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# Analysis of Factors Affecting the Recycling of Construction and Demolition Waste in Sharqia Governorate

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**Abstract**

Over the past decade (2015–2025), Egypt's construction sector has grown annually at one of the fastest rates globally (around 10% annual growth) — significantly outpacing both the MENA regional average (4.5%) and the global construction industry growth rate (3.0%) according to most international construction indexes. This unprecedented growth rate has led to massive construction and demolition waste (CDW) accumulations. CDW annual generation is estimated at 40 million tons, besides accumulations from previous years estimated at around 200 million tons. Egyptian Governorates are planning an ambitious program to attract investors to establish and operate CDW recycling stations. This research investigates factors affecting CDW recycling in "Sharqia Governorate", northeast of Egypt, as a case study. This governorate is a typical Delta province with annual construction spending of around 12.0 billion EGP and CDW generation of 3.0 million tons/year.

This research aims to identify the main factors affecting the recycling of C&DW in Sharqia Governorate based on the perceptions of expert practitioners in the construction industry. The research was conducted based on a previous review of literature and expert interviews to reveal the most critical factors. Over one hundred (100) responses were received from (150) questionnaires sent to industry professionals. Respondents pointed to the importance of waste recycling in reducing construction costs using recycled materials and the need to achieve the quality of recycled materials and products. Responses also recommended the reuse of CDW in national mega projects, and the need to impose fees for the disposal of unclassified waste to encourage the establishment of CDW recycling stations. In addition to the paramount importance of training stakeholders on effective management, and to develop government incentives and to supplement the current waste management regulations to encourage the private sector to build and operate CDW recycling stations.

**Keywords-** Construction and demolition waste; Recycling; Sustainability; Sharqia governorate; Quantitative analysis.

## 1. Introduction

Egypt is currently witnessing a major construction boom manifested in infrastructure, housing, and mega industrial and commercial projects, and the construction industry contributed US$25 billion (equivalent to 8.3%) of the Gross Domestic Product. Egypt's construction industry is growing much more than the overall national growth rate of 9% for construction compared to 5.5% for all economic sectors in 2019 [1]. The huge construction activities have accumulated large quantities of CDW throughout Egypt, including the Sharqia Governorate, without an integrated system of collection, transportation, recycling, and reuse, and in the absence of CDW recycling plants. This has exacerbated the problem and the urgent need to seek an environmental and sustainable solution. In addition, construction waste and demolition cause environmental pollution, making this a serious threat to the construction and construction sector's sustainable development [2].

Construction and demolition residues are defined in the Egyptian Waste Management Regulation: "Act No. 202 of the Year 2020 as "materials that have no physical or chemical reaction, such as materials resulting from quarry exploitation, demolition, construction, development, repair, roads, bridges, land cleaning, and construction".

In Egypt, major quantities of CDW are disposed of in informal dumps and on the roadside. This practice has escalated the problem of CDW, resulting in severe negative impacts on society, the environment, and the economy [3,4,5].

Egypt's efforts to improve CDW management include:

The development of a modern regulatory system to control waste generation and encourage recycling. Law No. 202 of 2020, "Regulation of Waste Management ", is a comprehensive regulation for all types of waste in Egypt. The Act contains four (4) specific articles related to the responsibilities and activities of local authorities for CDW management:

1) Article 42 of the new Law No. 202/2020 stipulates that to carry out demolition and construction activities, all entities and individuals are obligated to manage the transportation and recycling of waste or safe disposal through specialized and licensed entities. Those waste handling companies will be licensed to practice integrated demolition and construction waste management activities are fully responsible for recycling CDW or permanently disposing of it in the sites designated for that purpose.
2) Article 43 of the new Law No. 202/2020 stipulates that the administrative authority is responsible for issuing demolition or construction permits may not issue any licenses for such works except after the applicant submits proof of contracting with an establishment licensed who has been licensed by the Regulatory Authority Waste to carry out demolition by WMRA (Waste Management Regulatory Authority).
3) Article 44 of the new Law No. 202/2020 stipulates that the competent administrative authorities, in coordination with the Waste Management Regulatory Authority (WMRA), are responsible for designating and allocating specific sites for the collection, sorting, and processing of construction and demolition waste. This ensures that CDW streams are directed to authorized facilities and prevents illegal dumping on roadsides or informal sites.

4) Article 46 of the new Law No. 202/2020 stipulates that all entities and authorities implementing construction and infrastructure projects are obligated to utilize a minimum percentage of recycled materials and aggregates in their works. These recycled products must satisfy the technical specifications and engineering codes issued by the Housing and Building National Research Center (HBRC).

Collectively, these four articles establish a robust legal and operational framework for Construction and Demolition Waste (CDW) management in Egypt. Article 43, in particular, acts as a primary driver for the private sector by ensuring a consistent supply of raw materials through mandatory contracting for permits. Furthermore, Article 46 guarantees a stable market demand for recycled products by mandating their use in national projects. These legislative pillars significantly reduce investment risks and enhance the financial viability of establishing fixed recycling plants, as explored in the subsequent financial modeling and feasibility analysis of this research [6].

In 2019, the Ministry of Environment developed a national strategy for managing CDW, which includes the following directions [1].
(1) Develop policies to reduce C&D waste generation at construction sites.
(2) Establishment of an institutional and organizational structure to support integrated waste management activities in Egypt.
(3) Creating infrastructure: reduce, collect, separate, transport, and recycle C&D waste.
(4) Encourage private sector participation in waste management and development projects.
(5) Set a national target (40% by 2030) for the recovery of C&D waste.
(6) Establishment of a quality system and certification of recycled products.

The third strategic objective of establishing the infrastructure for CDW includes: site sorting, transportation, recycling, and disposal. The fourth strategic direction referred to the creation of economic incentives to stimulate private sector investments and the establishment of new recycling plants to recycle CDW. In a related context, the Waste Management Regulatory Authority was established to oversee all activities related to waste management.

The Egyptian Organization for Standardization & Quality (EOS), in coordination with the Housing and Building National Research Center (HBRC), completed the amendment of (16) Egyptian standards related to construction materials to allow the use of recycled CDW in different products (such as bricks, curbstones, tiles) and road construction [7].

The Ministry of Environment has conducted a comprehensive inventory of the accumulated quantities of construction and demolition waste in all governorates and new cities of Egypt. According to the data received from Governorates and the New Urban Communities Authority (NUCA), the amount of accumulated construction and demolition waste in Egypt for 2020 was estimated at 77,917,079.74 m3, equivalent to 123 million tons. The per capita accumulation in Egypt ranged from 0.746 $m^3$/capita, and the amount of waste generated annually was estimated at 40 million tons.

I also discussed a study by Eltobgy et al. [8], the impact of construction waste on construction projects in Egypt, by studying the main influencing factors for waste management and minimizing or limiting it using a survey of construction practitioners in Egypt. The study concluded that contractors with experience in construction work should be selected, and the appropriate materials should be used for facilities, and good storage should be ensured. For building materials, proper planning for construction projects, use of materials before expiration dates, early reporting of design changes, and effective communication between contracting parties to effectively perform construction projects.

In a related context, the study by El-Shaboury et al. [9] addressed the economic aspects of establishing and operating a concrete construction and demolition waste recycling plant in Egypt.
In addition to evaluating the savings resulting from recycling concrete waste to produce recycled aggregate, this includes several factors, taking into account the location and the design of the recycling plant, the equipment used, and the materials entering and leaving the plant.
The results indicated that solid waste recycling plants are considered economically feasible even in the absence of specific government policies. In addition, the cost of recycling includes capital, labor, operation, transportation, and disposal costs. Total costs can be reduced through careful taxation and government financial support.

Aly Kamel [10] also studied the reasons for the limited use of recycled aggregate resulting from construction and demolition activities by surveying various entities involved in the construction and demolition waste industries in Egypt. He also evaluated the national savings that could be achieved when recycling concrete waste by developing an economic model. He also evaluated the feasibility of creating new markets for recycled concrete aggregate, in addition to setting some specification limits for the properties of the aggregate. The results showed that the absence of government codes of practice, field experience, and knowledge of waste recycling, government subsidies, and environmental and economic concerns were the most important reasons for the limitations in recycling construction and demolition waste.

Based on previous studies on CDW in Egypt and other countries, the main benefits and challenges affecting the recycling of CDW have been summarized as follows:

### 1.1. Benefits of Recycling Construction and Demolition Waste

- Materials can be reused and thus provide an alternative to natural resources [11,12].
- Reduce the need for land used as landfills [13].
- Save consumed energy as well as reduce greenhouse gas emissions [13].
- Reduce health-related risks associated with CDW [13].
- Promote governmental strategies and industry standards to achieve environmental sustainability [14].
- Recycling programs can provide savings in landfill fees and build an image of social sustainability [15].
- Reducing raw material procurement costs [16].
- Providing direct and indirect job opportunities [16].

**1.2. Obstacles and Challenges in Recycling Construction and Demolition Waste**

- Lack of facilities or companies for recycling CDW [16,17,18].
- Lack of laws and regulations to regulate recycling and its enforcement mechanisms [17].
- Lack of coordination between parties involved in the CDW recycling system [17].
- Lack of economic feasibility of recycling CDW, for example, when the cost of recycling is greater than the value of the recycled waste or when the tipping fee for the landfill is lower than the direct disposal fee [12,19].
- Poor quality of recycled materials [12,20,21].
- Lack of community awareness or cultural resistance to recycling CDW [22].
- The illegal disposal of CDW [16].
- Lack of expertise, lack of knowledge, environmental and economic concerns, lack of administrative and economic models, lack of codes, and general practices [10].

**1.3. Recommendations for Stimulating the Implementation of the Construction and Demolition Waste Recycling System**

- Develop and implement effective economic mechanisms, tools, and strategies, such as incentives, taxation of non-compliant parties, imposition of sanctions, and provision of a mechanism for subsidies [12,13,18,19,23].
- Government initiatives to increase CDW recycling activities.
- For example, by not accepting unclassified waste in landfills, implementing policies aimed at more effective management of the recycling of CDW, and developing specifications and standards for recycled materials to increase their applications and achieve the establishment of a market for the recycling of CDW [12,13,16,24].
- Encourage innovations in construction, technology, and management.
- For example, reducing design modifications, improving the sorting of on-site CDW before it is sent to landfills, and developing technical regulations for the use of recycled materials in construction applications [23,24].
- Investing in scientific research and development, such as economic and environmental feasibility studies, reduces the generation and recycling of CDW [21,23].
- Research gaps can be identified, and the importance of this study is highlighted by reviewing current studies, for example, Eltobgy et al. [8], El-Shaboury et al. [9], and Aly Kamel [10], where these studies dealt with the recycling of construction and demolition waste in Egypt, except for the following:
  1) Analysis of the factors affecting the economic feasibility of recycling construction and demolition waste in Sharqia Governorate.
  2) In addition to using a question related to the profession and experience of professionals and the impact of this on their perceptions and behavior in treating construction and demolition waste in line with the strategic objectives of the Egyptian state.

This research aims to achieve the following objectives:

a) Identification of the main factors affecting the recycling of CDW in Sharqia governorate.

b) Ranking the factors based on their relative importance and the effectiveness of their application.

c) Compare the most important factors in Egypt with those of different countries.

**2. Research Methodology**

Literature review of previous studies, field visits to Sharqia governorate, the New Urban Community Development Authority in 10th of Ramadan City, and interviews with construction industry practitioners in Egypt. Thirty- Sixth (36) influential factors were identified and used in a survey questionnaire and classified under three categories:

1) benefits, 2) economic factors, 3) obstacles and challenges affecting recycling. Finally, additions Seven items of recommendations to enhance construction waste management and demolition.

2) Multiple statistical methods have been adopted for data analysis, including the Relative Importance Index (RII) under each category related to recycling and reuse of CDW. The alpha value of Cronbach determines the internal consistency of factors within each category. The analysis of variation (ANOVA) was used to test whether participants' perceptions of the questionnaire would depend on their different occupations or experiences.

The relative importance index for each of the different factors is calculated according to the Likert scale according to formula (1) [25], as follows:

$$RII=\sum w/A \times N \qquad (1)$$

Where w refers to the numerical score chosen by each participant for each particular factor, **A** is the highest score with a value (5). The **N** coefficient indicates the total number of responses. The RII value ranges from 0 to 1, and the RII value as it approaches 1 means a more positive attitude or a higher perception of respondents' responses to the target factor. The materiality levels [26] of the order of factors resulting from RII analysis are derived in **Table 1** as follows:

Table 1. Significance levels

| **Importance Levels** | **Abbreviation** | **Range** |
|---|---|---|
| High | H | 0.8<RII<1.0 |
| High– Medium | H–M | 0.6 < RII < 0.8 |
| Medium | M | 0.4 < RII < 0.6 |
| Medium– Low | M–L | 0.2 < RII < 0.4 |
| Low | L | 0.0 < RII < 0.2 |

- The value of Alpha-Cronbach ranges from 0 to 1; the highest value indicates increased consistency between the different factors within this axis. Otherwise, the value of Alpha-Cronbach is less correlated between the different factors.
- The ANOVA test was calculated to test statistical consistency between subgroups in their opinions and perceptions of different factors within each axis, using the null hypothesis, which states that there are no significant differences between the averages of values between subgroups for the factor studied, according to the Likert-scale based on the 5% level of significance.

- **Table 2** in the Appendix presents the different factors below each axis, giving each factor a symbol of its axis, which will later be used to analyze data from questionnaire responses that will be discussed.

## 3. Results and Discussion

The questionnaire was designed using two methods: Face-to-Face interviews and emails for (150) questionnaires between January and May 2022, (100) completed responses were received, (66%) response rate. The results of the survey are analyzed as follows:

### 3.1. Reliability of the Questionnaire Results

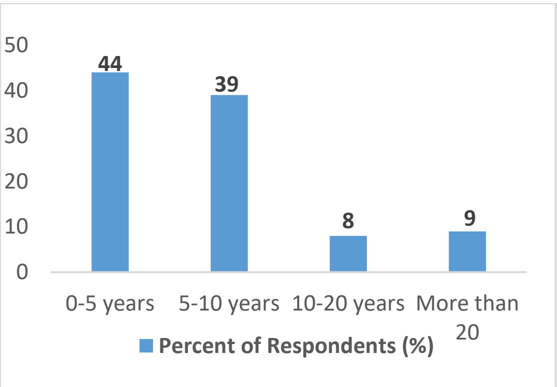
Alpha Cronbach was calculated using SPSS software to verify the consistency and reliability of the questionnaire. The reliability of the questionnaire was satisfactory (value = 0.894). This means acceptable reliability and validity of the survey data. In general, Alpha-Cronbach chirping refers to elements that are homogeneous enough with each other if their value is greater than 0.7 [27].

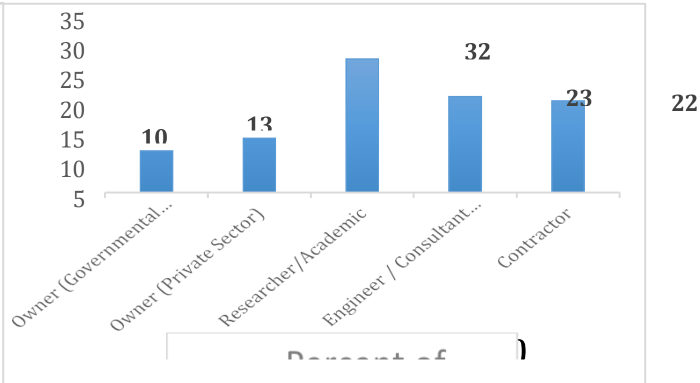
### 3.2. Background Information on Survey Participants

- **Figures 1 and 2** as follows present the demographics of survey participants, with years of practical experience ranging from "0 to more than 20 years". (83%) of participants have "0 to 10 years" experience.

Figure 1. Distribution of respondents by Years of Experience

Figure 2. Percentages of Different Occupations of Respondents




- Regarding the respondent's occupation, (10%) were government practitioners working in waste management in Sharqia governorate and the 10th of Ramadan City Authority, Waste Management Regulatory Authority (WMRA), Roads and Bridges Authority, Ministry of Housing and Utilities. 13% were “private sector” working in solid waste recycling or looking to invest in recycling.
- The percentage of engineer consultants and contractors converged at 23% and 22%, respectively. 32% of the sample had a postgraduate diploma, a master's degree, or a doctorate in civil, architectural, and environmental engineering.

### 3.3. Assessment of The Benefits of CDW Recycling

Respondents were asked about their perceptions and opinions on the benefits of promoting CDW recycling. The Cronbach alpha value for this axis is 0.891.

**Table 3** shows the seven factors from B1 to B7, the descriptive statistics of the questionnaire sample, and the ranking of the benefits of CDW recycling. According to their RII values, all elements were of high relative importance, and all RII values are greater than 0.800.

Table 3. Descriptive Statistics for the Category: Benefits of Applying the CDW Recycling System

| Factors | Mean | Std. Devotion | RII | Ranking by Category | Relative Importance Index |
|---|---|---|---|---|---|
| B1 | 4.40 | 0.876 | 0.880 | 2 | H |
| B2 | 4.39 | 0.777 | 0.878 | 4 | H |
| B3 | 4.31 | 0.774 | 0.862 | 6 | H |
| B4 | 4.29 | 0.807 | 0.858 | 7 | H |
| B5 | 4.40 | 0.738 | 0.880 | 2* | H |
| B6 | 4.49 | 0.797 | 0.898 | 1 | H |
| B7 | 4.34 | 0.794 | 0.868 | 5 | H |

*: indicates that two factors within this axis received the same RII value in order of relative importance

Respondents strongly emphasized the contribution of a recycling system to reducing the project budget when using recycled materials and saving natural resources, which is also considered one of the most important benefits of recycling concrete in the study conducted in the United States [29], Australia, and Japan [25] while achieving the required quality and recommending the application of recycling in national projects.

**Table 4** presents the ANOVA test to assess the subgroups for each of the seven factors included in the questionnaire.

Table 4. ANOVA Results for the Benefits Arising from the Application of the CDW Recycling System

| Factors | Mean | Std. Deviation | ANOVA Analysis for subgroups according to occupations | | ANOVA Analysis for subgroups with and without prior experience | |
|---|---|---|---|---|---|---|
| | | | F Value | P Value | F value | P Value |
| B1 | 4.400 | 0.8761 | 2.596 | 0.410 | 0.106 | 0.956 |
| B2 | 4.390 | 0.77714 | 3.380 | 0.194 | 0.602 | 0.615 |
| B3 | 4.310 | 0.77453 | 6.347 | 0.000* | 0.692 | 0.559 |
| B4 | 4.290 | 0.80773 | 2.156 | 0.082 | 1.145 | 0.335 |
| B5 | 4.400 | 0.73855 | 3.747 | 0.177 | 0.160 | 0.923 |
| B6 | 4.490 | 0.79766 | 1.094 | 0.364 | 0.340 | 0.797 |
| B7 | 4.340 | 0.79417 | 3.240 | 0.103 | 0.138 | 0.937 |

*: A p-value less than 0.05 indicates significantly different perceptions and opinions of the subgroups towards the studied factor

As presented in **Table 4**, ANOVA results indicate a high level of consensus among participants across different occupations and experience levels for most factors ($p > 0.05$). This reflects a uniform recognition of CDW recycling benefits, such as landfill conservation (B1) and legislative compliance (B5), within the Egyptian construction industry.

However, a statistically significant disparity was observed for factor B3 ($p = 0.000$) based on occupation. While the overall mean for B3 was 4.310, subgroup analysis reveals that private sector participants and contractors assigned significantly higher scores (4.84 and 4.71, respectively) compared to academic participants (3.93). This suggests that stakeholders directly responsible for project budgets perceive the immediate cost-reduction potential of recycled materials more strongly than those in academic roles.

**3.4. Assessment of Economic Factors Affecting the Feasibility of Recycling CDW**

Participants in the questionnaire were asked about their perceptions and opinions towards the factors related to the economics of CDW recycling in Sharqia Governorate. The value of Cronbach's alpha showed a (0.95) score, which indicates a significant internal consistency of these ten factors. **Table 5** lists as follows contain ten factors where the descriptive statistics and ranking of economic factors affecting the promotion of CDW were arranged and classified according to the RII values. There is a positive internal correlation between the perceptions and opinions of the participants in the questionnaire on the ten items related to economic factors.

Table 5. Ranking of Economic Factors Affecting the Promotion of CDW Recycling

| **Factors** | **Mean** | **Std. Devotion** | **RII** | **Ranking by Category** | **Relative Importance Index** |
|---|---|---|---|---|---|
| E1 | 4.54 | 0.593 | 0.908 | 5 | H |
| E2 | 4.55 | 0.657 | 0.910 | 3* | H |
| E3 | 4.58 | 0.554 | 0.916 | 1 | H |
| E4 | 4.58 | 0.606 | 0.916 | 1* | H |
| E5 | 4.47 | 0.758 | 0.894 | 7 | H |
| E6 | 4.31 | 0.982 | 0.862 | 10 | H |
| E7 | 4.39 | 0.984 | 0.878 | 9 | H |
| E8 | 4.49 | 0.674 | 0.898 | 6 | H |
| E9 | 4.55 | 0.744 | 0.910 | 3 | H |
| E10 | 4.48 | 0.747 | 0.890 | 8 | H |

*: indicates that two factors within this axis received the same RII value in order of relative importance

- Based on the statistical analysis, the critical drivers for the Construction and Demolition Waste (CDW) management system in Egypt can be categorized into the following key findings:

**Prioritizing Source Efficiency and Quality Control (E3 & E4):**

- E3 (On-site Sorting): The top ranking of this factor underscores that economic viability begins at the source. Pre-sorting minimizes contamination, which significantly optimizes transportation and energy costs.
- E4 (Quality Compliance): Market confidence is identified as a primary economic catalyst. Adhering to Egyptian standards is essential to mitigate the quality-related barriers to market acceptance highlighted by [20].

**Optimizing Strategic and Logistical Planning (E1, E2, & E5):**

- E2 (Capacity Matching): Linking plant capacity precisely to local waste generation rates is vital to prevent capital waste and ensure operational continuity.
- E1 (Site Selection): A strategic methodology for site selection is a decisive element in minimizing long-term logistics-related overheads.
- E5 (Market Dynamics): The price competitiveness of recycled aggregates is directly influenced by the availability and pricing of natural alternatives in the surrounding geographical area.

**The Role of Government Incentives and Support (E8, E9, & E10):**

- E9 (Financial Incentives): The high demand for tax and customs exemptions reflects the private sector's need for economic guarantees. This aligns with successful international models in China [29] and Vietnam [30].
- E8 & E10 (Market Stimulation): State-driven demand—through mandatory use in public projects (E8) and concessional financing for SMEs (E10)—is required to foster a comprehensive and inclusive investment ecosystem.

**Transitioning from Penalties to Incentives (E6 & E7):**

- While regulatory tools such as disposal fees (E6) and penalties for unsorted waste (E7) remain important, the findings suggest that stakeholders prioritize an "Incentives-First" approach. Fees and fines are viewed as secondary, complementary measures to ensure commitment to formal recycling pathways.

**Table 6** presents the ANOVA test that indicates differences in the views and perceptions of subgroups for each of the ten factors related to economic factors.

Table 6. ANOVA Results for the Benefits Arising from the Application of the CDW Recycling System

| Factors | Mean | Std. Deviation | ANOVA Analysis for subgroups according to occupations | | ANOVA Analysis for subgroups with and without prior experience | |
|---|---|---|---|---|---|---|
| | | | F Value | P value | F Value | P Value |
| E1 | 4.540 | 0.593 | 4.964 | 0.061 | 0.397 | 0.755 |
| E2 | 4.550 | 0.657 | 3.900 | 0.110 | 0.828 | 0.482 |
| E3 | 4.580 | 0.554 | 3.988 | 0.120 | 2.587 | 0.068 |
| E4 | 4.580 | 0.606 | 2.542 | 0.065 | 0.930 | 0.429 |
| E5 | 4.470 | 0.758 | 5.949 | 0.078 | 1.093 | 0.356 |
| E6 | 4.310 | 0.982 | 8.455 | 0.00* | 3.548 | 0.017* |

| | | | | | | |
|---|---|---|---|---|---|---|
| E7 | 4.390 | 0.984 | 3.811 | 0.088 | 2.800 | 0.076 |
| E8 | 4.490 | 0.674 | 4.666 | 0.117 | 1.110 | 0.349 |
| E9 | 4.550 | 0.744 | 3.765 | 0.101 | 0.863 | 0.463 |
| E10 | 4.480 | 0.747 | 3.928 | 0.105 | 1.469 | 0.228 |

*: A p-value less than 0.05 indicates significantly different perceptions and opinions of the subgroups towards the studied factor

Statistical analysis of the respondents' subgroups revealed a high level of consensus on most economic factors, with the notable exception of E6 (Imposing fees for the disposal of construction and demolition waste to encourage the establishment of factories). The following insights were observed:

- **Occupational Disparity:**

A significant divergence in perceptions regarding E6 was identified between practitioners and academics. Contractors and private-sector investors demonstrated a higher awareness of the economic necessity of these disposal fees, recording mean Likert scores of 4.95 and 4.77, respectively. In contrast, the academic subgroup showed a more neutral stance with a lower mean of 3.66. This suggests that practitioners, who operate directly within the market, have a deeper understanding of the ground-level financial mechanisms required to ensure the financial sustainability of recycling plants through steady revenue streams.

- **Impact of Professional Experience:**

The results further indicated a generational shift in attitudes toward environmental economics. Respondents with 5–10 years of experience showed robust support for E6 (mean = 4.51), whereas those with 10–20 years of experience were less decisive (mean = 3.50). This disparity suggests that the younger generation of professionals is more aligned with global sustainability trends and the United Nations Sustainable Development Goals (SDGs). Furthermore, this group shows a greater readiness to adopt the innovative financial instruments proposed in Egypt's Vision 2030 and the National Initiative for Industrial Development, reflecting a proactive approach to overcoming traditional barriers in the recycling sector and preserving natural resources for future generations.

The analysis of the previous table shows consistent opinions on the economic factors among the subgroups of the respondents' occupations. Participants under "contractors and private investors" have more expertise on construction sites and the need to charge for the disposal of waste to ensure the reduction of the project budget, the continuity of the plant's operation, and the disposal of waste compared to less experienced researchers working on construction sites.

### 3.5. Assessment of Obstacles and Challenges facing CDW Recycling

**Table 7** lists as shown (19) factors of the obstacles and challenges. The Cronbach alpha value of this axis, at 0.880, indicates a high internal correlation for all the factors mentioned.

Table 7. Descriptive Statistics for Challenges Affecting the Application of the CDW Recycling System Promotion of CDW Recycling

| Factors | Mean | Std. Deviation | RII | Ranking by Category | Relative Importance Index |
|---|---|---|---|---|---|
| O1 | 3.78 | 1.069 | 0.886 | 3 | H |
| O2 | 4.03 | 0.809 | 0.806 | 12 | H |
| O3 | 3.65 | 1.085 | 0.730 | 17 | H-M |
| O4 | 3.66 | 1.232 | 0.732 | 16 | H-M |
| O5 | 3.69 | 1.107 | 0.738 | 15 | H-M |
| O6 | 3.62 | 1.089 | 0.724 | 18 | H-M |
| O7 | 3.55 | 0.998 | 0.710 | 19 | H-M |
| O8 | 3.99 | 0.717 | 0.798 | 14 | H-M |
| O9 | 4.03 | 1.039 | 0.806 | 12* | H |
| O10 | 4.28 | 0.841 | 0.856 | 7 | H |
| O11 | 4.19 | 0.960 | 0.838 | 10 | H |
| O12 | 4.30 | 0.926 | 0.860 | 6 | H |
| O13 | 4.17 | 1.110 | 0.834 | 11 | H |
| O14 | 4.36 | 0.958 | 0.872 | 4 | H |
| O15 | 4.24 | 0.965 | 0.848 | 9 | H |
| O16 | 4.45 | 0.857 | 0.890 | 1 | H |
| O17 | 4.36 | 0.731 | 0.872 | 4* | H |
| O18 | 4.26 | 0.938 | 0.852 | 8 | H |
| O19 | 4.45 | 0.857 | 0.890 | 1* | H |

*: indicates that two factors within this axis received the same RII value in order of relative importance

- The statistical evaluation identifies a hierarchy of obstacles that hinder the efficiency of the recycling system in the Sharqia Governorate. The findings can be interpreted through the following key dimensions:

**Infrastructure and Expertise Gaps (O16 & O19):**

- The results highlight that the lack of specialized companies/experts (O16) and insufficient infrastructure (O19) are the most significant barriers. These factors indicate a critical deficiency in the technical and material foundations required for processing waste (including CDW) in the region. This aligns with the United Nations Sustainable Development Goals (SDGs), which advocate for resilient infrastructure as a prerequisite for sustainable industrialization and manufacturing.

**Economic and Financial Constraints (O1 & O14):**

- High recycling costs and labor intensity (O1) ranked third, confirming that economic viability remains a primary concern for stakeholders. This is further exacerbated by the lack of allocated budgets for research and development (O14). As highlighted in [31], while investors and owners are pivotal to environmental protection, the 'lack of demand from owners' (O17) and limited financial support for R&D act as major discouraging factors for technological advancement in the sector.

**Technical and Maintenance Feasibility (O3 – O8):**

- Conversely, barriers related to equipment installation and maintenance (O3 to O8)—such as crusher operations—received lower rankings (ranging from high-medium importance). This suggests that technical challenges are perceived as manageable through international procurement contracts and specialized technical training. Unlike the fundamental gaps in infrastructure and expertise, these operational issues are not viewed as insurmountable obstacles to the industry's establishment.

**Table 8** presents (an ANOVA) test for the challenges and obstacles affecting the promotion of CDW recycling.

Table 8. Analysis of Challenges Affecting the Promotion of CDW Recycling

| Factors | Mean | Std. Deviation | ANOVA Analysis for subgroups according to occupations | | ANOVA Analysis for subgroups with and without prior experience | |
|---|---|---|---|---|---|---|
| | | | F value | P value | F value | P value |
| O1 | 3.780 | 1.06913 | 2.643 | 0.168 | 3.588 | 0.062 |
| O2 | 4.030 | 0.80973 | 0.604 | 0.660 | 3.584 | 0.060 |
| O3 | 3.650 | 1.08595 | 2.830 | 0.307 | 0.820 | 0.486 |
| O4 | 3.660 | 1.23272 | 0.354 | 0.840 | 2.171 | 0.096 |
| O5 | 3.690 | 1.10732 | 0.721 | 0.580 | 1.204 | 0.313 |
| O6 | 3.620 | 1.08971 | 2.404 | 0.060 | 1.090 | 0.357 |
| O7 | 3.550 | 0.99874 | 1.327 | 0.265 | 1.436 | 0.237 |
| O8 | 3.990 | 0.71767 | 0.496 | 0.739 | 2.343 | 0.078 |
| O9 | 4.030 | 1.03918 | 7.812 | 0.000* | 0.899 | 0.445 |
| O10 | 4.280 | 0.84184 | 8.534 | 0.000* | 1.798 | 0.153 |
| O11 | 4.190 | 0.96080 | 12.021 | 0.000* | 5.455 | 0.002* |
| O12 | 4.300 | 0.92660 | 7.863 | 0.000* | 0.339 | 0.797 |
| O13 | 4.170 | 1.11060 | 10.058 | 0.000* | 3.146 | 0.029* |
| O14 | 4.360 | 0.95896 | 9.387 | 0.000* | 0.797 | 0.498 |
| O15 | 4.240 | 0.96525 | 7.517 | 0.000* | 3.103 | 0.030* |
| O16 | 4.450 | 0.85723 | 1.995 | 0.221 | 1.367 | 0.258 |
| O17 | 4.360 | 0.73195 | 0.499 | 0.917 | 5.255 | 0.002* |
| O18 | 4.260 | 0.93873 | 6.350 | 0.000* | 2.184 | 0.095 |
| O19 | 4.450 | 0.85723 | 1.995 | 0.221 | 1.468 | 0.228 |

*: A p-value less than 0.05 indicates significantly different perceptions and opinions of the subgroups towards the studied factor

**Table 8** shows that all subgroups share consistent views and perceptions on factors related to challenges and obstacles. Except for the following:

The ANOVA results revealed significant statistical differences across various factors, primarily driven by the divergent perspectives between practitioners and academics, as well as variations in professional experience.

**A. Disparity by Occupational Background**

- **Workforce Training (O9):** A substantial gap was observed regarding the necessity of specialized training. **Contractors** showed a significantly higher interest in training executive cadres (**Mean = 4.85**) compared to **academics** (**Mean = 3.48**). This underscores a perceived shortage of skilled labor on-site, which practitioners view as a critical prerequisite for implementing the national recycling strategy.
- **Quality and Market Challenges (O10, O11, O12):** Practitioners (engineers, investors, and contractors) expressed strong concerns regarding material quality and market availability, with mean scores ranging from **4.04 to 4.90**. Conversely, academics remained relatively neutral (**Mean = 3.52**), suggesting that while quality is a decisive economic driver in the field, it is often treated as a theoretical research point in academic circles.
- **Research, development, and investment (O13, O14):** A sharp variation was noted regarding investment in scientific research. Practitioners strongly advocated for larger R&D budgets within companies (**Mean: 4.47 – 4.90**), while academics were more neutral (**Mean = 3.42**). As noted in **[11]**, industry stakeholders prioritize practical, applied research to resolve immediate field-level bottlenecks.
- **Regulatory Standards (O15, O18):** Investors and contractors exhibited high agreement on the lack of demand (**O15**) and the absence of industry standards (**O18**) as major obstacles. This highlights the real-world conflicts that halt projects, reinforcing the findings in **[30]** regarding the pivotal role of government legislation in developing countries.

**B. Impact of Professional Experience**

- **Sustainability and Ambition (O11, O13):** A generational shift in perspective was identified; participants with **≤ 5 years of experience** were significantly more positive about expanding recycled product applications (**Mean = 4.36**). In contrast, those with **10-20 years** of experience remained neutral (**Mean = 3.00**), reflecting a higher level of ambition and sustainability awareness among the younger professional generation.
- **Market Demand and State Support (O15, O17):** Professionals with **10-20 years** of experience were more sensitive to the lack of owner demand (**O15**), likely due to their frequent direct dealings with investors. Meanwhile, senior experts (**> 20 years**) attached the greatest importance to government incentives (**O17, Mean = 4.11**), recognizing the state's essential role in establishing and protecting a new industrial sector.

### 3.6. Assessment of Recommendations to Promote CDW Recycling

This part focuses on suggestions to improve the CDW recycling industry. Respondents were asked for their opinions and perceptions about seven recommendations. The Alpha Cronbach scores are at 0.888, indicating a high internal correlation between the seven recommendations.

**Table 9,** as follows, presents the recommendations affecting the promotion of CDW recycling in Egypt. And indicates RII values and rankings, which indicate that most respondents highly agree with these recommendations (RII values were greater than 0.800).

Table 9. Descriptive Statistics for Recommendations Affecting CDW Recycling

| Factors | Mean | Std. Devotion | RII | Ranking by Category | Relative Importance Index |
|---|---|---|---|---|---|
| S1 | 4.47 | 0.717 | 0.894 | 3 | H |
| S2 | 4.44 | 0.671 | 0.888 | 5 | H |
| S3 | 4.47 | 0.626 | 0.894 | 3* | H |
| S4 | 4.52 | 0.673 | 0.904 | 2 | H |
| S5 | 4.54 | 0.702 | 0.908 | 1 | H |
| S6 | 4.43 | 0.768 | 0.886 | 6 | H |
| S7 | 4.17 | 1.110 | 0.834 | 7 | H |

*: indicates that two factors within this axis received the same RII value in order of relative importance

- S5 was considered the most important factor among the seven recommendations because effective communication between relevant stakeholders leads to the development and enhancement of the CDW recycling industry. In addition to S1 and S3, we conclude from this that there is great awareness among practitioners and stakeholders involved because the financial aspect plays a key role in the establishment or continuation of recycling plants.
- In addition to S4, it is necessary to do so as to save natural resources and reduce the budget of the project, and Innovation in construction and management technology, such as S2, and the application of economic tools and mechanisms, such as government financial incentives, such as S6, as well as S7.

**Table 10** lists the results of the ANOVA analysis to test the opinions and perceptions of the subgroups towards the seven recommendations.

Table 10. Analysis of Recommendations Affecting the CDW Recycling

| Factors | Mean | Std. Deviation | ANOVA Analysis for subgroups according to occupations | | ANOVA Analysis for subgroups with and without prior experience | |
|---|---|---|---|---|---|---|
| | | | F value | P value | F value | P value |
| S1 | 4.47 | 0.717 | 0.424 | 0.097 | 0.388 | 0.573 |
| S2 | 4.44 | 0.671 | 0.748 | 0.059 | 0.902 | 0.443 |
| S3 | 4.47 | 0.626 | 0.954 | 0.087 | 1.119 | 0.346 |
| S4 | 4.52 | 0.673 | 0.462 | 0.085 | 0.733 | 0.535 |
| S5 | 4.54 | 0.702 | 0.417 | 1.099 | 0.909 | 0.440 |
| S6 | 4.43 | 0.768 | 0.619 | 0.076 | 0.509 | 0.677 |
| S7 | 4.17 | 1.110 | 7.503 | 0.000* | 1.586 | 0.198 |

*: A p-value less than 0.05 indicates significantly different perceptions and opinions of the subgroups toward the studied factor

The ANOVA results regarding the proposed strategies for enhancing the recycling system (S1–S7) revealed a notable divergence in priorities based on occupational background, while maintaining a unified vision across different experience levels.

**A. Occupational Divergence on Disposal Levies (S7)**

- A significant statistical difference was identified concerning the proposal to increase fees for construction and demolition waste disposal (S7). While consulting engineers, academics, private owners, and contractors exhibited robust support for this measure (Means: 4.26, 4.54, 4.69, and 4.90, respectively), government sector representatives adopted a more moderate stance (Mean = 3.80).
- This disparity suggests that the public sector prioritizes a "foundational" approach over immediate fiscal penalties. From the government's perspective, the following strategic steps are perceived as more effective precursors to fee increases:
- **S2 (Categorization):** Defining waste categories based on specific product applications.
- **S5 (Communication):** Enhancing coordination and communication mechanisms among stakeholders.
- **S6 (Support):** Providing essential government subsidies and financial incentives.
- The analysis indicates that establishing these regulatory and supportive frameworks first would likely mitigate resistance from practitioners and contractors when disposal levies are subsequently implemented.

**B. Consensus Across Professional Experience**

- In contrast to occupational backgrounds, the analysis of variance based on years of experience showed no statistically significant differences. Participants, regardless of their career stage, shared consistent and positive views on all strategic proposals. This reflects a unified professional vision for the future of the recycling industry in the Sharqia Governorate, indicating that the sector's needs are clearly recognized by both emerging and senior experts.

## 4. Conclusions and Future Work

This study has contributed to CDW recycling in Egypt by adopting a comprehensive quantitative research methodology that revealed the following:

1) Identification and ranking of the main factors affecting the recycling of CDW in Sharqia Governorate and Egypt, using a survey questionnaire.
2) Assessing the opinions and perceptions of experts and practitioners of the construction industry based on their years of experience and occupations.

This evaluation included the benefits, economic factors, challenges, and obstacles facing the promotion of recycling of CDW. In addition to the recommendations to promote the CDW recycling industry in the Sharqia governorate and Egypt.

- Respondents recommended that sorting and recycling CDW will help to reduce construction costs and preserve natural materials, focusing on achieving the quality of recycled products and recommending the application in mega national projects.
- Imposing additional fees for the disposal of unclassified waste and focusing on the utmost importance of training executives to form executive cadres capable of effective management of CDW.
- It also considered the provision of governmental incentives, whether technical or financial, and the lack of government regulation, industrial standards, and technical guidelines for local authorities and contractors to recycle CDW.

The respondents also supported the seven recommendations, which could help government authorities, especially in Sharqia Governorate, in the establishment of a comprehensive CDW recycling plan for Sharqia Governorate and for Egypt in general, which can be expanded upon in future research, as follows:

- S1 stands for "Comprehensive and accurate assessment of the return on investment for CDW recycling."
- S2 stands for "Defining the categories of recyclable CDW according to the application of the recycled product, such as red brick, old concrete, clay, and others."
- S3 stands for "Promoting CDW recycling technologies in the early stages of the project."
- S4 stands for "promoting the technology and concept of recycling in the early stages of the project."
- S5 stands for “Effective communication between stakeholders, engineers, contractors, and consultants."
- S6 stands for "mandatory conditions or financial incentives from government agencies to recycle waste at construction sites."
- S7 stands for "increasing construction and demolition waste disposal fees."
- **Appendix**

| Category | Factors | Description |
|---|---|---|
| Benefits | B1 | The system helps to provide the spaces allocated for landfills and reduce the demand for new landfills. |
| | B2 | Helps save natural resources. |
| | B3 | Contributes to reducing the project budget by using recycled materials. |
| | B4 | Waste management contributes to saving the cost of transportation between the construction site and the sanitary landfill and saving the cost of disposal fees. |
| | B5 | Waste management contributes to achieving compliance with government policies related to green buildings and environmental protection. |
| | B6 | Contribute to enhancing competitiveness and increasing business opportunities for contracting and construction companies. |
| | B7 | It works to stimulate entrepreneurs in the field of reusing construction and demolition waste. |

| | | |
|---|---|---|
| Economic Factors | E1 | Preparation of a methodology for choosing the appropriate site for the establishment of a<br><br>recycling plant (in the case of establishing a fixed plant) to reduce the cost of transporting waste. |
| | E2 | Determine the production capacity of the recycling plant and link it to the quantities<br>generated or accumulated in the geographical area surrounding the plant to estimate the capacity of the required equipment. |
| | E3 | Classification and sorting of the different components of construction and demolition waste before the recycling process. |
| | E4 | The existence of a system to match the quality of recycled aggregates to the requirements of Egyptian standards. |
| | E5 | The availability and sale price of natural aggregate in the geographical area surrounding the recycling plant affect the economics of recycling. |
| | E6 | Imposing fees for the disposal of construction and demolition waste to encourage the establishment of factories, with a percentage of these fees directed to waste recycling plants |
| | E7 | Imposing an additional fee of up to 50 Egyptian pounds per ton for unsorted waste for disposal at the official sanitary landfill or recycling plant. |
| | E8 | Obliging government projects to use a specific percentage of recycled aggregate and construction products manufactured from the recycling output to stimulate the establishment and operation of recycling plants. |
| | E9 | Setting financial incentives, such as strikes and customs exemptions, for companies planning large investments in the system of recycling construction and demolition waste. |
| | E10 | For SMEs, concessional financing is an important financial incentive for them to invest in the system of recycling construction and demolition waste. |
| Obstacles and Challenges | Q1 | The high cost of recycling and labor intensity in the separation of construction and demolition waste. |
| | Q2 | The high cost of transportation between the work sites and the recycling facility. |
| | Q3 | Difficulty installing and maintaining recycling and reuse equipment (e.g., crushers) at work sites. |
| | Q4 | The cost of recycling waste is higher than burying it in a traditional landfill. |
| | Q5 | Increase the maintenance and management costs spent on the recycling of |

| | |
|---|---|
| | construction and demolition waste. |
| Q6 | The difficulty of developing a plan for the management of construction and demolition waste for small projects. |
| Q7 | Increase the workload of the supervisory team, such as recording and supervising activities related to the recycling of construction and demolition waste. |
| Q8 | Restructuring the policy of companies and work mechanisms to include the system of management of construction and demolition waste in their projects. |
| Q9 | Failure to train workers in the current recycling system to form executive cadres in this industry. |
| Q10 | Fear of low quality in materials manufactured from recycled materials |
| Q11 | Limited applications for recycled products. |
| Q12 | Lack of market for products manufactured from recycled materials. |
| Q13 | Not to invest in scientific research to recycle construction and demolition waste. |

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