aluminum), masonry (bricks and mortar), plastic (PVC pipes, plastic films for packaging, wall coverings), glass, ceramic tiles, insulation materials (mineral wool insulation, Styrofoam), drywall/gypsum board, filling materials (gravel, sand and soil), paper and cardboard, and marble and granite. Eze *et al.* [12] identified 20 main reasons for materials waste generation in construction sites as tabulated in Table 1.

Table 1. Main Causes of Materials Waste Generation [12]

Main Causes of Construction Materials Waste Generations
1. Frequent design changes and poor design
2. Poor materials storage system
3. Theft or vandalism
4. Poor site conditions
5. Poor strategy for waste minimization

6. poor procurement management (wrong purchasing order – quality, number, time of order)
7. Inclement weather
8. Poor and insufficient implementation of waste management plan
9. Poor materials handling on site
10. Poor quality and non-availability of equipment
11. Site management
12. Use of unskilled labor
13. Lack of workers' awareness and training on waste management practices
14. Poor coordinated documents
15. Long project duration
16. Traditional construction methods (labor intensive nature)
17. Time pressure
18. Waste resulting from poor packaging, delivery and transport
19. Lack of incentive for contractors to improve their practices
20. Poor segregation

2.3. Different Approaches of C&D Waste Management

Literature review revealed several approaches to manage C&D waste used worldwide. For instance, Zaki and Khial [29] stated that C&D waste can be managed using the waste management hierarchy which depends on the 4Rs' Golden Rule of Reducing, Reusing, Recycling, and Recovering of waste. **Reducing** of waste is defined by The Asia Foundation [26, p.7] as "any change in the design, manufacture, purchase, or use of materials or products (including packaging) to reduce their volume and amount of toxicity before they become municipal solid waste". **Reusing** of waste means usage of the same material in the construction process more than once either for the same function or a new function [28]. **Recycling** of waste is defined by Eurostat [11] as "any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes". **Recovering** of waste is defined by Environment Agency [9, p.1] as "using waste to replace other non-waste materials to achieve a beneficial outcome in an environmentally sound manner". Yuan and Shen [28] stated that C&D waste can be managed using waste management hierarchy which depends on the following: the 3Rs' principles of Reducing, Reusing, and Recycling of waste, and disposal of waste. **Disposal** of waste is defined by Environment Agency [9, p.2] as "getting rid of waste in a safe and environmentally sound manner".

The components of the aforementioned waste management hierarchies are arranged in an ascending order according to their negative impact on the environment from low to high as illustrated in Figure 2 [28]. The main components of waste management hierarchies therefore tend to focus on reducing resource consumption and preventing environmental pollution, which are two of the main pillars of sustainability [28]. It has been mentioned in several studies that "reducing of waste" approach is the most effective approach for managing waste due to many reasons outlined as follows: (1) protecting the environment from pollution; (2) reducing the cost assigned for waste transporting, recycling, and disposing; (3) increasing profit; (4) enhancing the company's corporate image; (5) saving the loss of construction time; and (6) providing cleaner and safer site condition [12, 28, 29]. Since 2000, many researchers focused on "C&D waste reduction", which shows that C&D waste reduction is the most preferable way to manage C&D waste from the perspective of saving resources and protecting the environment [28].

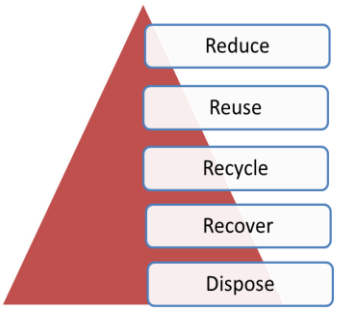

Figure 2. Different Construction Materials Waste Management Approaches

A number of visions, strategies, methodologies and action plans have been developed over the years to alleviate the materials waste problem in construction sites. They included for instance: Industrialization, Computer Integrated Construction, Constructability, Partnership, Robotized and Automated Construction, Lean Construction (LC), Building Information Modeling (BIM), Value Engineering (VE), Sustainable Supply Chain Management (SSCM), etc. [16, 22, 24]. These different approaches can reduce the generation of waste up to 70% [16]. In spite of the valuable contribution of these solutions, the performance of the Egyptian construction industry is considered very low in managing materials waste problem [1].

3. Procurement Management and Materials Procurement Models

Many construction projects encounter problems, such as time and cost overruns and materials waste generation, due to lack of proper materials procurement management. Zeb *et al.* [30, p.171] defined materials procurement as "purchasing of materials needed for execution of a project. Procurement is organizing the purchasing and scheduling delivery of materials to the suppliers". Procurement is responsible for obtaining construction materials in the right quantity, quality, time, cost, and place [18].

Problems in materials procurement management are caused by lack of early planning before the start of the project, incorrect planning, late and wrong deliveries, purchasing materials with nonstandard specifications, etc. Materials procurement management is the process needed for procuring products and service from outside the project team. It consists of four main steps as follows: planning procurements, conducting procurements, administering procurements, and closing procurements [18]. **Planning procurements** is the process of recording procurement decisions, determining the procurement approach, and identifying of potential vendors [18]. It is based on listing the required materials and the suppliers who can provide these materials for the particular project and at the lowest cost. This includes surveying and visiting sites and shops for suppliers to ensure their quality and performance [6].

Conducting procurements is the process of getting vendor responses, choosing a vendor, and awarding a contract [18]. Owners and contractors can get best price for the required materials by analyzing suppliers' proposals. This analysis is based on cost, delivery, production capability, general laws and previous vendors' background [5]. The proposal requests should mention that the vendor must submit specifications for materials and equipment which meets or exceeds the specifications required [19]. **Administering procurements** is the process of managing procurement relationships with vendors, monitoring the performance, and making corrections and modifications when needed [18]. This practice should ensure that the materials supplied meet the requested specifications at a good price and delivered on the specified dates. Tracking of vendor's performance and maintaining a good relationship are considered the basis for sound purchasing technique [5, 6]. Finally, **closing procurements** is the process of completing procurement contracts with vendors [18].

In construction industry, there are different material procurement models. For instance, Daneshgari and Harbin [7] investigated three materials procurement models in the construction industry as follows: specialty contractor procurement model (SCPM), general contractor procurement model (GCPM), and owner procurement model (OPM). In **SCPM,** a specialty contractor is responsible for procuring materials for the project owner. The procurement process takes place once the specialty contractor is assigned. In this model, the owner and general contractor of the project mainly depend on the specialty contractor to procure all the materials for the project. Nowadays, project owners use this model over 90% of the time for materials procurement [7]. In this model, the specialty contractor has the privilege to review the design specifications, update the owner and general contractor of the project for any problem arising due to materials incompatibility with the design specifications, and give recommendations for any design changes. After finalizing the design, the materials order is issued by the specialty contractor to the vendors. Then, the materials are sent by the vendors to the specialty contractor at the jobsite.

In **GCPM**, the general contractor is responsible for procuring materials for the project owner. The procurement process takes place before the specialty contractor is assigned. In this model, the owner instructs the general contractor to procure all the required materials for the project. Nowadays, project owners use this model about 2% of the time for materials procurement [7]. Once the general contractor purchases the materials needed for the project without inputs from the specialty contractor, he/she may assign the purchase order to the specialty contractor. In this case, the specialty contractor carries the responsibility for receiving the materials on site, sorting out inaccurate orders, and rectifying the incompatibility of materials with specifications.

In **OPM**, the project owner directly procures the required materials from the vendors. The procurement process takes place before either general contractor or specialty contractor is selected. Nowadays, project owners use this model about 10% of the time for materials procurement [7]. In this model, the project owner depends on the design specifications produced by the engineering firm and his/her own experience to procure the required materials. Due to the fact that project owners may have individual relationships with speciality contractors, specialty contractors may give inputs and recommendations about materials procurement to the owner. Once the materials are purchased by the owner from the vendors, they are shipped directly to the site and stored until usage and installation by the specialty contractor.

Comparing the three models regarding waste generation, the **GCPM** was introduced to the supply chain to solve the waste generation problem. However, it has been proven to be more inefficient than **SCPM** [7]. Both models suffer from inadequate materials management process which leads to waste generation. The **OPM** is better than both models regarding waste generation aspect. Comparing the three models regarding the cost of procured materials, both models **GCPM** and **SCPM** are similar in materials cost. The **OPM** provides slightly less expensive costs of procured materials than **GCPM** and **SCPM** [7].

4. Materials Procurement and Materials Waste Generation

Materials waste occurs during the construction activities on site due to various actions and activities at design, materials procurement, and construction stages of a project. The literature is very rich on design and construction strategies for minimizing materials waste as outlined in the end of section 2.3. However, few efforts have been exerted to investigate

materials procurement measures to reduce waste generated by construction activities [2]. It is known that the wasted materials are purchased during materials procurement process. Additionally, materials procurement could contribute up to 50% towards the total project cost. Despite the fact that different studies [3, 14] have clearly stated that ineffective application of materials procurement process is a main cause of materials waste, procurement measures for materials waste reduction have neither been explored nor adequately addressed. According to Fadiya *et al.* [13], materials procurement contributes 11.12% of total materials waste generation among other eight factors contributing to waste in the UK as shown in Figure 3. This supports the claim that materials procurement is a main cause of materials waste.

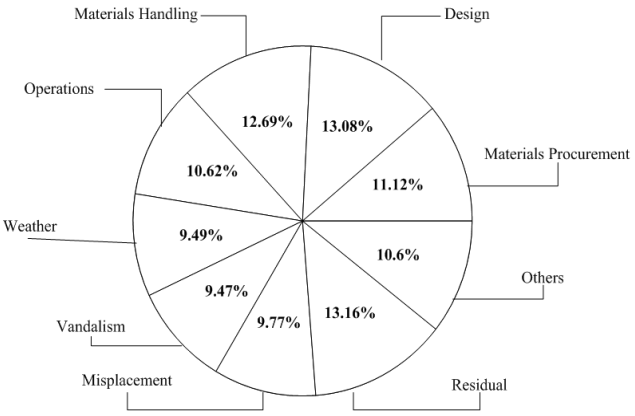

Figure 3. Contributions of Different Sources of Construction Materials Waste in the UK [13]

5. Need for a New Approach in Materials Procurement to Reduce Waste in Egypt

Materials procurement measures can be an effective approach to reduce materials waste in the Egyptian construction industry. This is due to the significant increase in the number of mega construction projects currently being implemented or planned in Egypt such as National Project for the Development of Sinai, National Projects for Roads, National Project for the Development of Upper Egypt, Establishment of New Cities (e.g., New Administrative Capital, East Port Said City, The New Ismailia City, The New Alamein City, and an Integrated City at Al-Galala), The National Electricity Project, Al Galala Plateau Project, The Golden Triangle Project, North-Western Coast Development Project, The National Project for Social Housing, East Owainat Project, etc. [17]. Therefore, applying effective materials procurement practices may lead to lower rates of materials waste and better cost savings for these megaprojects in Egypt.

Different measures can be considered during the material procurement process to reduce the generation of materials waste in Egypt drawing on the lessons from developed countries. In the UK, Ajayi *et al.* [2] was able to define four clusters of strategies for reducing materials waste through materials procurement as follows: (1) suppliers' low waste commitment; (2) low waste purchase management; (3) effective materials delivery management; and (4) waste efficient bill of quantity. Each cluster consists of different measures which should be adopted to reduce materials waste generation. For example, **suppliers' low waste commitment** includes four main measures: suppliers' flexibility in supplying small quantities or modification to products in conformity, commitment to take back scheme (packaging, unused, reusable and recyclable materials), supply of quality and durable products, and usage of minimal packaging (without affecting materials safety).

Also, **low waste purchase management** includes five main measures: procurement of waste efficient materials/technology (pre-assembled/cast/cut), purchase of secondary materials (recycled and reclaimed), purchase of quality and suitable materials, avoidance of variation orders, and correct materials purchase. E**ffective materials delivery management** includes four main

measures: effective protection of materials (during transportation, loading & unloading), effective onsite access (for ease of delivery), efficient delivery schedule, and usage of Just in Time (JIT) delivery system. Finally, **waste efficient bill of quantity** includes three main measures: accurate materials take-off, prevention of over/under ordering, and reduced waste allowance. These different measures can be considered while preparing for materials purchase and during materials purchase and delivery to the site. These measures can be adopted within various materials procurement models discussed to evaluate materials suppliers towards materials waste reduction in construction projects. Findings from the literature review and field studies to be carried out will provide the basis to develop a conceptual framework that will have a significant impact in reducing waste in the Egyptian construction industry and the achievement of Egypt's SDS 2030.

6. Conclusion and Recommendations

Egypt is currently progressing towards the sustainable development of the society by constructing various mega projects as planned in Egypt's SDS 2030. Unfortunately, the construction industry suffers from the generation of materials waste which has its negative impacts on the environment. Besides, materials waste leads to financial loss of construction companies. This paper has investigated the relationship between materials procurement and materials waste reduction in the construction industry to identify best practices that can be applied in Egypt. There are several materials procurement measures which should be considered in practice by industry professionals to mitigate the negative environmental and economic impact of construction materials waste. These measures guide the practitioners towards procuring construction materials in a waste efficient and cost-friendly manner.

Many research focused on construction materials waste minimization during design and construction stages, but the literature review revealed that few studies focused on materials waste minimization during materials procurement stage. Materials procurement plays an important role in materials waste generation and total project cost. As effective procurement process is efficient in reducing waste and the total cost of construction projects, it is therefore recommended that research should be focused on efficient materials procurement process to reduce waste. It is recommended to explore the materials procurement approach for minimizing materials waste in different situations to identify context specific measures that will be applicable in Egypt's construction industry.

This review is part of a PhD research project which will contribute to the existing body of knowledge for practitioners and academics. At the industry level, this research aims to develop an evidence-based conceptual framework which can guide practitioners and professional organizations in the Egyptian construction industry on adopting key measures for efficient materials procurement practice. At the academic level, this research will explore materials procurement practices critical at the interface between design and construction stages using strategies for reducing materials waste that is more suited to the Egyptian context.

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