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Evaluation of Construction and Demolition Waste Management in Kuwait

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Abstract: This research aimed to evaluate Kuwait's current construction and demolition waste (C&D waste) situation by focusing on C&D waste generation and management issues. This work also investigated the causes and factors affecting C&D waste to understand the actual waste management activities and proposed strategies to minimize the waste generated at the local level. This study estimated C&D waste generation rates based on data collected from five construction projects and two demolition projects in Kuwait. In addition, a questionnaire survey was conducted to evaluate the causes of C&D waste generation. The results showed that the average C&D waste quantities generated by construction activities were 49.5 kg/m^2 for public/commercial building projects and 35 kg/m^2 for residential projects. At the same time, public/commercial construction, residential construction, and demolition works generated 1.480 ton/m^2, 0.0495 ton/m^2, and 0.035 ton/m^2, respectively. The average composition of C&D waste from the construction sector was 35.4% concrete waste, followed by 19.2% tiles/blocks, and 14.2% metals, with the remainder being other materials. Meanwhile, the demolition waste was composed of 70% concrete and cement waste and 20% metals. The results showed that 54% of the projects disposed of their C&D waste directly in the landfills. The leading causes of C&D waste generation were reworks due to changes in specifications, poor material quality, improper material handling, and improper site management. Strategic C&D waste management practices are necessary for sustainable natural resource management and conservation of the environment.

Keywords: construction waste; waste management; sustainability; life cycle assessment; construction phase

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1. Introduction

Globally, the demand for natural resources is high due to population growth and increasing living standards. The construction industry consumes huge amounts of natural resources and produces significant construction and demolition (C&D) wastes [1]. According to reports, the construction sector consumes nearly 40% of all consumed materials yearly [2]. C&D waste constitutes an enormous volume of all solid wastes [3]. Various studies have reported a massive amount of C&D waste generated annually [4]. For example, the European Union generated over 2538 million tons of waste in 2016, and the contribution of construction was 36.4% [5]. The construction industry is also responsible for about 29% of landfilling in the United States, 40% in Brazil, 44% in Australia, 44% in the United Kingdom [6], 27% in Canada [7], and 23% in Hong Kong [8]. Thus, the construction industry's consumption of raw materials and waste generation is draining natural resources and producing high amounts of greenhouse gases [9]. These overwhelming quantities are the causes of greenhouse effects and pose threats to resource conservation and environmental biodiversity [10,11].

C&D waste is generally defined as a mixture of inert and non-inert materials arising from construction, excavation, renovation, refurbishment, demolition, roadworks, and

other construction-related activities. Inert materials can be either soft inert materials such as soil, earth, and slurry, or hard inert materials such as rocks and broken concrete. Non-inert materials also include waste made up of metals, timber, plastics, and packaging [5]. C&D wastes represent huge masses of materials and are often deposited without consideration and inviting illegal deposits of other kinds of waste and garbage. Thus, the building and construction industry plays a significant role in waste generation [12]. Due to rising amounts of C&D waste, several issues are arising, such as the scarcity of landfill space and the ever-increasing building costs. Hence, government agencies and private businesses are forced to reduce waste production. Therefore, managing C&D waste is a significant objective, especially in developing countries, where such waste is poorly handled by mostly uncontrolled landfills [13]. A literature review showed many studies on the factors of construction waste generation. For instance, it has been reported that construction design, operation, and material handling caused site waste in Singapore [14]. Lack of awareness, offcuts resulting from poor design, and reworks and variations generated construction waste in the United Arab Emirates [15]. Nine sources of construction waste in the UK's construction industry included weather, residual, handling, data error, operations, design, other factors, misplacement, and vandalism [16]. Muhwezi et al. [17] stated that changes in design during construction, a lack of skilled workers or subcontractors, non-compliant products, improper material storage, and changing orders/instructions generated waste in the Ugandan construction industry.

The production of indispensable C&D waste can have adverse social, economic, and environmental impacts. Landfilling vast quantities of C&D waste is an environmental concern, as this waste often includes hazardous materials such as asbestos, heavy metals, persistent organic compounds, and volatile organic compounds (VOCs). These wastes affect human health and the natural/artificial environment. Overall, C&D waste impacts the economic sustainability of countries because the construction sector is a basic and essential variable related to all the other sectors [18]. The effective management of C&D waste has become one of the significant environmental issues in the construction industry. When considering ecological and economic factors, C&D waste prevention/reduction is a top waste management priority [19]. It has been widely acknowledged that proper quantification of C&D waste is crucial for establishing an effective management system at both the project and regional levels [20]. C&D waste is a real problem in many countries; hence, various laws have been developed. Specifications and recommendations on C&D waste management are part of state policy [21]. However, some countries still need integrated plans and comprehensive policies to tackle C&D waste problems, which require us to fill the gaps in information about C&D waste generation and to diagnose incomplete or incorrect implementation of C&D waste management. Kuwait has a wealthy petroleum-based economy. Due to its development plan, the economy of Kuwait is expected to keep growing and it aims to become a developed nation. The construction industry in Kuwait has registered steady growth. According to government statistics, the initial budget set for implementing the Kuwaiti development plan was USD 155 billion from 2012 to 2016. The development plan included 500 projects for infrastructure, housing, and the expansion of energy and natural gas projects [22]. These projects led to an increase in the environmental C&D waste problems. One of the main obstacles to handling these wastes is the absence of data related to the quantities, costs, and environmental impact. To the best of the authors' knowledge, there is no comprehensive study about C&D waste management in Kuwait. Therefore, this study aimed to explore waste minimization practices in Kuwait's construction industry with the following objectives: to evaluate and quantify the C&D waste in Kuwait produced by various construction activities; to assess the C&D waste minimization practices of reducing, reusing, and recycling in Kuwait's construction industry; and to propose strategies to improve the implementation of waste management plans in the construction sector in Kuwait.

2. Materials and Methods

2.1. Study Area and Selected Projects

Seven projects were selected to evaluate the generation, characteristics, and management practices of C&D waste. Data were collected from five projects in the construction stage and from two demolition sites by conducting several visits to the project sites. The construction projects included two ongoing government projects, one commercial project, and two residential projects. The two government projects were part of the new Kuwait University in the Shadadiya area of Kuwait, which included the College of Law (for men) building, which consisted of 8 floors with a total floor area of 7500 m^2, and the College of Social Sciences (for women) building, which has 11 floors with a total floor area of 16,000 m^2. The commercial project was a hotel building comprising 15 floors with a total spatial area of 6000 m^2. Two residential projects in the city of Alsalmia with a total floor area of 700 m^2 were selected. The two demolition projects were residential complexes with a total floor area of 3000 m^2 and 2000 m^2. These two projects were located in Bneid Alghar and Daiaya in Kuwait City.

2.2. Research Design

The research methodology included collecting and analyzing the data on C&D waste as shown in Figure 1. Here, we explain the research type and design, followed by a description of the research area, the research instruments, and the data collection procedures.

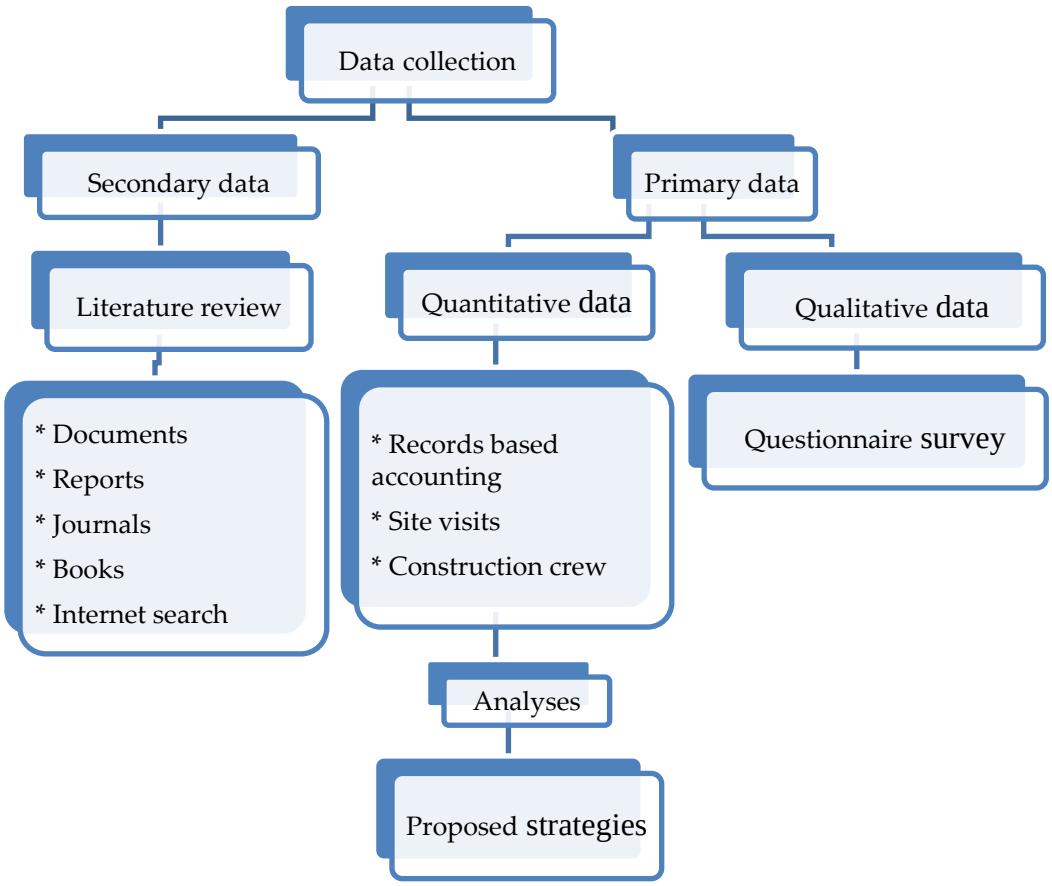

Figure 1. Flowchart of the research methodology.

This study used a combination of primary and secondary data to achieve the objectives. The primary data consisted of quantitative and qualitative data. The quantitative data included C&D waste generation data that were collected by making periodic site visits to the selected construction sites. The available invoices for C&D waste disposal by trucks

were summarized to obtain the quantities of C&D waste. The qualitative data included a questionnaire survey to obtain onsite information about C&D waste generation and the current status of C&D waste management in Kuwait. The data were analyzed using Excel software.

2.3. Data Collection and Analysis

Data related to past C&D waste generated in Kuwait were collected to estimate the magnitude of C&D waste, the activities generating C&D waste, and the composition of C&D waste. The data were collected through direct interviews, the documentation and records of the official authorities (Kuwait Municipality—Head of the Municipality, the Department of Construction Waste, and Kuwait's Central Statistical Bureau, CSB), surveys, and visits to the construction, demolition, and disposal sites. Furthermore, data on the current recycling and reuse of C&D waste materials were obtained. Data collection was carried out through the following steps:

1. gathering of primary empirical data through periodic site visits to selected projects;
2. reviewing the existing secondary data, including monthly progress reports, information on waste management in Kuwait, and data related to waste disposal costs, waste composition, and the frequency of disposal;
3. structured interviews and surveys of related personnel to supplement and qualitatively improve the abovementioned primary and secondary data obtained;
4. the analysis of the composition of C&D waste was determined by collecting random samples of truckloads at the site.

The primary and secondary data were processed using a Microsoft Excel spreadsheet and a double-entry variable matrix. The second variable interpreted answers. The sample is described using filters; each variable crossing is interpreted. Graphs are created to identify CDW rates, attributes, or trends.

2.4. Questionnaire Design

A structured questionnaire was developed based on the study's objectives and was distributed via e-mail and through direct visits to the construction sites. A group of professionals working on various construction projects in Kuwait was targeted as the population sample to cover the subject of this research as much as possible. The professionals included project managers, resident engineers, site engineers, quality control engineers, supervisors, and heads of projects. Due to time limitations, 50 questionnaire forms were e-mailed or given during site visits, and 30 forms were received with feedback. Thus, a response rate of 60% was achieved.

The guidelines recommended by Kitchenman and Pfleeger [23] were followed in developing the questionnaire. The questionnaire consisted of four sections: Section A—demographic information; Section B—information on C&D waste generation; Section C—information on waste minimization and recycling; and Section D—barriers and challenges.

Section A—demographic information: This section covered the respondents' details such as their working experience and the nature of their work. These questions were framed to analyze each respondent's knowledge of the subject area. Originally, a population of 100 participants was planned, but most respondents were reluctant to participate in the survey.

Section B—information on C&D waste generation: This section covered the type and size of the project, the quantities of waste generated, and waste disposal practices at the site. It also investigated the possible causes and factors that may lead to C&D waste generation, as illustrated in Table 1.

Section C—information on waste minimization and recycling: This section covered waste minimization and recycling practices at the site.

Section D—barriers and challenges: This section covered questions related to the difficulties and challenges faced by the construction sector in implementing management practices.

Table 1. C&D waste generation factors.

Main Causes and Factors	Subcases
Design and documentation	Changes in the design Documentation problems Design errors Errors in construction drawings
Materials and procurement	Improper material storage Improper material handling Material transportation problems Packaging problems Damaged materials
Construction methods and planning	Coordination problems Control and supervision Poor waste management Construction errors Ineffective planning and scheduling
Human resources	Incompetent workers Designers' inexperience
Demolition waste	Demolition of residential buildings Demolition of commercial buildings Demolition of government buildings Demolition of bridges and roads

3. Results and Discussion

3.1. Waste Generation Rates (WGRs)

The data collected from the site visits and the questionnaire survey were analyzed to determine the C&D waste generation factors and Kuwait's general C&D waste disposal practices. The results showed that the participants in the questionnaire survey had good construction experience, as illustrated in Figure 2. Moreover, 20% of the respondents were either project managers or resident engineers, and 50% were site engineers with good experience in handling construction projects.

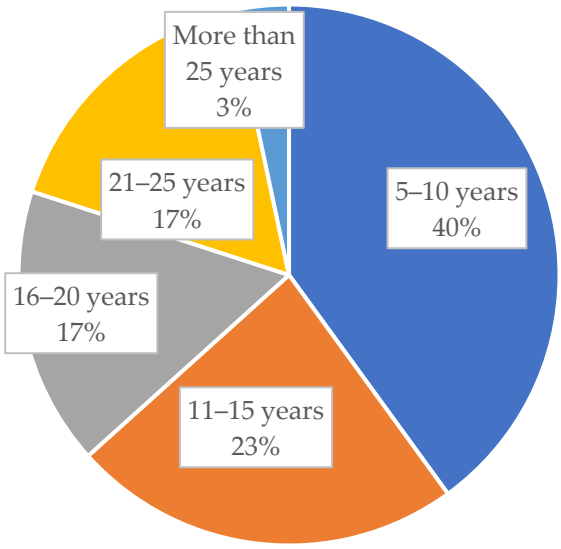

Figure 2. Experience of the participants in the survey.

Classifying the construction projects is essential because it directly affects the quantity of C&D waste generated. Each construction project had a unique design based on its purpose and required special techniques for its execution. This work affected the generation

rate and composition of construction waste [24]. The results showed that 47% of the projects were government (or public) buildings, 30% are residential complexes or private villas, and 20% are commercial complexes, as shown in Figure 3. Most of the building projects are multistory buildings. The results revealed that 23% of the buildings have 6–10 floors, 10% have 10–15 floors, and 10% have more than 15 floors. These projects have different floor areas ranging from 100 m^2 to more than 10,000 m^2, as depicted in Figure 4.

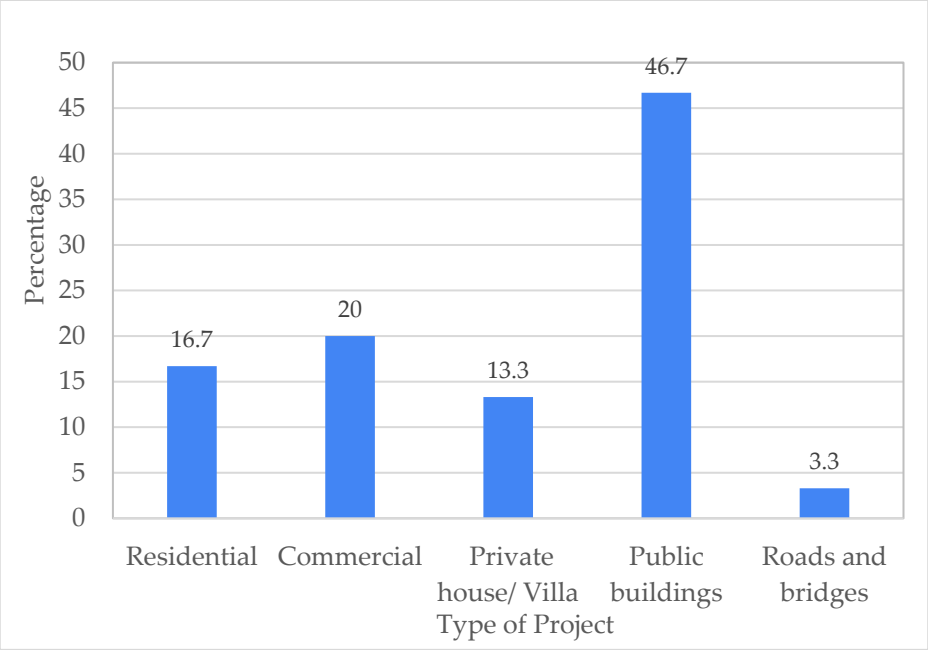

Figure 3. Type of projects handled by the respondents.

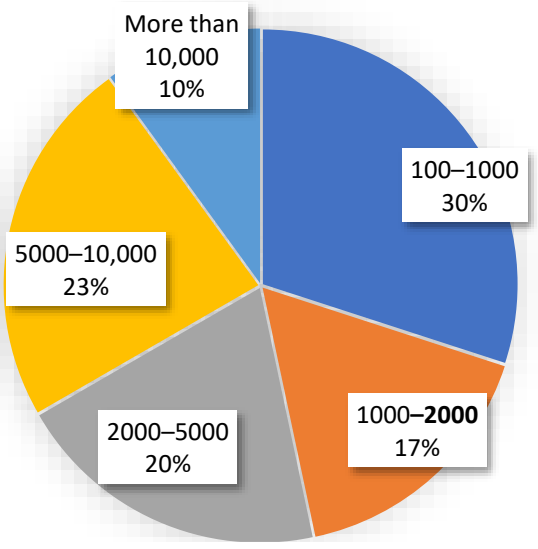

Figure 4. The floor area of the projects.

The results showed that the annual average floor area of various construction projects in Kuwait was 7,843,181 m^2 for 2012 to 2016, as declared by the Municipality of Kuwait. The construction activities included the construction of hospital buildings, residential and commercial buildings, industrial buildings, and others. These results may influence the massive amount of waste that should be handled [25]. The annual amount of floor area constructed is illustrated in Figure 5.

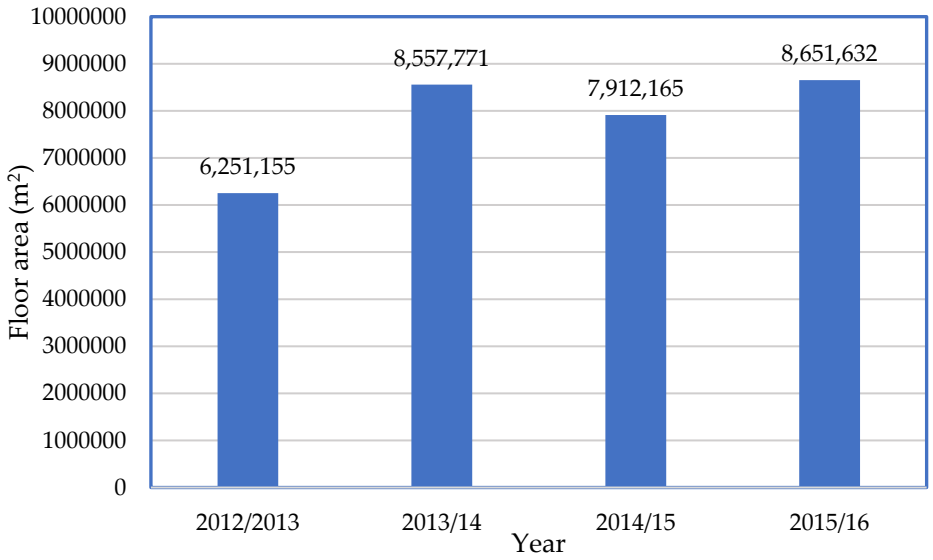

Figure 5. The constructed floor area in Kuwait during the period 2012–2016.

The results showed that millions of tons of C&D waste were disposed of in Kuwait. The annual quantities of C&D waste generated from 2010–2019 are illustrated in Figure 6. These results showed that C&D increased approximately annually, which can be attributed to the flourishing construction sector. Moreover, most companies do not have a specific policy of reducing waste or reducing the waste at the source, such as avoiding the generation of waste by the construction process. The collected data from site visits indicated that the average quantity of C&D waste generated by construction activities was 49.5 kg/m^2 for public/commercial building projects and 35 kg/m^2 for residential projects.

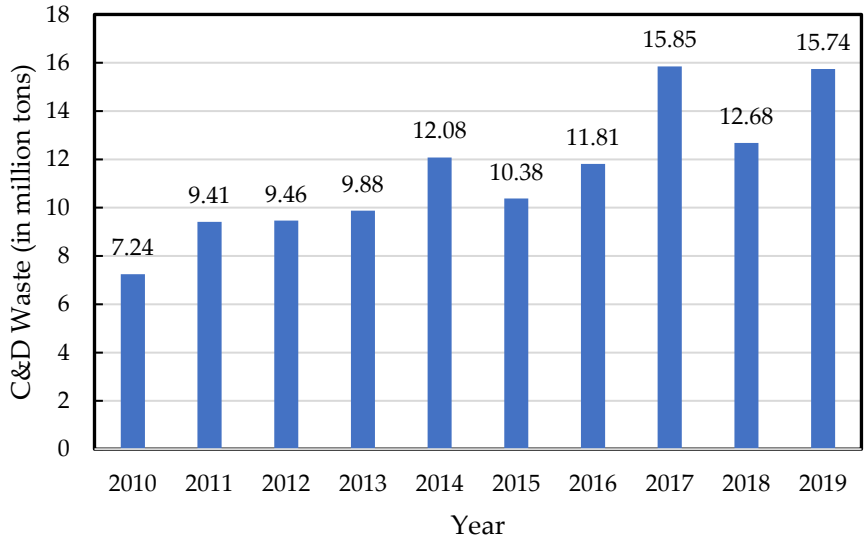

Figure 6. Quantities of C&D waste generated in Kuwait.

The waste generation rates and disposal costs were calculated and are presented in Table 2. These results showed that the average quantity of C&D waste generated by demolition, public/commercial, and residential construction activities was 1.48 ton/m^2, 0.0495 ton/m^2, and 0.035 ton/m^2, respectively. Obviously, the rate of C&D waste generated by demolition works is higher than that of construction activities. It was further noticed that at the construction sites, material sorting and recycling activities were rare.

Table 2. Waste generation rates (excluding soil/earth) and disposal costs.

Project	No. of Projects	Waste Quantity (tons)	Floor Area (m^2) (FA)	WGR (ton/m^2)	Waste Disposal Costs in KWD	Disposal Cost/Floor Area (KWD/m^2)
Residential projects	2	24.5	700	0.0350	950	1.357
Public/commercial buildings	3	1460	29,500	0.0495	52,650	1.785
Demolition projects	2	7400	5000	1.480	5200	1.040
Total	7	8235	35,150			

The average disposal cost of C&D waste was reported in Kuwaiti dinar. The results revealed that the disposal cost of demolition waste (1.04 KWD/m^2) was lower than the disposal cost of construction waste, as presented in Table 2. The disposal costs of construction waste were 1.357 KWD/m^2 for residential projects and 1.785 KWD/m^2 for commercial projects. This difference in disposal costs is related to the composition of C&D waste, which is illustrated in Table 3. The C&D waste mainly consisted of concrete, metals, tiles/blocks, sand/soil mixed with cement, plastic, glass, and other materials that consisted of paper, gypsum board, cardboard, etc. The composition of C&D waste was determined from random samples of truckloads at the site. Apparently, concrete waste constituted the largest part of both the ongoing construction and demolition projects. For the ongoing construction projects, the average composition of C&D waste was 35.4% concrete waste, followed by 19.2% tiles/blocks, 14.2% metals, and the remainder being other materials, as listed in Table 3. If we consider the main component (concrete), compared with other countries, in India, concrete represents nearly 23–35% of construction waste [26]. Meanwhile, in Peru, it ranges between 14% and 34% depending on the stage of work [27]. According to a previous study, the composition of C&D waste in Tehran consists of concrete (19%), bricks (10%), metal (0.75%), and others (70%) [28]. Another study conducted in Brazil on the composition of C&D waste showed that it consisted of mineral waste (65%), wood (13%), plastic (8%), and other components (14%) [29]. For demolition works, concrete and cement waste made up 70%, followed by 20% of metals (including reinforcement steel), and other materials were also found. Generally, scrap metal is recovered at the site, and concrete waste is sent to the recycling facilities. However, steel reinforcement bars are separated at the site using JCB-type excavator machines during demolition, and no other segregation occurs. The remaining waste, such as cement rubble, brick waste, roofing material, other metals, etc., was sent to landfills. Apart from the demolition projects, the segregation of concrete waste and other materials was carried out only in one of the projects. However, only 3–8% of the C&D waste was sorted out at the site. Meanwhile, the rest of the C&D waste was sent to the recycling facilities or landfills. Therefore, the proposed C&D waste recycling and management regulations should include the financial benefits of proper waste management.

Table 3. Composition of C&D waste at the worksites.

Project No.	Project Description	Percentage of Components (%)						
		Concrete	Soil/ Sand	Tiles/Blocks	Metals	Plastic	Glass	Other
P1	Government Building 1	35	3	25	18	7	3	9
P2	Government Building 2	37	4	20	17	9	5	8
P3	Commercial Project (hotel)	40	5	18	15	8	9	5
P4	Residential Complex 1	33	10	17	11	9	10	10
P5	Residential Complex 2	32	12	18	10	9	10	9
	Average	35.4	6.8	19.6	14.2	8.4	7.4	8.2
P6	Demolition Project 1	70	4		20		3	3
P7	Demolition Project 2	70	5		20		2	3
	Average	70	4.5		20		2.5	3

3.2. Recycling of C&D Waste in Kuwait

The investigation revealed that two recycling facilities have been established to separate and recycle C&D waste. These facilities are operated by Environmental Protection Industrial Company (EPIC) and Arab International Industrial Projects (AIIP) Company. There are no incineration plants in Kuwait for C&D waste. The official authorities of Kuwait Municipality collect monthly data from these facilities and landfill sites. A statistical analysis was performed to identify these facilities' annual quantities of C&D waste. Usually, the C&D waste was segregated from concrete waste at the recycling plants, and the remaining rubble was sent to the landfills. The quantities were calculated on the basis of the number of trucks arriving at each facility and the landfills. It is evident from Table 3 that an increasing amount of C&D waste has been generated over the years, except in 2020. The WHO declared COVID-19 a global pandemic on 11th March 2020. Thus, the main construction activities ceased due to the lockdown and the restrictions, which decreased the quantity of C&D waste in 2020.

It is important to mention that the C&D waste generated by construction and demolition sites was sent directly to landfills or recycling facilities for offsite sorting. Sorting was carried out mainly for concrete waste, and steel and metal objects sent to recycling facilities. Concrete waste was sorted at the recycling facilities using mechanical segregation tools to produce recycled concrete aggregate (RCA) of different sizes as per market requirements. However, the use of RCA is limited in Kuwait due to the lack of proper specifications that should be applied to construction projects. This practice is more common because it is convenient to hire contractors to clear the onsite waste and this is an advantage for projects with limited or no storage area. The main impact of this approach is the transportation of waste, which involves transferring mixed waste to offsite material recovery facilities, then to recycling facilities, and finally to landfills or dumpsites. Furthermore, bulky mixed waste needs necessary precautions from the perspective of safety and requires a greater number of trips for transportation, thereby increasing the emissions and costs. Figure 7 shows the percentage of C&D waste (excluding soil/earth) received by the recycling facilities and landfills. The results revealed that the average C&D waste landfilled or buried is about 64% of the total C&D waste generated during these five years. This means that only 36% of the C&D waste is subjected to recycling. This highlights the need for new strategies and policies to improve the management of C&D waste in Kuwait. The results indicated that landfilling is the most common practice for the disposal of C&D waste materials. Landfilling of C&D waste adversely affects the environment and is also not viable economically. Proper recycling of C&D waste materials helps conserve natural resources and saves the energy required to process raw materials.

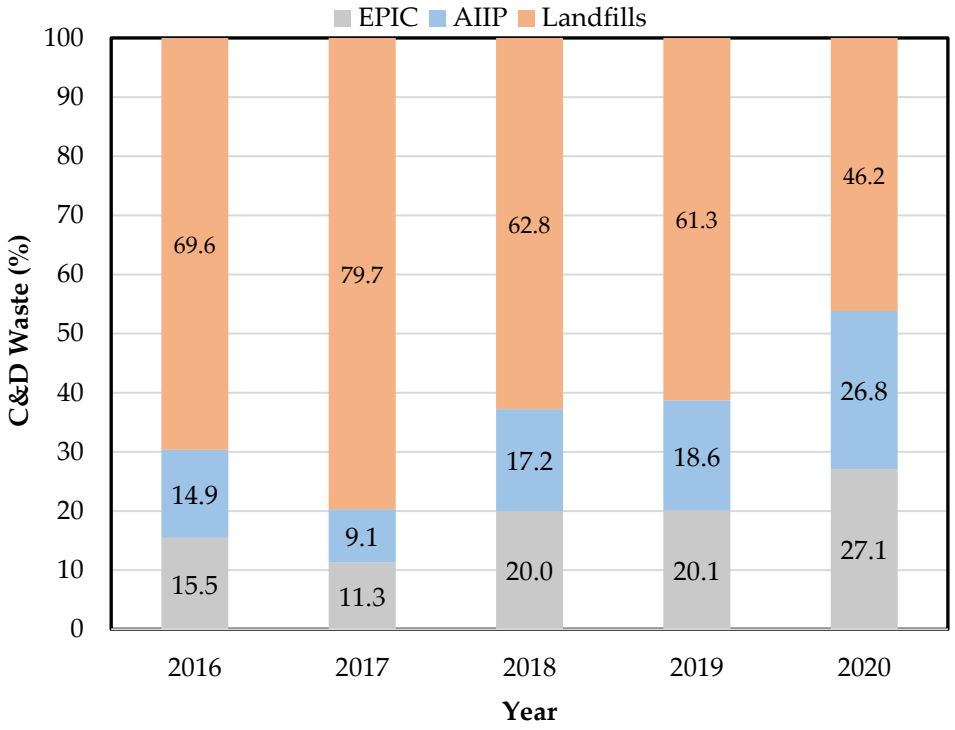

Figure 7. Percentages of C&D waste handled by different facilities.

Nearly 5000 tons of C&D waste were recycled daily at the two recycling facilities, which amounts to 150,000 tons per month. The process of recycling typically starts after receiving the C&D waste. Different materials are separated by sorting. These materials are classified into demolition waste, concrete blocks, building rubble, asphalt, wood, plastic, and iron/metal waste. Specialized equipment is used for crushing the concrete aggregate and then the material is screened to separate aggregates of different sizes. Even though the cost of these recycled materials is approximately half that of the virgin material, their use is very limited due to the lack of specifications on their use in various construction projects. The recycled aggregates are used mainly in infrastructure works, the pavements of road projects, and some maintenance works. Recycled concrete slabs are also among the products of waste recycling. The amount of C&D materials depends on the number of construction activities taking place in the country. The construction sector plays a vital role in the economic growth of a country, as it provides housing and creates jobs and income for the growing population. Thus, the growth of the construction industry can be viewed as an indicator of economic growth. The average waste generation rates were estimated on the basis of the data collected. According to the Kuwait Municipality's data, the construction industry experienced steady growth of 8 to 14% from 2012 to 2016. The average growth rate of construction recorded was 12.9% for the same period. The economy of Kuwait is expected to keep growing, and a number of infrastructure and development activities are planned for the next five years. The inflation rate in Kuwait averaged 2.79% from 1995 until the first quarter of 2021 and is projected to trend around 2.5% in 2022 [22]. The inflation rate can be considered as an indicator of the growth of the construction industry. Thus, with a number of construction projects lined up for the next five years, it can be assumed that Kuwait's construction sector will continue to grow at the same rate or even higher. Recycling C&D waste is a cost-effective and environmentally friendly way to produce aggregates for reusing materials instead of disposing of them. Processing the waste near the work sites reduces the need for truck transportation, resulting in lower logistic costs. Concrete, asphalt, steel, and wood are some of the most valuable materials from C&D waste that can be recycled.

3.3. Factors of C&D Waste Generation

Figure 8 presents the current C&D waste disposal practices in Kuwait. As per the survey data, 54% of the projects are disposing of their C&D waste directly to the landfills; 33% are clearing the waste through subcontractors, who send it to recycling facilities; and only 3% segregate the material onsite and send it to the recycling facilities. It is evident that segregation and recycling are not common practices in the construction sector.

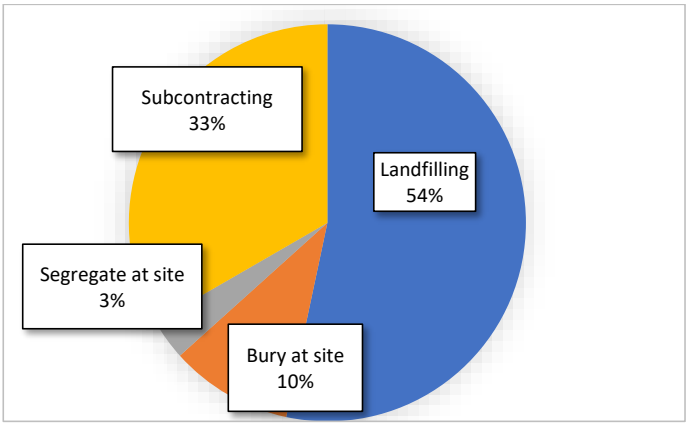

Figure 8. Methods of C&D waste disposal at the project sites.

The causes of C&D waste generation at the site are illustrated in Figure 9. The results indicated that the main causes of C&D waste generation are reworks caused by changes in specifications, poor material quality, improper material handling, and improper site management. These results indicate that most sites do not follow the C&D waste management practices. These results are consistent with Gavilan and Bernold's [30] findings. They stated that the major causes of waste were design, operation, material handling, procurement, and leftover scraps onsite. However, these factors may be different in other countries. For instance, Alwi et al. [31] found schedule delays, non-skilled workers, raw materials, repair works, waiting for materials, material waste onsite, and lack of supervision greatly influenced the waste generation rates in construction companies in Indonesia. Other research reported that waste could be generated by poor coordination and control during the construction process, the incorrect choice of construction methods, and reworking [32–36]. In general, sorting C&D waste onsite is considered to be a time-consuming and labor-intensive activity, which construction participants try to avoid. Onsite waste separation is rare in Kuwait, except for the materials that yield a higher resale value.

Generally, the C&D waste was disposed of once or twice a week, depending on the accumulation of waste debris. Figure 10 shows the frequency of C&D waste disposal by the sites, and some large projects disposed of the waste daily. The composition of the waste varied depending on the project's construction stage. In general, the C&D waste consisted of 30% concrete waste, 20% bricks/tiles and soil, and about 20% metals (iron, aluminum, wires, cables, etc.), and the remainder was soil, paper, plastics, glass, etc.

The factors affecting the management of C&D waste at the project sites are presented in Figure 11, which shows that 40% of the responses indicated that there was no plan (or schedule) for managing C&D waste at the site, which means the companies did not have policies for addressing these wastes. A similar observation was recorded by Faniran and Caban's study, which was conducted to identify the factors of construction waste generation [37]. Generally, cost, labor, and time were found to be the main factors of waste generation in Kuwait. The project staff concentrated more on completing the projects on time and were not interested in segregating waste materials. Usually, the C&D waste from the project sites was disposed of in large trucks of about 15 m^3 in capacity. Most projects hired subcontractors to dispose of the C&D waste, who used medium to large trucks. The number of trucks used for waste disposal ranged from 5 to 20 per month.

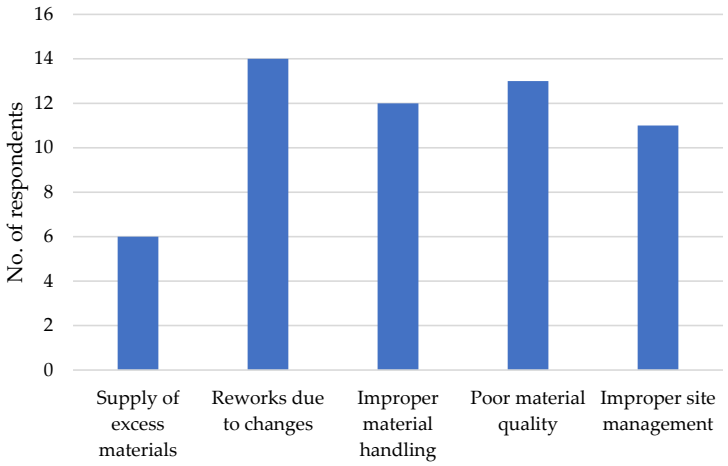

Figure 9. Survey responses on the causes of C&D waste generated at the sites.

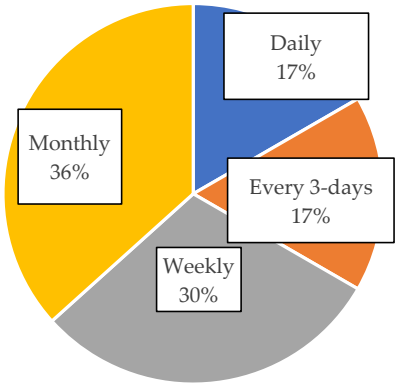

Figure 10. Frequency of C&D waste disposal by the sites.

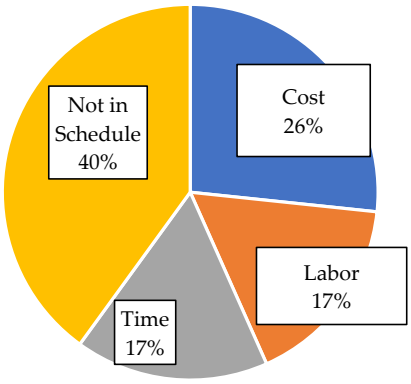

Figure 11. The factors affecting the management of C&D waste.

3.4. Proposed Strategies for the Effective Management of C&D Waste in Kuwait

The Environment Public Authority is responsible for setting waste management strategy policies in Kuwait. This authority works based on Article No. 34 of Law 42 of 2014 and its amendments, and therefore it leads the coordination with the competent authorities. It is responsible for preparing the national program for the integrated management of waste, including the preparation, development, and updating of a national strategic policy for the integrated management of municipal solid waste, medical and liquid waste, and hazardous waste, together with work plans, the responsibilities of state institutions, and monitoring and implementation schedules for control programs. Therefore, this authority should consider the outcomes of the present study.

The construction industry in Kuwait has faced many challenges, including the necessity of reducing waste, eliminating inefficiency, and improving productivity while also considering the sustainability of construction projects. For the construction industry to be sustainable, there is an urgent need to conserve natural resources, reduce the disposal of C&D waste into landfills, and encourage the recycling and reuse of C&D waste materials. This will also benefit the environment, construction safety, and the economy. Recycling C&D waste helps in reducing the production of greenhouse gas emissions and other pollutants by decreasing the need to extract raw materials and transport new materials. There are general regulations on maintaining safety and hygiene at site works, but special regulations regarding the onsite management of C&D waste in Kuwait are lacking. Most of the responses to the questionnaire indicated there was no plan for onsite C&D waste management.

Other challenges include the lack of a market for recycled materials, transportation, sorting and cost management complexities, and the risk of contamination in mixed materials. Labor is the most significant element in any construction project due to its ability to connect all other resources to achieve the ultimate goals of the project. Most respondents revealed that extra labor, cost, and time are needed for the onsite management of C&D waste. Further, there are no plans in the projects' schedules for this purpose. Thus, the attitude of stakeholders reflects the status of C&D waste management. Accordingly, C&D waste can be efficiently managed through changing attitudes rather than altering techniques.

In general, demolition sites generate more waste than construction sites, which implies that demolition sites will have more recoverable materials than new construction sites. Thus, different processes need to be used at the demolition sites from those at the construction sites as follows.

- The first step before demolishing any structure is to extract the reusable material. After completing the demolition process, many materials can be gathered from the rubble, which can be reused once various treatment methods have removed the contaminants.
- Onsite sorting can be carried out by placing containers for specific materials to separate the different materials effectively. Furthermore, the quality of reclaimed materials can be ensured. By improving the demolition and construction processes, the increased quality will ensure strict adherence to the necessary material conditions and specifications.
- Onsite sorting at the construction sites will improve the safety and cost-effectiveness of construction projects. For example, new material pieces, packaging, old materials, and debris all constitute recoverable materials.
- Recyclable or reusable waste in various sizes is mostly left over from new development activities. If the recovered material can be used for other works, this saves on hauling and dumping expenses and reduces the demand for new materials.
- Onsite sorting of waste as soon as it is generated creates considerably clean waste. This approach leads to a reduction in transportation and energy costs. Thus, onsite sorting leads to the minimization of the environmental impacts of C&D waste. Furthermore, it promotes environmentally friendly methods of managing waste at the projects' sites. However, this approach requires trained workers to collect, handle, and separate the different components of components. Through the approach of onsite sorting, a considerable amount of waste can be diverted from landfills. This can be accomplished by hiring a contractor with experience, trained staff, and resources. Government agencies should monitor and control demolition sites to implement this C&D waste management strategy.
- The questionnaire survey revealed that extra labor, extra time, and cost are needed to manage the onsite sorting of C&D waste. Furthermore, there is no proper plan for managing the C&D waste in the projects' schedules. The 3R principles of reducing, reusing, and recycling strategies are viable solutions for effectively managing C&D waste. The waste management policies should therefore be updated and enforced properly to increase the recycling and reuse of C&D waste materials.

- The waste management policies should be updated and appropriately enforced to increase the recycling and reuse of C&D waste materials. Guidelines or regulations should be developed to reduce the generation of C&D waste. Recycling can be made more effective by encouraging the incorporation of recycled products in government and private sector projects. Public awareness is important in waste management and in recycling products. Public participation in recycling programs through education should be encouraged.
- Planning for reduced C&D waste must happen at the start of a project and be part of an integrated design approach. Procedures facilitating waste segregation and recycling at construction sites should be introduced. Reusing materials and components and specifying materials with recycled content can enhance the circular economy. This study focused on the onsite sorting of C&D waste in Kuwait. It recommended several improvements in C&D waste management strategies to support the decision-making process and increase awareness among the stakeholders.
- A recycling decision-support framework can be helpful for maximizing the practicality of C&D waste management plans. Bao and Lu [38] developed a general decision-support framework for planning the recycling of construction waste that could be adopted in Kuwait, as seen in Figure 12.

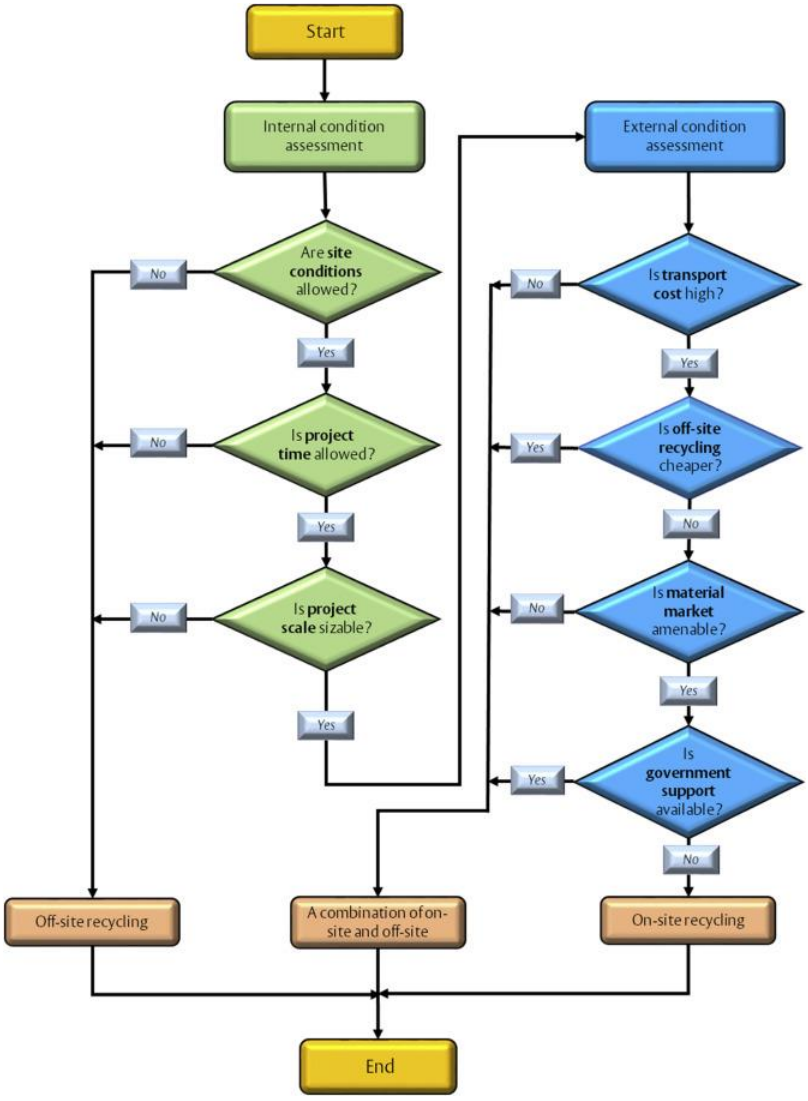

Figure 12. Decision-support framework for recycling C&D waste, adapted with permission from [38].

4. Conclusions

The quantification of C&D waste showed that the average quantity of C&D waste generated by construction activities was 49.5 kg/m^2 for public/commercial building projects and 35 kg/m^2 for residential projects, and it was 1480 kg/m^2 for demolition projects. Meanwhile, the average cost of disposing C&D waste was 1.357 KWD/m^2 for residential projects, 1.785 KWD/m^2 for commercial projects, and 1.04 KWD/m^2 for demolition projects. Sorting materials and recycling activities are not usual practices at the project sites, and more than half of the C&D waste was directly disposed into landfills without recycling. Approximately one-third of C&D waste was sent to recycling facilities. Therefore, this study suggested several steps to enhance Kuwait's C&D waste management practices. Onsite sorting and recycling should be strictly applied, and the authorities should regulate this process. Additionally, this study encourages the incorporation of recycled products in government and private sector projects. Planning for the reduction of C&D waste must happen at the start of the project and be part of an integrated design approach. Procedures to facilitate waste segregation and recycling at construction sites should be introduced. As a further recommendation, the development of C&D waste recycling and management models should include the financial benefits of proper waste management. Moreover, a comprehensive study with an advanced statistical analysis could assist in identifying the distribution trends of C&D waste production. This study recommends that all stakeholders in the construction industry, not just contractors and subcontractors, should develop waste management plans with a focus on design and document management to ensure clear and comprehensive information for construction and human resource management by having well-trained staff and field workers. Moreover, the authorities are invited to develop a comprehensive plan to manage C&D waste. Issuing specific legislation could improve the management of C&D waste, and the government should grant extra incentives and recognition to stakeholders.

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