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Identifying the Barriers to Sustainable Management of Construction and Demolition Waste in Developed and Developing Countries

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Abstract: The construction industry is a vital part of every nation's economy. Construction activities influence the social, environmental, and economic aspects of sustainability. There are so many barriers to sustainable construction and demolition waste management (C&DWM). This study aims to identify barriers for effective sustainable C&DWM in developed and developing countries. To achieve the objective, 11 barriers have been selected and identified based on an excessive and comprehensive literature review, and then reviewed by experts. These reviewed barriers were further examined by various experts within different organizations using a questionnaire survey. Ranking of the barriers was carried out using the Relative Importance Index (RI), and the results were statistically analyzed using Statistical Package for Social Sciences (SPSS). Practical solutions were proposed to overcome the identified barriers. The overall ranking of barriers by RI indicates that insufficient attention paid to C&DWM, lack of law enforcement, lack of regulation, and financial constraints represent the four major barriers to sustainable C&DWM in these countries. The findings of this study and the proposed solutions are enablers for decision-makers to develop effective strategies to tackle construction and demolition wastes in sustainable manners.

Keywords: barriers; sustainability; construction and demolition waste; waste management; relative importance index

1. Introduction

The population and economic growth due to urbanization have increased the amount of municipal waste, notably construction and demolition waste (C&DW) generated from increased demand for housing and municipal expansion [1]. This massive amount of C&DW creates environmental burdens, for example by depleting resources, reducing green space, and increasing air and land pollution and toxic waste discharge [2,3].

Consequently, the rapid increase in global urbanization has increased the demands placed upon the construction industry [4,5]. The construction industry now not only needs to meet this increasing demand for urban spaces but also effectively address all the negative externalities associated with increased urbanization. This includes the large-scale clearance of agricultural land, high energy consumption, and rising environmental degradation [6]. The amount of C&DW generated by the industry is also increasing at a rapid rate. Globally, more than 10 billion tons of C&DW are produced every year [7,8]. The construction industry is seen as a major generator of waste and pollution, as waste from construction activities significantly pollutes the environment [8,9]. The proper management of this waste is a challenge in many countries, particularly developing countries. Moreover, construction projects in most developing countries have been characterized by poor performance in terms of sustainability [10]. C&DW mainly consists of inert and non-biodegradable materials such as concrete, plaster, wood, metal, broken tiles, bricks, and masonry [11]. In some parts of the world, the disposal of C&DW often creates additional hazards as it is disposed of indiscriminately and illegally on any available space, including on the shoulders of major roads [12].

Although the construction industry has a vital role in developing cities, its contribution to environmental degradation is widely acknowledged [13]. Infrastructural development can lead to significant C&DW generation if it is not designed and constructed sustainably. The C&DW is considered the largest waste flow worldwide, and has reached 30–40% of the total solid waste (SW) [14–16], for instance, the European construction sector produces 820 million tons of C&DW every year, which is around 46% of the total amount of SW generated in Europe [17]. Sustainable construction has become a focal point for countries worldwide, as the Earth's resources are under severe pressure due to increasing population and economic expansion. As a result of this, many countries are striving to implement sustainable construction practices in their construction industries [10].

Sustainable management of C&DW is therefore of paramount importance to mitigate and reduce the environmental impacts of C&DW. Thus, it takes into consideration reducing raw material consumption, reusing materials, appropriate recycling mechanisms, and minimizing waste generation from construction and demolition tasks [18]. Despite great previous efforts, the current practice in the construction industry is far from reaching the goals of sustainability to fully achieve sustainable construction. Recent research has shown that the construction industry requires significant transformation to fully implement sustainable practices to contribute to the achievement of sustainable development goals [1].

Understanding the barriers to sustainable development can promote the development of eco-friendly, socially harmless, and economically viable strategies [1]. Prior studies have assessed the barriers to sustainable construction and demolition waste management (C&DWM). Some studies showed that the economic concerns are the most influential in C&DWM from both governmental and institutional perspectives [18,19]. Negash et al. [1] found that the eliminating regulatory and social barriers can significantly enhance the performance of C&DWM. Also, Dong et al. [20] showed that the technical barriers areas are important due to the complexity of waste management; technical resources such as appropriate processes, procedures, and people are needed for waste management activities. Furthermore, Ghaffar et al. [21] emphasized that improvement in the regulatory system, social awareness, technical practices, and the development of waste infrastructure using innovation to treat waste are necessary to achieve sustainable C&DWM.

Therefore, this research contributes to provide qualitative information about the challenges and barriers to sustainable C&DWM and aims to investigate, identify, and rank the barriers to C&DWM. Effectively, the identifications of these barriers may help decision makers to develop the strategies required to mitigate them.

This study is organized as follows: Section 1 introduces the research; Section 2 is focused on literature reviews on the barriers to achieve sustainable C&DWM; Section 3 outlines the methodology used in this study including identification barriers and data analysis procedures; Section 4 presents and discusses the results including categorization of the construction industry, evaluation of the barriers to effective and sustainable C&DWM, suggestion solutions to tackle the barriers to effective sustainable C&DWM, and statistical analysis for the obtained results; Section 5 states the main conclusions from the present study, summarizes limitations, and presents recommendations for future studies.

2. Literature Review

The construction industry encompasses the design, construction, maintenance, and demolition of assets, buildings, engineering, and infrastructure works. It involves the entire life cycle of buildings and infrastructure from concept and design, to development, use, and ultimate demolition [22] and the importance of the construction industry to the economy of a country cannot be underestimated. It has been argued that a country's construction industry is vital to its economic development and national growth [23], yet stakeholders are increasingly demanding construction companies take responsibility beyond their economic contribution to include their impact upon the wider environment and society [24]. Unlike many industries, the construction industry also operates almost wholly in the public eye and so is subject to a greater level of scrutiny over its practices, specifically around waste minimization, reuse, and recycling practices. The construction industry involves several participants and stakeholders, their consciousness and commitment can have a major impact on the effectiveness of C&DWM.

C&DWM is considered to be one of the most important environmental challenges faced by policymakers worldwide because of the rate of increase and associated pollution. Accordingly, many researchers have identified many barriers to effective C&DWM around the world. Bufoni et al. [25] identified socio-political, technological, regulatory, financial, and human resources constraints as the barriers to effective C&DWM. This is supported by Menegaki and Damigos [26], who also identified the lack of regulatory and financial resources as hindrances to sustainable C&DWM. Similarly, Udawatta et al. [27] found that the main barriers to effective C&DWM include the rigidity of construction practices, construction project characteristics, awareness, experience and commitment, and the rudimentary nature of waste management systems, and human and technical factors. Aghimien et al. [28] revealed that the major barriers to sustainable construction practices are fear of higher investment costs, no local green certification available, lack of government policies or support, and lack of financial incentives. Opoku and Ahmed [29] recognized the importance of public awareness and proper knowledge and understanding of sustainability as being essential to the successful promotion of sustainable construction practices in the various construction organizations. Aghimien et al. [28] noted that sustainability awareness and the knowledge-related factor are crucial barriers to sustainable construction. Karji et al. [5] found that pre-construction constraints, managerial constraints, legislative constraints, and financial and planning constraints are the most influential challenges that the industry faces to foster sustainable construction. Furthermore, the barriers to effective C&DWM are classified under three dimensions: behavioral, technical, and legal [30]. Huang et al. [31] also acknowledge that ineffective management systems, immature recycling technology, under-developed market for recycled C&DW products, and immature recycling market operations constitute barriers to C&DWM. Also of note is the findings that barriers to effective C&DWM vary from country to country and regions of the world. This is hardly surprising given the differences in levels of socio-economic cultural norms, institutions, energy sources, and climate [32].

Prior studies highlighted that the consideration of economic barriers is essential because contractors usually seek and give high priority to financial gains [19,33]. Lockrey et al. [34] underlined that economic viability is a significant barrier and has a substantial effect on contractors' performance, practices, and behaviors regarding C&DWM. Chen et al. [19] identified economic barriers as having the most influence on both government institutions' and contractors' management strategies. Negash et al. [1] revealed that the economic barriers are significant and should be investigated to improve the understanding of the obstacles to managing waste generated from construction works and provide solutions that address these obstacles. Moreover, technical barriers that involve the absence of the right expertise, knowledge, and technologies needed to promote sustainability are obstacles to implement C&DWM [35,36]. Mahpour [30] argues that technical, legal, and social barriers are fundamental barriers that make it difficult to achieve sustainability. Negash et al. [1] noted that the technical weaknesses are significant sources of problems related to C&DWM and need to be considered. Social barriers, such as the lack of contractor awareness and lack of community involvement, significantly hinder the implementation of sustainability practices [34]. Abarca-Guerrero et al. [37] argue that social awareness affects the sustainability performance of C&DWM. Insufficient or the lack of management regulations, such as weak policies and inadequate supervision, create significant challenges for attaining sustainability in construction works [15,30,38]. Similarly, Negash et al. [1] indicate that it is necessary to consider the significance of regulatory barriers when assessing C&DWM.

On the other hand, policymakers and industry practitioners must improve their awareness and efforts to promote and implement effective C&DWM [39]. Albeit, the emergence of building information modeling technology provides new opportunities to reduce construction waste generation and project costs by enhancing the quality of design and construction management with inherent capabilities like material quantity take-off, spatial conflict analysis, and multidisciplinary data communications. However, few studies have focused on how to more effectively manage demolition waste generated from existing buildings with the aid of building information modeling applications [39,40]. Han et al. [39] identified the main barriers hindering the extensive adoption of building information modeling in C&DWM as the inefficient building data acquisition and integration process, moreover, existing waste management software and inherent waste analytic functionalities are not compatible with building information modeling.

3. Methodology

This study used data from the Science Direct and Web of Science database during the years 2019–2021 to explore research published in journals, books, chapters, and studies on the sustainable construction industry. The main keywords to search the database included construction industry, sustainable waste management, sustainable C&DWM, challenges, barriers and obstacles to sustainable C&DWM, management of C&DW in developed and developing countries, Egypt, Ghana, UK, and KSA, statistical analysis, relative importance (RI), proposed solutions to eliminate and overcome barriers to sustainable construction, etc. The papers included in this study were published between the years 1998 and 2021. This was done to identify barriers to sustainable C&DWM in some developed and developing countries as well as to investigate the possible solutions to tackle the barriers. The initial search yielded more than 300 publications in the English language. They were analyzed individually to assess if they focused on sustainable C&DWM in developed and developing countries. Thus, general and non-relevant articles were excluded from these articles. At the end, a total of 78 research items has been retained including 77 research articles and 1 technical report.

The methodology of the study consists of three main steps: In the first step, identify the barriers based on the literature review. In the second step, the questionnaire was assessed by experts in construction projects. In the third step, the reviewed questionnaire was sent to respondents to identify and rank the barriers. Ranking of the barriers was carried out using the RI, and the results were statistically analyzed using Statistical Package for Social Sciences (SPSS). Practical solutions were proposed to overcome the identified barriers. Figure 1 shows the methodology for the current research.

3.1. Identification of Barriers

There are so many barriers that hinder the effective and sustainable implementation of waste management policies and strategies in construction projects. In the first phase, 82 papers were reviewed and eleven barriers were identified; later, 24 papers were reviewed and the selected barriers were the same. This is due to the overlap of suggested barriers investigated through the reviewed papers, as well as experts' recommendations, as indicated in Table 1. All these barriers are widely acknowledged in the literature and are highly applicable in the current context of this study. The literature review focused mainly on two criteria for journal selection: indexed in Science Citation Index and a publication focusing on waste management.

Table 1. Barriers to effective C&DWM.

Serial Number	Barriers to Effective C&DWM	References
B1	Institutional Fragmentation	[4,27,31,33,41–47]
B2	Lack of Fundamental Data on C&DW	[27,30,43,48–52]
B3	Lack of Law Enforcement	[2,15,30,31,41,50,53–56]
B4	Insufficient Attention Paid to C&DWM	[2,15,27,33]
B5	Socio-political	[1,10,21,25,46,52,53,57]
B6	Technological	[1,20,25–27,30,33,42–46,48,51,52,57]
B7	Lack of Regulation	[1,2,10,15,21,25,26,31,33,43,45,49–51,53–56,58]
B8	Financial	[1,10,15,25,26,31,43,44,52,53,57–59]
B9	Human Resources Constraints	[2,4,25,27,30,42,52,54,55]
B10	Construction Project Characteristics	[27,46,53,60]
B11	Rigidity of Construction Practices	[27,52,60–62]

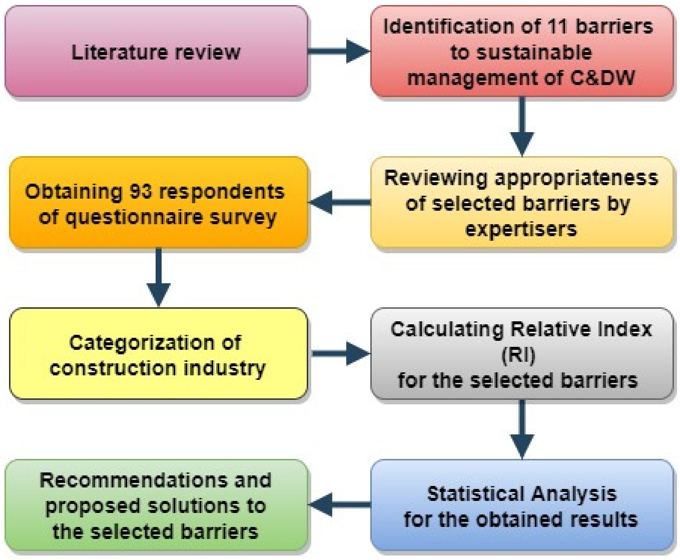

Figure 1. Research methodology scheme.

B1: Institutional Fragmentation.

Several institutions are involved in waste management, and as often as it is the case, many of these institutions reneged on their responsibilities, hoping other institutions would tackle the problem. This scenario occurs mostly under extensive bureaucracy where there are no clearly defined lines of responsibilities [2,46,47]. Institutional fragmentation is particularly a major challenge to effective and sustainable C&DWM, and rather than a weak and bureaucratic waste management system, requires effective and strong institutional arrangements for waste management [4,41,63,64].

B2: Lack of Fundamental Data on C&DW.

Sustainable waste management requires reliable data on rates of generation and composition of the wastes. However, the fundamental data on C&DW that will inform effective planning for sustainable C&DWM is absent in many developing countries and woefully inadequate in some developed countries [27,51,52]. Notwithstanding this, C&DW comprises the largest waste stream in most developed countries and is also increasing at alarming rates in the developing world, due to an increasing rate of urbanization [65].

B3: Lack of Law Enforcement.

Many countries have a long history of safeguarding the environment, including attempts in ensuring proper C&DWM, and have enacted appropriate legislations; nonetheless, the enforcement of legislations is a major challenge in many countries, particularly in developing countries [41]. The non-compliance and non-enforcement of laws and regulations governing C&DW have significantly contributed to poor C&DWM in many countries [2,30,41,54].

B4: Insufficient Attention Paid to C&DWM.

Stakeholders in the construction industry usually focus more on completing the project within budget, at the expected time, and to the desired quality, and much less attention is paid to the waste emanating from construction activities [15,27,33,66]. This has given a bad image to the construction industry, as improper disposal of C&DW results in far-reaching environmental consequences [2].

B5: Socio-political factor.

The construction industry, like other industries, is characterized by cultural and socio-political differences across firms' types, age, and size. Consequently, several studies have linked the construction industry's culture with its waste intensiveness [1,10,21,52,67]. This means that an effective and sustainable waste management system cannot be established unless the cultural and socio-political patterns of construction firms are fully understood [25,46,53,57].

B6: Technological.

The C&DW technology and management choices in many countries have become very complicated, especially when reductions in greenhouse gasses, elimination of landfill sites, and land reclamation are targeted goals [42,44]. The C&DW sector has become a specialized industry involving huge and indivisible capital requirements, and sophisticated technology, requiring in-depth experience and expertise in research and engineering [26,30,43–46,51,57]. Technical information and guidance, advanced technologies and methodologies for sustainable construction represent important requirements for effective C&DWM [1,20,52].

B7: Lack of Regulation.

Environment regulation, including C&DWM, is essential for ensuring effective and sustainable environmental management and governance [1,2,10,21]. However, weak enforcement of environmental regulations in many countries allows construction firms to flout regulations on C&DWM without sanctions [50,51,55].

B8: Financial.

Financial resources are critical for effective waste management; however, these are generally scarce in many countries [25,44]. Poor economic policies, coupled with extreme poverty and infrastructure deficit, make the financial consideration one of the obvious constraints to developing appropriate C&DWM systems in most developing countries [1,10,26,43,52,68].

B9: Human Resources Constraints.

Human resources are essential for effective waste management, especially the daily operations of C&DWM [2,52]. Nonetheless, many countries do not have the human resources with the requisite expertise required for the effective and sustainable management of a C&DW system [25,27,30,42,54,55].

B10: Construction Project Characteristics.

Several construction project characteristics have the potential to influence C&DWM, which include: the complexity of the project, type of project, size of project, location of the project, the importance for the project to be completed on time, the form of contract, and project funding [27,46,53,60].

B11: Rigidity of Construction Practices

Many stakeholders are involved in the construction industry who play varied and crosscutting roles. The effectiveness of a C&DWM system in a particular location or country depends on the performance of these stakeholders in terms of their awareness of the impact of construction SW on the environment, and flexibility or rigidity in their practices [27,61,62]. With high public awareness about the problems posed by inadequate C&DWM, broad consultation and the involvement of all stakeholders are needed for the sustainable development of C&DWM strategies and policies [52,60].

3.2. Data Collection and Analysis

The questionnaire is a systematic technique of data collection and it is used to obtain professional opinions. A questionnaire survey was distributed amongst various stakeholders within different organizations to investigate barriers to effective waste management implementation in the construction industry in the selected countries. In this study, the construction industry in the studied countries was categorized in terms of ownership (public or private), type of the organization, size of the organization, role of the respondent in the organization, and experience of the respondent in the construction industry. A two-step procedure was adopted to assess its appropriateness and rationality. In the first step, the questionnaire was assessed by 15 persons having expertise in construction projects, to ensure clarity and technical applicability. In the second step, the reviewed questionnaire was sent to respondents to identify and rank the frequency (i.e., 1 = Never, 2 = Rarely, 3 = Occasionally, 4 = Sometimes, 5 = Frequently, 6 = Usually, and 7 = Always) of the eleven barriers.

The distribution was conducted across various countries, mainly the UK, the KSA, Ghana, and Egypt. Due to the ongoing COVID-19 pandemic, the Google questionnaire survey form was used. Around 150 experts in the construction field were invited to participate in the study and 93 responses were collected over the course of two months in 2020. A convenience sampling approach was adopted to select participants from each country; 93 valid responses were received and considered for analysis (UK: 18, KSA: 31, Ghana: 32, and Egypt: 12). All results were reported descriptively with the aid of Statistical Package for Social Sciences (SPSS), Microsoft Excel, and RI.

The study adopts the RI research method to identify and rank the critical barriers to the sustainable implementation of construction demolition waste management in the countries investigated. The RI is widely used in the analysis of construction strategies and policies. Equation (1) [69,70] depicts the RI measurement.

$$\mathrm{RI} = \sum(\mathrm{ax}) \times \frac{100}{7} \quad (1)$$

where: a = constant (weight) 1 to 7, x = n/N, n = Frequency of responses, N = Total responses.

Finally, the questionnaire included the reasons for organizations' engagement in effective C&DWM. It was investigated by asking the respondents "Why do you think your organization should engage in effective C&DWM activities?" This was performed to know the current trends and needs to achieve sustainable C&DWM in their organizations.

4. Results and Discussion

The results discussed under this section are based on the extensive literature review that produced the barriers to effective C&DWM and the responses to the questionnaire by experts from the UK, the KSA, Egypt, and Ghana. Thus, the responses of 93 experts in the construction industry are discussed.

4.1. Categorization of the Construction Industry

The classifications of respondents in relation to ownership of the organizations are shown in Figure 2a. It can be seen that 49.5% of the respondents were from the public sector, whereas 50.5% work in the private sector. Thus, both the public and private sectors of the economy were equally represented.

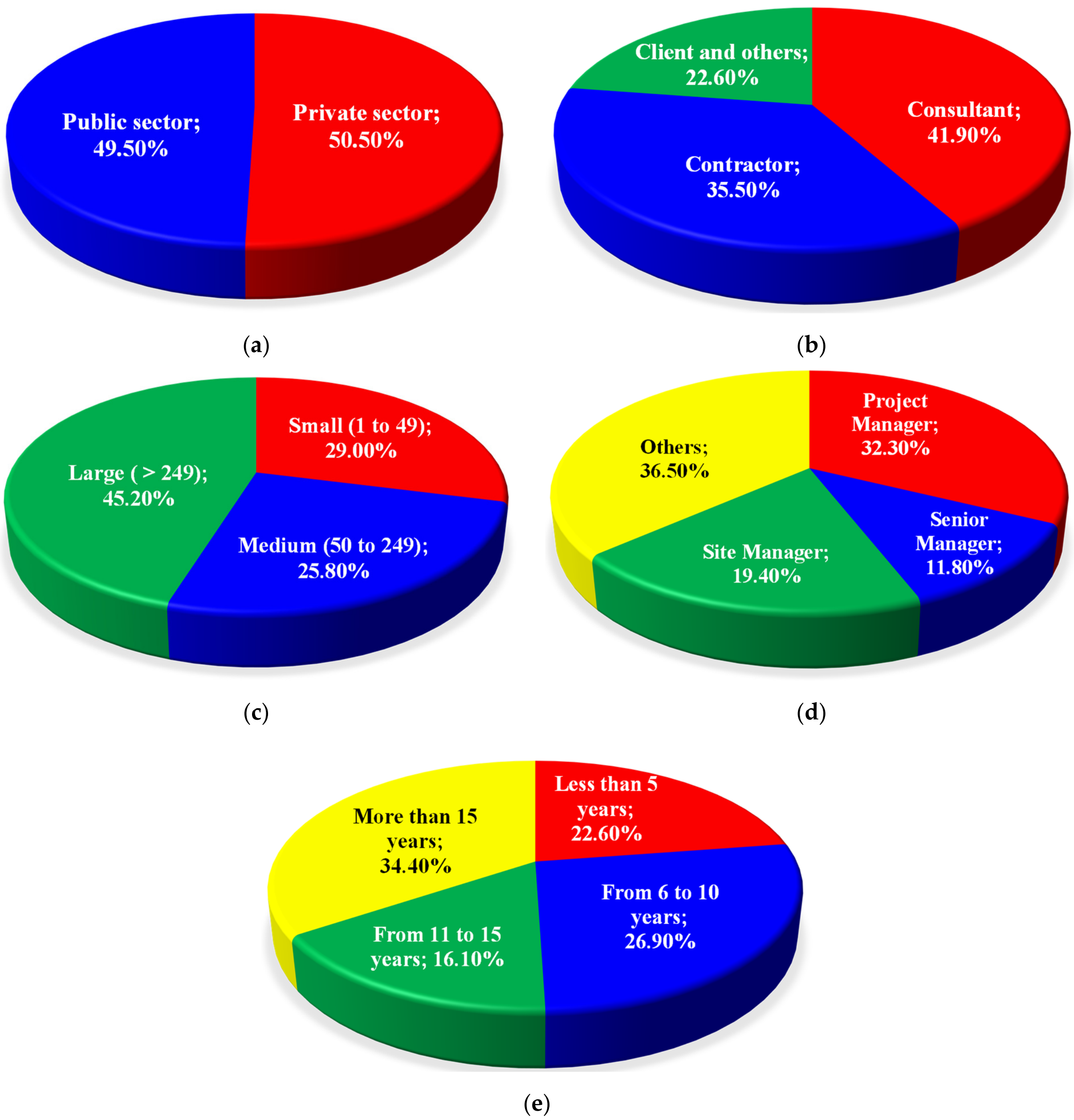

Figure 2. Categorization of the Construction Industry: (**a**) Ownership of the organization, (**b**) type of organization, (**c**) size of organization, (**d**) position in organization, and (**e**) years of experience.

Also, on the type of construction industry, a majority of the respondents (41.9%) were from consultancy firms and remaining respondents were contractors, clients, and other built environment professionals, as indicated in Figure 2b. These represent the main stakeholders in the construction industry of the four countries under study. Furthermore, Figure 2c indicates percentages of organizational size based on the number of employees. The organizations were categorized in sizes as: large organization (<249 employees), medium organization (50 to 249 employees), and small organization (>49 employees). The large size organization accounted for the highest percentage of respondents at 45.2% of all respondents.

In addition, the position of respondents in the organizations are classified in Figure 2d. Project managers recorded 32.8% of respondents, and the significance of this is that they were well placed to assess the barriers to an effective and sustainable C&DWM system. The classification of respondents according to the years of experience is shown in Figure 2e.

The category of respondents with more than 15 years of experience stood at 34.4%, whereas those with 6 to 10 years' experience constituted 26.9% of respondents.

It can be observed from the characteristics of respondents that the majority are from consultancy firms, large organizations, project managers, and have considerable experience of the workings of the construction industry in their respective countries.

4.2. Organizations' Engagement in Effective and Sustainable C&DWM

The result on organizations' engagement in effective and sustainable C&DWM were obtained and illustrated in Figure 3. The most prominent reasons identified by 70% of respondents was the desire "to make a positive difference to society". This clearly shows that respondents are aware of the adverse environmental effects of construction activities on the natural environment, and the need for the industry to make a difference to society in the manners that it conducts its activities. Though not as significant, 15% of respondents hold the view that the primary objective of their organization's engagement with sustainable C&DWM is to meet the primary objectives of delivering quality projects timely and within costs.

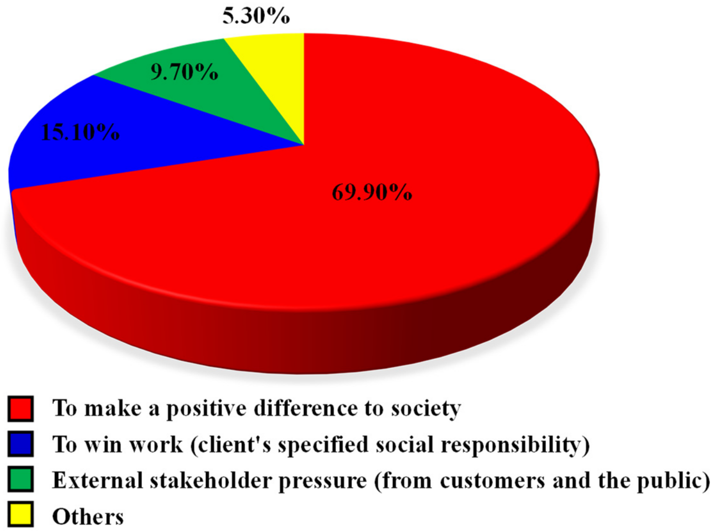

Figure 3. Reasons for organizations' engagement in effective C&DWM.

4.3. Evaluation of Barriers to Effective and Sustainable C&DWM

Based on the results obtained from the experts, the estimated RI values range from 0.45 to 0.70, as shown in Figure 4. These values were divided into three levels: strong barriers (0.60–0.70), moderate barriers (0.50–0.60), and weak barriers (<0.50).

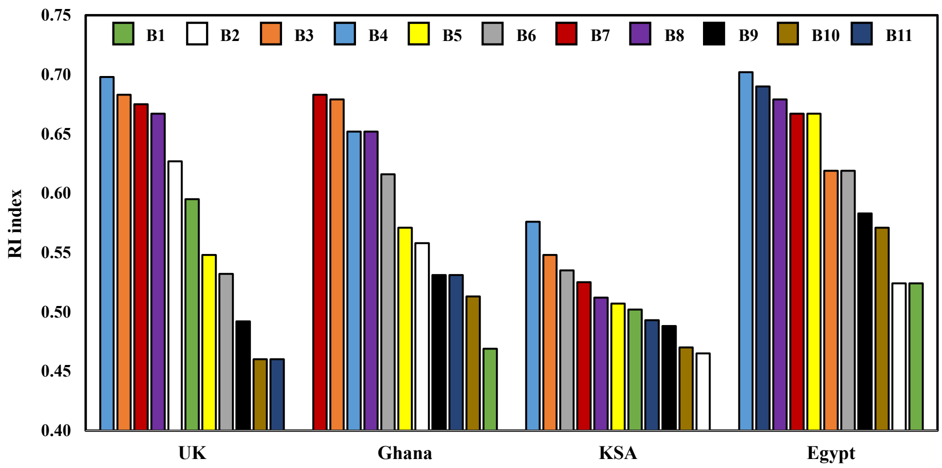

Figure 4. Variation of RI index for UK, Ghana, KSA, and Egypt.

4.3.1. Critical Barriers in the UK

According to the questionnaire in the UK, B4, B3, B7, B8, and B2 constitute the five strongest barriers to effective and sustainable C&DWM. Additionally, B1, B5, and B6 were regarded as moderate barriers to effective and sustainable C&DW. Notwithstanding these, the UK Government has been using a combination of regulations, economic instruments, and voluntary agreements to meet targets of ethical, social, and environmental performance in driving the waste management agenda [71,72]. Also, the UK implements legislative and fiscal measures which lead not only to construction waste reduction, but are directly related to the rising landfill tax, increasing cost for waste disposal, and compliance requirements with site waste management regulations from 2008 [73,74].

4.3.2. Critical Barriers in the KSA

The experts in the KSA indicated that the top seven barriers to sustainable C&DWM are B4, B3, B6, B7, B8, B5, and B1. Despite these barriers, the country has moderate RI values (0.50–0.60), the plurality of them is a major challenge to adopt feasible approaches to tackle the barriers. Identification of these barriers can support the efforts of decision makers in the Kingdom to meet their 2030 Vision. There are no data available on C&DW characterization [75]. Despite the fact that contractors play an important role in collecting C&DW from their sites by licensed waste haulers who are subcontracted to perform this task, the subcontractors usually dispose of these wastes indiscriminately in unapproved sites or by the roadsides, resulting in environmental and visual pollutions, and blockage to roads and drainage [2].

4.3.3. Critical Barriers in Egypt

The C&DWM challenges are not different in Egypt compared to the KSA and Ghana, as C&DWM is a major problem in the construction industry. Consequently, experts who responded to the study questionnaire identified seven strong barriers to sustainable C&DWM in Egypt. These barriers are B4, B11, B8, B7, B5, B3, and B6. The remaining barriers were regarded as moderate level barriers. Recently, Waste Management Law No.202 of 2020 has been adopted for waste management including construction and demolition waste in Egypt [76]. The main goals of the law are the development of an integrated municipal, industrial, agricultural wastes, and C&DWM system; to promote reuse; the recycling, treatment, and final disposal of waste; and to manage waste in a way that reduces damage to public health and the environment. The implementation of these policies will ensure effective and sustainable C&DWM in Egypt.

Notwithstanding this, Daoud et al. [77] posit that 5.8 million tons of C&DW is generated annually, which accounts for 6.4% of the total SW generation in Egypt. This figure may not reveal the extent of the problem owing to lack of accurate data on SW generation and characteristics in Egypt [78]. Similar to C&DW disposal in the KSA, C&DW is also usually dumped on roadsides and in open spaces. In the particular case of C&DW, contractors usually find it cheaper to transfer C&DW to illegal sites. This problem is continuing despite the new legislation, and this is due to several reasons including the existence of unregistered construction firms operating without permits, lack of regulatory enforcement, poor C&DW collection and disposal, limited local government participation, and poor financial commitments to C&DWM [77].

4.3.4. Critical Barriers in Ghana

The construction industry in Ghana, as with most others in sub-Saharan Africa, is underdeveloped, relying on imported materials and expertise to function. The relative underdevelopment of the sector is characterized by weak institutions and institution building capacity, hence the limited absorptive capacity for managerial, technology, technological innovations, as well as institutional development [10]. The current study indicates B7, B3, B4, B8, and B6 have the highest range of RI (0.60–0.70) and represent the major barriers to effective and sustainable C&DWM in Ghana. The other barriers are considered moderate barriers and only B1 is disregarded based on its factor. In this context, previous studies showed that the additional financial cost of providing measures to improve the sustainability of construction works, the government policies, legislation and government commitment, the management of the construction industry, the technical information on sustainable construction, the desire of stakeholders in the construction industry to be committed to change, and congruent goals and objectives represented the main components for successful implementation of sustainable construction in the Ghanaian construction industry [10].

4.4. Common Barriers and Proposed Solutions

Opinion data from respondents were integrated and analyzed for all the countries studied. Table 2 indicates the descriptive information for the results and the overall ranking of barriers using the Relevance Index method. As can be observed, B4, B3, B7, and B8 are strong major barriers to sustainable C&DWM. However, the other barriers are considered as moderate barriers, with only B10 being considered as a weak barrier and can be disregarded due its low RI value (<0.50). The correlation coefficients of the results have also been determined to get the relationship between the different barriers. Table 3 shows the correlation coefficients, where the values between 0.5 and 1 indicate closely related barriers. The strongest relation has been found between B10 and B11 followed by the relation between B9 and B10. The lowest one has been detected between B1 and B10. These barriers can be mitigated and managed by organizations through proper management and leadership.

Table 2. Descriptive statistics of the received data and RI index for the overall countries.

Barriers to Effective C&DWM	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Confidence Level (95.0%)	RI	Rank
B1	93	1	7	3.56	2.01	4.05	0.41	0.512	10
B2	93	1	7	3.69	1.79	3.20	0.37	0.536	7
B3	93	1	7	4.36	2.05	4.18	0.42	0.628	2
B4	93	1	7	4.45	1.85	3.41	0.38	0.642	1
B5	93	1	7	3.87	1.89	3.59	0.39	0.558	6
B6	93	1	7	3.99	1.81	3.27	0.37	0.573	5
B7	93	1	7	4.38	1.94	3.75	0.40	0.627	3
B8	93	1	7	4.30	1.95	3.79	0.40	0.611	4
B9	93	1	7	3.55	1.86	3.46	0.38	0.516	9
B10	93	1	7	3.42	1.62	2.61	0.33	0.496	11
B11	93	1	7	3.67	1.76	3.11	0.36	0.525	8

N: Number of valid Respondents, RI: Relative importance index.

Based on the evaluation of the barriers to effective and sustainable C&DWM in the four studied countries, practical solutions to overcoming barriers to effective and sustainable C&DWM have been proposed in Table 4. The proposed solutions to tackle the barriers to effective sustainable C&DWM include cooperation and collaboration among construction companies, providing complete data about the amount of C&DW and their composition, the reuse, recycling and reducing of waste and minimizing its negative impact on the environment, choosing the suitable material that can minimize waste or be reused or recycled, increasing the awareness of the benefits and the procedures used for deconstructing buildings and selective demolition that uses fewer tools and equipment, reduces pollution and toxicity in the removal process and increases the longevity of buildings, enforcing regulations on waste management, stakeholder's involvement in C&DWM, application of sustainability policies in C&DWM, and adoption of integrated waste management.

Table 3. Correlation coefficients and *p*-values of the barriers for the overall countries.

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	C.		0.513 **	0.460	0.219	0.453	0.346	0.374	0.330	0.168	0.143	0.224
	p-V.		<0.001	<0.001	0.019 *	<0.001	0.002	0.012	0.012	0.834 *	0.529 *	0.783 *
B2	C.	0.513 **		0.739 **	0.590 **	0.551 **	0.508 **	0.624 **	0.393	0.169	0.271	0.269
	p-V.	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	0.011	0.774 *	0.115 *	0.130 *
B3	C.	0.460	0.739 **		0.692 **	0.517 **	0.509 **	0.679 **	0.450	0.220	0.281	0.270
	p-V.	<0.001	<0.001		<0.001	<0.001	0.020	<0.001	0.011	0.315 *	0.195 *	0.268 *
B4	C.	0.219	0.590 **	0.692 **		0.562 **	0.540 **	0.643 **	0.596 **	0.422	0.458	0.553 **
	p-V.	0.019 *	<0.001	<0.001		<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001
B5	C.	0.453	0.551 **	0.517 **	0.562 **		0.652 **	0.580 **	0.485	0.216	0.176	0.282
	p-V.	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	0.479 *	0.045	0.189 *
B6	C.	0.346	0.508 **	0.509 **	0.540 **	0.652 **		0.668 **	0.654 **	0.290	0.265	0.260
	p-V.	0.002	<0.001	0.020	0.001	<0.001		<0.001	<0.001	0.075 *	0.250 *	0.507 *
B7	C.	0.374	0.624 **	0.679 **	0.643 **	0.580 **	0.668 **		0.684 **	0.255	0.353	0.400
	p-V.	0.012	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	0.285 *	0.169 *	0.024
B8	C.	0.330	0.393	0.450	0.596 **	0.485	0.654 **	0.684 **		0.536 **	0.483	0.494
	p-V.	0.012	0.011	0.011	<0.001	<0.001	<0.001	<0.001		<0.001	0.001	<0.001
B9	C.	0.168	0.169	0.220	0.422	0.216	0.290	0.255	0.536 **		0.771 **	0.663 **
	p-V.	0.834 *	0.774 *	0.315 *	0.001	0.479 *	0.075 *	0.285 *	<0.001		<0.001	<0.001
B10	C.	0.143	0.271	0.281	0.458	0.176	0.265	0.353	0.483	0.771 **		0.775 **
	p-V.	0.529 *	0.115 *	0.195 *	<0.001	0.045	0.250 *	0.169 *	0.001	<0.001		<0.001
B11	C.	0.224	0.269	0.270	0.553 **	0.282	0.260	0.400	0.494	0.663 **	0.775 **	
	p-V.	0.783 *	0.130 *	0.268 *	<0.001	0.189 *	0.507 *	0.024	<0.001	<0.001	<0.001	

C: Correlation, *p*-V.: *p*-Value, ** Correlation is significant and strong positive, * *p*-value is not significant.

Table 4. Proposed solutions to barriers to effective and sustainable C&DWM.

Barriers to Effective C&DWM	Proposed Solution(s)	References
B1	The government, organizations, and individuals should establish effective communication tools to achieve cooperation and collaboration among construction companies. The government should have an appropriate framework to encourage and regulate companies' practices. Construction companies and their projects should realize the strategic importance of C&DWM and implement it at organizational and project levels.	[4,41]
B2	Municipalities should provide fundamental data about the approximate amount of C&DW and their compositions based on the project type. Moreover, they should provide data about the protocols, procedures and alternatives for the available management of C&DW (reuse, recycle, reduction, and disposal).	[51,52]
B3	Implementation of waste management rules and regulations by enforcing the environmental regulations and penalties regarding C&DWM.	[2,30,41]
B4	Promote environmental awareness by organizing discussions, seminars, training, and workshops on sustainable construction and its importance for contractors, consultants, and stakeholders. Moreover, provide clear understanding about the benefits and the used procedure of deconstructing buildings and selective demolition.	[2,15,27,52]

Table 4. *Cont.*

Barriers to Effective C&DWM	Proposed Solution(s)	References
B5	Social awareness, change in culture and attitude by branding and use of social media, as well as incentives such as tax reduction and applicable sustainability policies by government agencies can support sustainable C&DWM.	[10,52]
B6	Technical information in sustainable construction, advanced technologies and methodologies, production and distribution of technical guidance documents for best practices should be available.	[46,52]
B7	Governments should review and evaluate existing legislations and suggest amendments in coordination with responsible regularity authorities. Moreover, governments with the support of stakeholders should develop legislation, regulations, codes, and standards relating to sustainable construction practices.	[2,10]
B8	Additional financial cost should be provided for sustainability management. Reduction in costs by improving quality and reusing materials or recycled products, determining the best routes and use of waste transportation and material recycling to achieve economic and environmental gains by reducing fuel consumption.	[10,52]
B9	Developing appropriate training for all levels of workers in order to develop their skills and knowledge.	[2,4,52]
B10	The construction project characteristics should be provided to organize and achieve effective and sustainable C&DWM such as type, size, location, and complexity of the project, as well as the importance for the project to be completed on time, contract form, and project funding.	[46,60]
B11	Creating and improving awareness and knowledge of sustainable construction amongst various actors in the construction industry, especially for stakeholders. Funded projects should include provisions that encourage and obligate the stakeholders and contractors towards proper C&DWM.	[52,61,62]

5. Conclusions

The large amount of C&DW with poor management has severely affected sustainability. Sustainable construction efforts in some countries have been unsuccessful due to so many barriers to its successful implementation. This study identified sustainability barriers to effective and sustainable C&DWM in four countries (UK, KSA, Egypt, and Ghana). Eleven barriers (institutional fragmentation, lack of fundamental data on C&DW, lack of law enforcement, insufficient attention paid to C&DWM, socio-political, technological, lack of regulation, financial, human resources constraints, construction project characteristics, and rigidity of construction practices) have been identified and ranked by RI. The overall ranking of barriers indicated that the insufficient attention paid to C&DWM, lack of law enforcement, lack of regulation, and financial constraints represent the four major barriers to effective and sustainable C&DWM. Consequently, practical solutions to tackle the barriers have been proposed. The proposed solutions include cooperation and collaboration among construction companies, providing complete data about the amount of C&DW and its composition, enforcing regulations on waste management, stakeholder's involvement in C&DWM, application of sustainability policies in C&DWM, and adoption of integrated waste management. These findings can support decision makers to achieve effective and sustainable C&DWM.

Although this study identified and ranked the barriers to sustainable C&DWM and suggested solutions to tackle these barriers, there are still some limitations to the study. The barriers and suggested solutions were identified based on the literature review. The number of respondents was limited. Future studies should consider more barriers hindering the adoption of building information modeling and increase the number of respondents from different countries to be more reliable and closer to the real conditions.

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