Waste Minimization during the Construction Phase of Buildings

Subjects: Construction & Building Technology

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It is thought that there is a low level of awareness of key competencies that drive material waste reduction at the construction stage of a project which has led to the low impact of waste minimization in the construction industry. The awareness and the implementation of the various competencies that drive waste minimization shall ensure proper collaboration among construction stakeholders as well as a positive attitude towards waste minimization to enhance high productivity.

Keywords: competencies ; waste minimization ; construction

1. Introduction

The construction sector is a major economic backbone of most countries. However, construction waste (CW) has been a principal problem in this sector for years. Ebekozien et al. [1] defined CW as any inefficiency that results in the use of equipment, materials, or labor in the construction of a building. USEPA [2] also defined CW as building and site improvement materials and other solid waste resulting from construction, remodeling, renovation, or repair operations. The Government of Hong Kong defined CW as anything which is generated because of construction works, then abandoned, regardless of whether it has been processed or stockpiled [3]. In a nutshell, CW could be defined as an activity or material that adds no value to any production in the construction stage of buildings.

Sharma [4] indicated that waste could be classified either as unavoidable (or natural waste) or avoidable. If the cost of waste is higher than the cost to prevent it, it is classified as avoidable waste. If the necessary investment for its reduction is higher than the economy produced, it is classified as unavoidable waste [4]. Wu et al. [5] grouped waste from the construction field into inert, non-inert, and hazardous categories. Large amounts of waste are generated in the construction sector as compared to other sectors. In 2017, 569 million tons of construction and demolition (C&D) waste was generated in the United States, and this amount of waste is more than twice the amount of municipal solid waste. However, demolition activities account for more than 90 percent of total waste generation, while the portion attributed to construction activities amounts to less than 10 percent [6]. In the European Union (EU), C&D waste accounted for 36.4% of all waste in 2016 [7]. In 2016, 66.2 million tons of non-hazardous C&D waste were reported in the UK and 59.6 million in England [8]. The Ghanaian construction industry has also experienced an enormous range of CW over the years [9]. According to Agyekum et al. [10], there is a wide variation in wastage rates of between 5% and 27% of total materials purchased for construction projects in Ghana.

Research reveals that design decisions contribute more to materials waste generation on construction sites. In addition, materials waste can be produced during the construction and operation stages [10][11]. Project duration, project size, activities during project delivery, as well as worker numbers greatly influence waste generation. Tzourmaklioutou [12] and Amudjie et al. [13] postulated that mistakes, unplanned work delivery, redundant activity, movement, delayed or premature inputs, and products or services that do not meet customer needs comprise the causes of waste on construction sites. According to Agyekum et al. [9] and Salgın [14], the constructability of a project should be considered in the design process to prevent or reduce the generation of excessive waste.

CW has negative effects on the environment and economy, as well as impacting project costs. The high level of waste recorded at construction sites has led to a great demand for construction materials on construction sites. The stage of construction as well as the method of construction practice, influences waste generation in project delivery. This, therefore, tends to lead to devastating effects on the environment [15]. Construction players have roles to play in minimizing CW to bring value for money at the end of construction projects and protect the environment through the usage of circular principles such as the five (5) ‘Rs’ (reduction, re-use, recycle, repair, and recover).

Bajjou and Chafi [16] defined waste minimization as “the understanding and changing of processes in order to reduce waste at source”. Rasanjali [17] also stated that any procedure, method, or action that prevents or reduces waste at its source or facilitates reuse/recycling is considered waste minimization. It could be understood from the above literature that the concept of material waste minimization tackles waste at the initial stages of the construction activity. Jaillon et al. [18] conducted a study to reveal the waste minimization potential of prefabrication usage compared to traditional

construction and found that prefabrication provides benefits in waste minimization (approximately 52%) on sites. Mendis [19] argued that there are two waste minimization strategies, i.e., planning and controlling. Lu and Yuan [20] postulated five (5) waste minimization factors at the construction stage of projects, including minimizing waste by government legislation and through design, establishing an effective waste management system, use of low-waste technologies, and improving practitioners' viewpoints toward waste reduction. Ding et al. [21] developed a system dynamic model for waste minimization at the construction stage to simulate the environmental benefits of CW reduction. Some research shows the importance of workers' positive attitudes toward CW minimization [22]. According to Salgın et al. [23], the primary cause of waste during the construction stage of buildings is "improper workmanship and practices". Tam and Tam [24] examined a kind of reward system called the Stepwise Incentive System (SIS), and it was found that 23% less waste was generated when SIS was implemented in a case study project in Hong Kong. According to Khan et al. [25], providing training and education among staff is an important factor in waste minimization. Despite the existence of these strategies, little impact has been felt on the construction industry as far as waste minimization is concerned. It is thought that there is a low level of awareness of key competencies that drive material waste reduction at the construction stage of a project, especially in the setting of a developing country.

2. The Concept of Competency

The concept of competency has been touched on by various literature works, with Taylor, McClelland, and Boyatzis spearheading it in the 20th century [26]. Competency is the collection of knowledge, skills, and attributes that are capable of influencing an individual's performance [27]. The Iceberg Theory, as propounded by Spencer and Spencer [28], viewed competency as an iceberg at sea level depicting a visible part and a hidden part. Knowledge and skill form the visible part, while interpersonal, motive/trait/concept, and value/moral forms the hidden part. Prifti et al. [29] defined competency as a behavior that produces successful results through the combination of knowledge, skill, attitude, and value. Competency is a series of skills and traits needed by workers for effective work delivery.

3. Components of Waste Minimization Competencies

To ensure waste minimization in the construction industry, there is a need to explore the core competencies required by the construction players to ensure effectiveness. Na'im [30] proposed leadership and organization, basic literacy, target management, and emotional intelligence as core competencies that could drive waste minimization. The Project Management Institute [31] categorized competency under knowledge, performance, and personal competencies. This study focuses on skills and knowledge as the main components of waste minimization competencies. This reiterates the position of Spencer and Spencer [23] on viewing competency as an iceberg showing forth a visible part (Skills and Knowledge) and a hidden part (Trait).

Ebekozien [32] defined skill as the capacity to perform a task of a mental or physical nature in order to have a specified outcome. Skills could be easily identifiable or abstract. Zhao et al. [33] and Geoghegan and Dulewiz [34] asserted that the effectiveness of any project's success depends on the leadership role of the construction professionals. Therefore, in focusing on key competencies that drive waste minimization at the construction stage of a project, leadership skill was targeted. Leadership skill encompasses self-awareness, emotional resilience, intuitiveness, interpersonal sensitivity, influence, motivation, and conscientiousness [33] of the construction professional in waste reduction.

The construction manager or the head in charge of waste minimization at the construction site should be able to efficiently communicate with all parties involved in CW reduction on policies governing waste management to fulfill sustainability goals. According to Li et al. [35], effective communication of organizational waste management policy mobilizes support for the minimization objectives. Wagstaff [36] also postulated that working cooperatively with others as opposed to separately or competitively is a prerequisite for influencing a team to perform in a desirable manner. Effective communication, information sharing, early warning systems, and the early contribution of expertise on CW needs to be enhanced to prevent construction errors, reworks, and waste [37]. Developing and implementing a waste management plan contributes immensely to CW reduction at the construction stage of a project. It helps to identify the forms of waste and their sources and specifies mitigating measures for them. The plan reflects the peculiarities of the project in terms of the nature and amount of waste anticipated and prescribes ways of managing them [15].

According to Tatham [38], supply chain management skills involve the capacity to obtain suppliers' highest commitment, achieve just-in-time delivery, and enable lean construction in order to avoid waste due to long storage or ordering unneeded materials. The just-in-time delivery approach enables the usage of material as and when needed. This reduces double handling and damage that erupts from long storage. Alvanchi et al. [39] asserted that the implementation of a Material Logistics Plan (MLP) at construction sites is an efficient way to reduce CW. Logistics management involves effective planning of materials ordering and purchase, inbound, materials movement, and storage on construction sites [40]. Waste minimization requires adequate estimation of materials required at different stages of projects in an attempt to reduce the likelihood of materials over-ordering and subsequent leftover, which is a key cause of waste generation [40]. Bearing skills in logistics management ensures efficient waste reduction.

In a nutshell, potential key factors frequently used during the construction phase of building projects to drive CW minimization were derived from existing literature, and twenty-four (24) competencies were identified under two (2) components as knowledge and skill (see **Table 1**).

Table 1. Potential Key Competencies that Drive Material Waste Minimization.

No	Competency	Brief Explanation	Component	Reference
1	Leadership	In managing construction waste, the construction manager must be able to provide direction to inspire others, track his weaknesses and strengths, and show personal commitment to pursuing waste minimization.	Skill	Geoghegan and Dulewiz [34]
2	Effective Communication	The construction manager or the head in charge of waste minimization at the construction site should be able to efficiently communicate with all parties involved in construction waste reduction on policies governing waste management to fulfill sustainability goals. Effective communication of organizational waste management policy mobilizes support for the minimization objectives.	Skill	Li et al. [41]
3	Waste Management Plan Implementation	Developing and implementing a waste management plan contribute immensely to construction waste reduction at the construction stage of a project. It helps identify the forms of waste and their sources and specifies mitigating measures for them. The plan reflects the peculiarities of the project in terms of the nature and amount of waste anticipated and prescribes ways of managing them.	Skill	Alvanchi et al. [39]
4	Supply Chain Management (SCM) Skills	Supply chain management skills involve the capacity to obtain suppliers' highest commitment, achieve just-in-time delivery, and enable lean construction in order to avoid waste due to long storage or ordering unneeded materials. The just-in-time delivery approach enables the usage of material as and when needed. This reduces double handling and damage that erupts from long storage.	Skill	Al-Hajj and Hamani [42] and Tatham [38]
5	Material Logistic Plan Implementation	Logistics management involves effective planning of materials ordering and purchase, inbound and on-site materials movement, and materials storage. Bearing skills in logistics management ensures efficient waste reduction.	Skill	Alvanchi et al. [39]
6	Teamwork	Working cooperatively with others as opposed to separately or competitively is a prerequisite for influencing a team to perform in a desirable manner. This, therefore, means teamwork is an important factor when talking about key competencies that drive waste minimization at the construction stage of a project. The construction manager should ensure that effective coordination exists among all project stakeholders (i.e., clients, consultants, and suppliers) in the drive to waste minimization at a construction site. Effective communication, information sharing, early warning systems, and early contribution of expertise on construction waste need to be enhanced to prevent construction errors, reworks, and waste.	Skill	Hwang and Ng [43]
7	Delegation	Delegating decision-making power to employees can lead to more innovative ideas and solutions for waste minimization. Employees who are closer to the work processes are often better placed to identify opportunities for reducing waste and can implement changes more effectively. Delegation can ensure that the responsibility, decision-making, training, and accountability are distributed across the organization, resulting in more effective waste reduction strategies and a culture of sustainability.	Skill	Shi et al. [44]
8	Problem solving skills	By using problem-solving skills to identify potential sources of waste, analyze the root cause of waste, develop and implement waste reduction strategies, and monitor and adjust waste reduction efforts, the project team can significantly reduce waste and improve project efficiency.	Skill	Shi et al. [44]
9	Onsite practical skill	Skilled workers can use their expertise to cut and shape materials in the most efficient way possible, minimizing waste by avoiding unnecessary cuts or shaping. By implementing efficient material selection, cutting and shaping, reuse and recycling, lean construction techniques, and minimizing errors, skilled workers can help to reduce waste and improve the sustainability of the construction industry.	Skill	Shi et al. [44]
10	Personnel quality	High-quality personnel can drive waste minimization by implementing and monitoring waste reduction practices, continuously improving processes, and ensuring that products are manufactured with minimal waste. This can help organizations reduce costs, improve efficiency, and enhance their environmental sustainability.	Skill	Shi et al. [44]

No	Competency	Brief Explanation	Component	Reference
11	Professional learning	By providing education and training on waste reduction practices and promoting the use of sustainable materials and lean construction practices, construction professionals can help reduce the amount of waste generated during construction and improve the environmental sustainability of buildings.	Skill	Shi et al. [44]
12	Creative thinking	Creative thinking is a key ingredient in driving waste minimization during the construction phase of a building project. By thinking outside the box, it is possible to identify new opportunities to reduce waste, optimize processes, and create sustainable buildings that minimize their environmental impact.	Skill	Shi et al. [44]
13	Personnel commitment to pursuing an ethical solution to waste minimization	By fostering a culture of waste minimization, identifying opportunities for waste reduction, implementing waste reduction strategies, monitoring progress, and encouraging collaboration and communication, project leaders can help minimize waste and create sustainable buildings that have a minimal impact on the environment.	Skill	Ajayi [37]
14	Provision of direction to inspire others	Providing direction involves setting clear goals and targets for waste minimization. By articulating specific waste reduction targets and communicating them clearly to the construction team, project leaders can inspire others to take action and prioritize waste minimization in their work.	Skill	Geoghegan and Dulewiz [34]
15	Awareness of CW minimization practices	Awareness of CW minimization practices is necessary for waste minimization during the construction phase of a building project since professionals will only indulge in practices they are conversant or knowledgeable of.	Knowledge	Pittri et al. [45]
16	Construction Sequencing and Planning	Most waste on construction sites happens due to a lack of planning and sequencing of construction activities. Planning and scheduling is a critical factor in the quest to achieve sustainability; hence, it needs to be well addressed and reflected in construction schedules to avoid any delays and wastage of materials.	Knowledge	Hwang and Ng [43]
17	Health and Safety Management	The construction manager needs to understand the health impact of construction waste on site workers and the danger improper management of construction waste brings. Accidents that normally happen from poor site waste management could be reduced through proper health and safety management.	Knowledge	Hwang and Ng [43]
18	Human Resource Management	In human resource management, practices such as organizing waste management and materials handling vocational training for operatives, having a dedicated site team or specialist sub-contract package for on-site waste management, the appointment of labor solely for waste management, etc., could enhance the minimization of waste.	Knowledge	Ajayi [37]
19	Modern Construction Methods	Modern construction methods, such as the use of prefabricated construction products and modular construction, contribute to construction waste minimization at the construction stage of a project. Prefabrication makes use of precast components and modules, modular construction techniques, and other offsite technologies. Modular construction also refers to factory-produced building units that are delivered and assembled on-site as building elements or volumetric components. The use of precast materials has the potential to reduce the amount of on-site damage and rework, thereby contributing to waste reduction output by up to 84%.	Knowledge	Ajayi [37]
20	Reuse and Recycling of Waste	The recycled content as well, as the recyclability of construction material, enhances sustainability which eventually contributes to waste reduction as the recycled content of ready-mixed concrete makes it sustainable. Using materials that can be recycled reduces the use of raw materials and embodied energy. Additionally, recycling takes less energy than producing whole new material.	Knowledge	Kabirifar et al. [46]
21	Standardization and the Implementation of Sustainable Construction Practices	In the construction phase of a project, standard material sizes could be opted for to reduce waste during trimming processes. Mixing of concrete can also be done on-site to readily control the amount needed. Minimal construction waste during installation reduces the need for landfill space and also provides cost savings. Knowledge of sustainable construction practices ensures effective waste reduction.	Knowledge	Kabirifar et al. [46]
22	Adherence to Project Design/Drawings	This includes ensuring that materials, equipment, and construction methods are in line with the design, as well as implementing any necessary changes or modifications in a way that maintains the integrity of the overall project design. Adherence to project design/drawings is essential for ensuring waste minimization.	Knowledge	Osmani et al. [47]

No	Competency	Brief Explanation	Component	Reference
23	Waste Auditing to Monitor Environmental Performance	A waste audit is a systematic process of quantifying and characterizing the types and amounts of waste generated by an organization or community. The goal of a waste audit is to identify opportunities for waste reduction, reuse, and recycling, as well as to assess the effectiveness of current waste management practices. This helps to monitor the environmental performance of any project.	Knowledge	Osmani et al. [47]
24	Thorough review of the project specifications by contractors at the construction stage	The contractors responsible for carrying out the construction work should carefully examine and analyze the project specifications before beginning any construction activities. This review is important to ensure that the contractors fully understand the project requirements, such as design plans, building codes, safety regulations, sustainable plans for waste reduction, and other relevant specifications.	Knowledge	Osmani et al. [47]

Li et al. [41] defined knowledge as the awareness or understanding of facts, rules, principles, guidelines, concepts, theories, or processes needed to complete a task. Most wastes on construction sites happen due to a lack of planning and sequencing of construction activities. Pérez and Bastos Costa [48] asserted that planning and scheduling is a critical factor in the quest to achieve sustainability; hence it needs to be well addressed and reflected in construction schedules to avoid any delays and wastage of materials. The recycled content, as well as the recyclability of construction material, enhances sustainability which eventually contributes to waste reduction. For instance, according to Senaratne et al. [49], steel can be recycled from construction debris, which makes it a commonly recycled building material. Glass is a recyclable construction material, but its separation from a CW is difficult [50]. Using materials that can be recycled reduces the use of raw mater and embodied energy [50]. He further stated that recycling takes less energy than producing a whole new material. Health and Safety Management is critical when focusing on key competencies that drive waste minimization at the construction stage of a project. The construction manager needs to understand the health impact of on-site workers and the danger improper management of CW brings.

Accidents that normally happen from poor site waste management could be reduced through proper health and safety management [43]. Hwang and Ng [43] postulated that construction managers should select parties for construction activities based on their knowledge of CW. In human resource management, practices such as organizing waste management and materials handling, vocational training for operatives, having a dedicated site team or specialist sub-contract package for on-site waste management, the appointment of labor solely for waste management, etc., could enhance the minimization of waste [37]. Modern construction methods, such as the use of prefabricated construction products and modular construction, contribute to CW minimization at the construction stage of a project. Prefabrication makes use of precast components and modules, modular construction technique, and other off-site technologies [37]. Modular construction also refers to factory-produced building units that are delivered and assembled on-site as building elements or volumetric components. The use of precast materials has the potential to reduce the amount of on-site damage and rework, thereby contributing to waste reduction output by up to 84% [37].

In the construction phase of a project, standard material sizes could be opted for to reduce waste during trimming processes. Salgın [51] states that choosing dimensionally coordinated building products with the building helps to avoid the required cut-offs in the construction stage to ensure CW minimization is provided. Mixing of concrete can also be done on-site to readily control the amount needed. These points are supported by Menegaki and Damigos [15] with the claim that minimal CW during installation reduces the need for landfill space and provides cost savings. Sustainability is a concept that aims at protecting our environment, ensuring economic profitability, and creating social awareness [9]. Requisite knowledge of sustainable construction practices ensures effective waste reduction.

Other knowledge competencies cited by researchers include adherence to project design/drawings, waste auditing to monitor the environmental performance, and thorough review of the project specifications by contractors at the construction stage [52]. Hwang and Ng [43] stated delegation and problem-solving as key skills that could drive CW minimization. Shi et al. [44] also added continuing professional learning, on-site practical skill, and personnel quality as skills that should be possessed by construction professionals in waste minimization. Creative thinking, provision of direction to inspire others, and a personal commitment to pursuing an ethical solution to waste minimization are also skills that could drive material waste minimization if portrayed by construction site workers [43][44].

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