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RECEIVED : 29 /01 /2025

ACCEPTED : 16/10/ 2025

PUBLISHED : 30/ 04/ 2026

**KEYWORDS:**

Construction, Erbil,  
Management, Projects,  
Residential, Waste.

# Evaluation of Construction Waste Management Process of Residential Complex Projects: A Case Study of Erbil Governorate

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## ABSTRACT

Construction projects are major contributors to environmental degradation, as they generate substantial quantities of waste, intensively consume natural resources, and accelerate resource depletion. This study examines the key factors influencing construction waste generation from a professional perspective. Specifically, it identifies the types and sources of waste produced during the construction of residential complexes in the Erbil Governorate and evaluates the prevailing waste disposal practices. A questionnaire survey was administered to 150 professionals, covering 54 factors categorized into seven major groups, distributed among relevant stakeholders. The analysis revealed that management-related factors represent the most significant contributors to waste generation, followed sequentially by material-handling practices, worker-related issues, and design deficiencies. Ten factors were classified between the categories of “most important” and “very important.” The most influential waste-generating factors included inadequate planning, inappropriate material storage methods, poor site management, absence of waste management plans, insufficient control and supervision, construction errors, inefficient unloading practices, design changes, and material damage caused by workers. Findings further demonstrated that no formal waste management strategies are currently implemented in residential complex projects. Instead, construction waste is often disposed of illegally in remote areas without consideration of environmental impacts. The study emphasizes the urgent need for the enforcement of regulatory frameworks by Erbil city authorities to ensure the sustainable management of construction waste, thereby mitigating environmental pollution and promoting resource efficiency.

## 1. Introduction

One of the most important goals of modern society is sustainable development. As the demand for commercial buildings, residential development, and infrastructure projects continues to rise, the construction industry has grown into one of the world's largest sectors (Nagapan et al., 2012a). According to (Yang et al., 2022) Construction and demolition waste constitutes a significantly larger volume compared to other types of waste. It occupies a significant volume, thereby limiting the capacity available for other types of waste (Sinoh et al., 2023). The construction sector is a major consumer of natural resources, accounting for approximately 25% of total consumption. Around 30% of the materials used on construction sites often become waste, which has significant environmental and financial consequences (Fitriani et al., 2022). According to the perspective on waste generation, particularly in developing countries, it has become a significant challenge (Nagapan et al., 2012a). Proper waste disposal, recycling, and reuse of waste materials require large resources and may have harmful effects (CHOWI et al., 2024). Illegal dumping sites and waste leachate present significant risks, as construction and demolition waste contains various pollutants that increase the danger to nearby water sources, groundwater, and soils (Tafesse et al., 2022). According to (Kabirifar et al., 2020). Waste contributes to approximately 50% of the total material disposed of in landfills, 40% of drinking water is polluted, and 23% of air pollution. The breakdown of organic waste in landfills generates a powerful greenhouse gas that contributes to climate change. In addition to consuming natural resources and energy, and extracting and processing new construction materials, this leads to environmental degradation (Zada et al., 2021). From an economic perspective, poor waste management results in lost opportunities for material recovery and reuse, increased costs associated with waste disposal, and potential fines for regulatory non-compliance. According to (Woodard, 2021). Improving waste management practices is therefore critical, as it can generate substantial

benefits, particularly by promoting circular resource flows (Aiguoabarueghian et al., 2024). Construction and demolition activities have significantly increased due to recent economic growth, urban expansion, and city development in the Kurdistan region of Iraq. Over the past 17 years, there has been a strong trend for the private sector to establish residential complex projects in Erbil Governorate. This resulted in the production of massive amounts of construction waste, which contributes to environmental pollution and poses a significant global challenge to sustainable development. While numerous researchers have examined the importance of construction waste management in developed countries, studies on this issue in developing nations are gradually increasing. Due to the limited studies on Erbil's residential waste management, the author conducted this study.

The following are the study objectives:

- 1-To identify the significant factors that generate construction waste.
- 2-To identify the waste generation rates of using various materials throughout the construction period.
- 3-To identify the different waste types and the method used for disposal.

"The Gulf Cooperation Council (GCC) countries consistently fall within the top 10% of per capita waste producers on a global scale (Ouda et al., 2018). They stated that only 13.6% of construction and demolition (C&D) waste is recycled or repurposed in Saudi Arabia annually, while the remaining volume is ultimately disposed of in landfills. (Hittini and Shibeika, 2019) Conducted a study in Abu Dhabi and found that insufficient awareness continues to exert a detrimental influence on construction waste management and control. In Qatar, construction materials constitute more than 75% of total solid waste, with the majority being deposited in desert landfill sites located at considerable distances from Doha (Reid et al., 2016). However, the recycling sector in the region is underdeveloped, and only 10–15% of this waste undergoes recycling (Mariyam et al., 2022). In Abu Dhabi, 67.8% of construction waste is directed to

landfills and dumpsites (Hittini and Shibeika, 2019). A major challenge facing the UAE remains the increasing volume of construction waste being disposed of in landfills (Al-Hajj and Hamani, 2011). Similarly, in the Kurdistan Region, (Maruf, 2017) reported that a considerable portion of C&D waste is disposed of in unauthorized locations, including roadside areas within urban environments. The study highlighted several barriers to effective construction and demolition (C&D) waste management, including the inadequate quality of recycled materials, the high economic costs associated with recycling processes, the absence of landfill taxation policies, the limited availability of recycled products in the market, and insufficient awareness of the environmental impacts arising from C&D waste. Overall, the evidence suggests that landfill disposal remains the predominant waste management strategy across most Middle Eastern countries. The existing literature highlights numerous studies on waste management in the Middle East, with particular emphasis on identifying the factors contributing to construction waste across different phases of a project's lifecycle. (Al-Hajj and Hamani, 2011) analyzed the causes of construction material waste in the United Arab Emirates (UAE) and identified several key contributing factors, including limited awareness, excessive off-cuts resulting from inefficient design, and rework. In Jordan. (Al-Rifai and Amoudi, 2016) investigated the principal causes of construction waste and concluded that management-related and workforce-related factors are the primary contributors. (Latif, 2020) reported that frequent design changes, poor site conditions, construction errors, and improper material storage practices constitute the major sources of construction waste in urban areas. (Bekr, 2014) highlighted that design decisions play a critical role in initiating waste generation. Similarly, the existing literature highlights numerous studies on construction waste management worldwide (Fitriani et al., 2022) identified eight major factors contributing to construction waste generation in Indonesia. The most significant are inadequate management of sites and human resources, limited collaboration

and support among stakeholders, inefficient equipment management, poor material logistics, and substandard working conditions. (Wang et al., 2008) emphasized that insufficient material handling and the lack of proper equipment are primary drivers of waste generation in England. (Ajayi et al., 2017) reported that poor site management leads to material damage and double-handling, both of which exacerbate waste levels in the UK. While, (Oyedele et al., 2014) noted that excessive raw material consumption and improper handling during construction activities significantly contribute to waste. Effective procurement of materials has been shown to mitigate waste (Ajayi and Oyedele, 2018). (Nagapan et al., 2012b) found that the major causes of construction waste in Malaysia were inadequate site management and supervision, frequent last-minute design changes initiated by clients, and insufficient training in waste management (Olanrewaju and Ogunmakinde, 2020). Identified last-minute client-driven design changes and inadequate training in waste management as key contributors to waste generation and barriers to effective waste practices in Nigeria. Examining waste management practices in each country is essential, as sustainability, particularly in the construction sector, is shaped by a nation's distinct social, economic, cultural, and legal framework. As a result, the implementation strategies can vary among countries.

### **1.1 Categories of Waste**

Construction waste can be categorized into several types. In housing projects, the quantity and composition of waste vary according to the construction methods employed and the specific stage of the construction process. According to (Enobie et al., 2024) By identifying these types, an effective waste management strategy can be developed. (Lee et al., 2024) and (Foo et al., 2013) Classified the types of construction waste into the following:

1-Concrete waste is one of the most abundant types, resulting from demolition, construction, and renovation activities.

2-Metal waste: produced during construction and demolition processes, typically including materials such as aluminum, copper, and steel.

3-Wood waste: originates from framing, flooring, formwork, and finishing activities.

4-Glass waste: generated from the installation and replacement of doors, windows, and other glazing components.

5-Plastic waste: arises from plastic sheets, PVC pipes, insulation, and packaging.

6-Gypsum waste: comes mainly from plaster, drywall, and other gypsum-based wallboard materials.

7-Asphalt waste: produced primarily during road construction and roofing applications.

8-Cardboard and paper waste: commonly generated on-site from material packaging and documentation.

9-Bricks and blocks: widely used for constructing walls, contributing to waste when broken, cut, or overordered.

10- Insulation waste: includes materials such as fiberglass, foam boards, and mineral wool, typically discarded due to off-cuts or improper installation.

**2. Methodology**

This study employed a quantitative research approach. According to (Tenny et al., 2022). Quantitative research investigates real-world issues using numerical data and statistical analyses, enabling the generation of hypotheses, interpretation of results, and exploration of how and why phenomena occur, rather than simply measuring how many or how much. Researchers typically aim to examine the topic within its natural context. Data were collected using questionnaires and structured interviews, which are commonly employed in survey-based studies (Naoum, 2012).

A stratified random sampling method was utilized to select the respondents. This probability sampling technique divides the population into distinct, non-overlapping subgroups (strata) that share similar characteristics, and random samples are then drawn from each stratum. The number of participants selected from each stratum was proportional to its size in the population. This approach ensures adequate representation of key subgroups and enhances the precision of estimates compared to simple

random sampling. Individual elements were randomly selected from construction projects completed within the past 15 years in the Erbil Governorate. Within each stratum representing large companies, participants were chosen randomly. These companies were primarily engaged in residential complex projects. The final sample consisted of project managers, consultants, and contractors involved in such projects. A total of 200 questionnaires were distributed to contractors, engineers, and project managers. Of these, 172 were returned. However, 22 of the returned questionnaires contained errors and were therefore considered invalid and excluded from the analysis. Consequently, the data analysis was conducted using 150 completed and valid questionnaires. The respondents' profile is presented in Table 1.

**Table 1:** Number of respondents and the years of experience

Years of experience	No. of Project Managers	No. of Engineers	No. of Contractors	Total
1 - 5	0	5	2	7
6 - 10	2	9	15	26
11 -15	10	10	20	40
16 -20	8	13	18	39
> 20	10	13	15	38
Total Number	30	50	70	150

Stage 1: Participants were asked to evaluate the causes of construction waste across seven categories, comprising a total of 54 items. These factors represent potential sources of waste in any residential construction project. The objective of this stage was to assess the relative significance of each factor.

Stage 2: Respondents were then required to report their experience by estimating the proportion of each type of construction waste, expressed as a percentage of the total waste generated. This stage aimed to evaluate the respondents' ability to quantify the different types of waste accurately.

Stage 3: A case study was conducted on 60 residential complex projects constructed in Erbil Governorate between 2008 and 2023. This stage

aimed to examine the frequency of each type of construction waste and the methods employed for its disposal.

**2.1 Data processing**

A Likert scale is used to express the significance of waste factors. The respondents had to rank the importance of waste causes on a scale of 1-5. Where 1 indicated the lowest level of importance and 5 indicated the highest. Based on the weight assigned to each answer, the significance of each factor can be determined. The ranking makes it possible to compare the importance of waste factors. Using the following equation, the relative importance (RII) is calculated. (Mohammed, 2016).

Relative importance is calculated as the weighted average multiplied by 100:

$$\text{Relative importance} = \frac{\sum W}{AN} * 100 \dots\dots\dots(1)$$

W = weight assigned to each factor of waste, range (1-5)

A = maximum weight assigned to the factor of waste, in this study = 5

N= denotes the total number of responses, which is 150 in this case

The values assigned to the respondents' ratings are:

1 = designated as not significant, 2 = designated as least significant, 3 = designated as significant, 4 = designated as highly significant, 5 = designated as most significant.

For the case study, a four-point scale of 1- 4 frequency index was adopted to evaluate the frequency of the source of waste for each type. The frequency index represents how often the factor occurs. It is calculated using the following formula:

$$\text{Frequency Index (F.I)} = \frac{\sum_1^4 an}{4N} \dots\dots\dots(2)$$

The following numerical values correspond to the respondents' ratings: 1 = rarely; 2 = sometimes; 3 = often; 4 = always.

The same approach was adopted by (Mohammed, 2023).

Where:

"a" represents the constant that indicates the weight assigned to each response (ranging from 1 for "rarely" to 4 for "always"), "n" denotes the

frequency of each response, and "N" stands for the total number of responses.

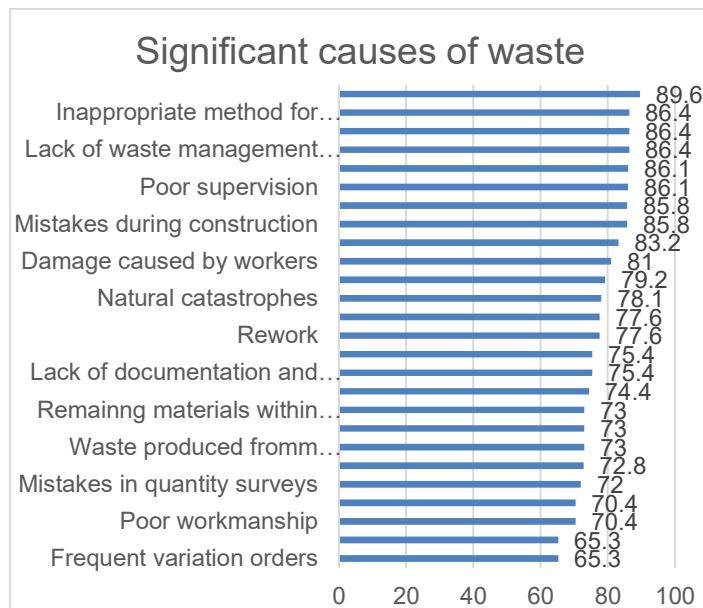
On the other hand, respondents were asked to evaluate the disposal methods used for each type of construction waste. In accordance with ISO standards, they were instructed to assign a full weight of 100% to methods that are regularly practiced, a weight of 0% to those never practiced, and 50% to methods that are partially practiced. This evaluation approach aligns with the methodology used in a similar study conducted by (Mohammed, 2024)

Table 2 presents the respondents' evaluations of the relative importance and rankings of the factors contributing to construction waste.

**Table 2:** Relative importance of factors affecting waste causes

No.	Categories and their factors	RII	Rank
<b>Design related</b>			
1	Complicated design	33.6	23
2	Poor coordination between design teams	65.3	16
3	Error in contract documents	40.8	21
4	Poor design quality	40.8	21
5	Inexperienced designer	40.2	22
6	Design errors	79.2	7
7	Design changes	83.2	5
8	Lack of design information	72.8	13
<b>Handling related</b>			
1	Using unsuitable tools	57	17
2	Inefficient method of unloading	85.8	4
3	Equipment failure	56.8	18
4	Supplying materials in loose form	40.2	22
5	Damage during handling	74.4	11
6	Poor material quality	56.8	18
7	Inappropriate method for storing material	86.4	2
<b>Workers Related</b>			
1	Shortage of skilled workers	40.8	21
2	Improper use of materials	73	12
3	Mistakes during construction	85.8	4
4	Poor workmanship	70.4	15
5	Damage caused by workers	81	6
6	Poor attitude of workers	51.2	20
7	Incompetent workers	56.8	18
8	Workers lacking experience	33.6	23
9	Lack of awareness among workers	26.4	24
<b>Management related</b>			
1	Rework	77.6	9
2	Lack of documentation and daily reporting	75.4	10
3	Poor planning	89.6	1
4	Using inappropriate construction	70.4	15

	methods		
5	Poor controlling	86.1	3
6	Poor site management	86.4	2
7	Inadequate tools and equipment	77.6	9
8	Communication problems	51.2	20
9	Lack of waste management plans	86.4	2
10	Poor supervision	86.1	3
<b>Procurement related</b>			
1	Frequent variation orders	65.3	16
2	Mistakes in quantity surveys	72.0	14
3	Items non-compliant with specifications	75.4	10
4	Different methods used for estimation	22.9	27
5	Suppliers' errors	29.9	27
6	Ordering errors	56.2	19
7	Wrong procedure for delivery	22.9	27
<b>Site Condition related</b>			
1	Poor lighting	22.9	27
2	Bad site conditions	56.2	19
3	Remaining materials within the site	73	12
4	Waste produced from packaging	73	12
5	Combustion of the site	40.2	22
6	Interference with other crew on the site	22.9	27
7	Difficulties accessing the construction site	22.9	27
<b>External</b>			
1	Effect of bad weather	24.8	25
2	Natural catastrophes	78.1	8
3	Topography	24.5	26
4	theft and vandalism	56.8	18
5	Accidents	24.5	26



**Figure 1: Most significant factors that cause construction waste**

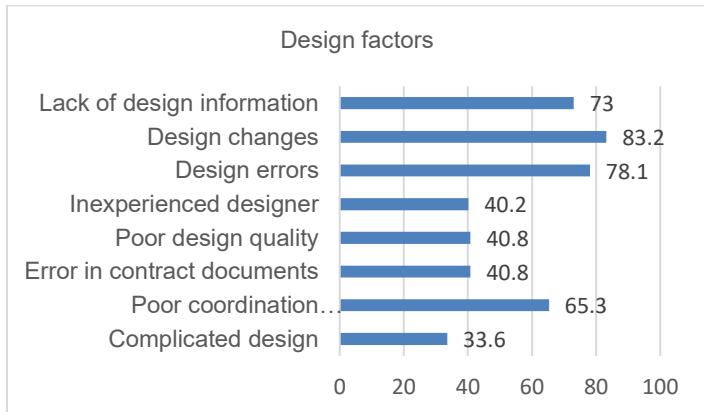
The outcome of the figure indicates that poor planning ranks first among factors contributing to construction waste, with a rate of 89.6%. Inappropriate methods of material storage, poor site management, and the absence of waste management plans collectively rank second, with a rate of 86.4%. Poor supervision and inadequate control are ranked third at 86.1%, followed by construction errors and inefficient unloading methods in fourth place at 85.8%. Design changes rank fifth with 83.2%, while damage caused by workers is sixth at 81%, and design errors rank seventh at 79.2%. Natural catastrophes occupy the eighth position with 78.1%, and inadequate tools and equipment, along with rework, are ninth at 77.6%. Non-compliance with specifications, lack of documentation, and insufficient daily reporting share the tenth rank at 75.4%, while damage during handling ranks eleventh at 74.4%. Remaining materials on-site, improper use of materials, and waste from packaging are jointly ranked twelfth at 73%. Lack of design information ranks thirteenth at 72.8%, errors by quantity surveyors fourteenth at 72%, and inappropriate construction methods combined with poor workmanship rank fifteenth at 70.4%. Finally, frequent variation orders and poor coordination among design parties rank sixteenth at 65.3%.

The results indicate that ten factors are classified between the “very important” and “most important” categories, of which five are related to the management phase. Additionally, fourteen factors fall between the “important” and “very important” categories, with five also associated with management. This highlights that management-related factors are the most significant contributors during the construction process. Conversely, two factors are rated between “important” and “least important,” while eight factors fall within the “least important” to “not important” range.

Figure 1 summarizes the most significant factors, categorized between ‘important’ and ‘most important,’ that contribute to construction waste among all identified factors.

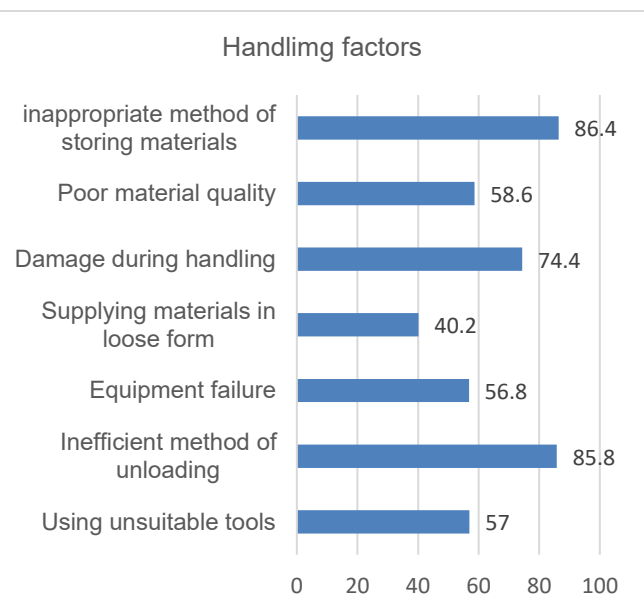
Figure 2 highlights the design phase factors that contribute to construction material waste generation. Within this category, eight factors have been identified as significant contributors to waste production

**Figure 2:** Significant design factors generating waste.



Frequent design changes are the primary contributor to construction waste, accounting for 83.2%, followed by design errors at 79.2%, and lack of design information at 73%. The least influential factor within this category is complicated design, contributing 33.6% to waste generation.

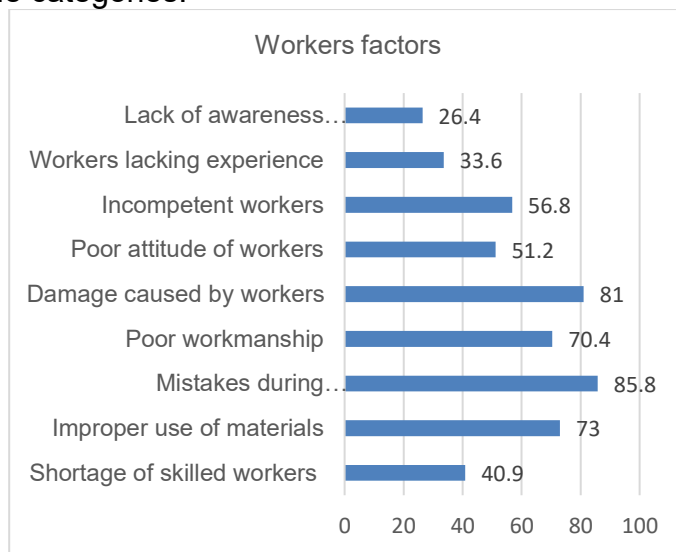
Figure 3 presents the respondents' rankings of the significance of factors contributing to construction material waste during the handling process.



**Figure 3:** Significant handling factors

Within this category, seven factors contribute to the generation of construction waste. The highest rated factor is the use of inappropriate methods for storing materials, with a significance rate of 86.4%. Another major contributor is inefficient unloading methods, rated at 85.8%, followed by damage during handling at 74.4%. The least influential factor is the supply of materials in loose form, with a rate of 40.2%.

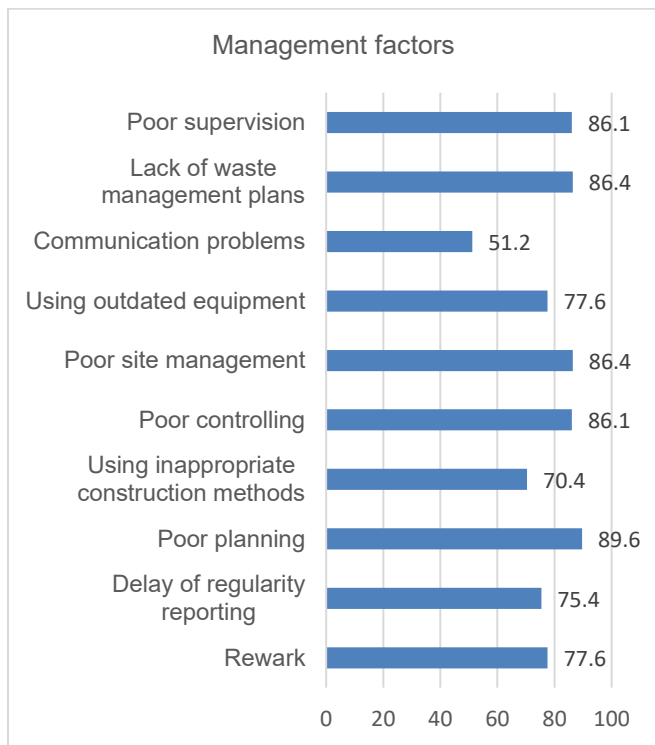
Figure 4 presents the respondents' assessment of the significance of construction management flaws related to worker factors, encompassing nine categories.



**Figure 4:** Significant worker factors

Mistakes during construction received the highest significance rating at 85.8%, followed by damage caused by workers at 81%, improper use of materials at 73%, and poor workmanship at 70.4%. Other notable factors include incompetent workers at 56.8% and poor worker attitude at 51.2%. The least influential factor contributing to waste was identified as a lack of awareness among workers.

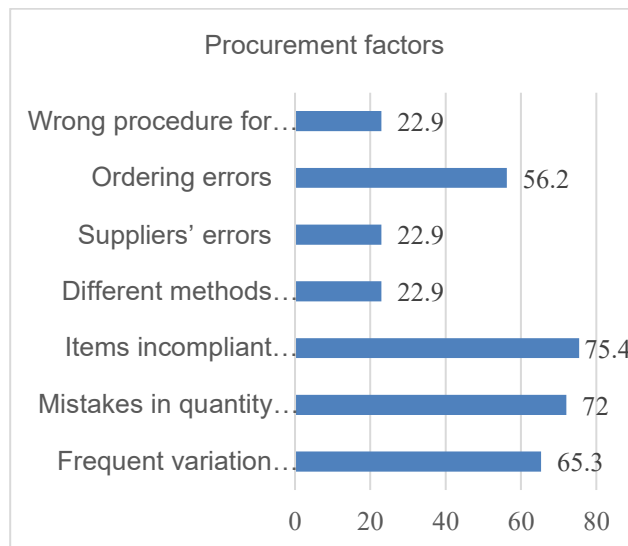
Figure 5 shows the respondents' rankings of the significant construction management factors contributing to construction material waste.



**Figure 5:** Significant management factors

Management encompasses the largest number of contributory factors to construction material waste. Poor planning received the highest significance rating within this category, at 89.6%. Poor site management and the lack of waste management plans ranked second, each at 86.4%, followed closely by poor supervision and inadequate control at 86.1%. Rework and the use of outdated equipment were rated at 77.6%, delays in regular reporting at 75.4%, and inappropriate construction methods at 70.4%. Communication problems were identified as the least influential factor in this category, with a rating of 51.2%.

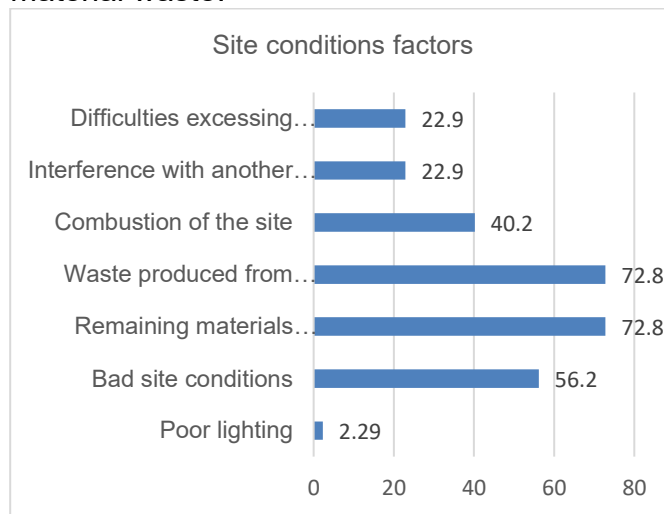
Figure 6 presents the respondents' rankings of the significant factors contributing to construction material waste related to procurement, encompassing seven categories.



**Figure 6:** Significant procurement factors

The highest-rated factor in this category is ordering errors, with a significance rate of 75.4%, followed by mistakes in quantity surveying at 72%, and frequent variation orders at 65.3%. Notably, ordering errors are mentioned again with a rate of 51.2%, which may require clarification or correction. The least influential factors contributing to waste include incorrect delivery procedures, supplier errors, and estimation methods, each rated at 22.9%.

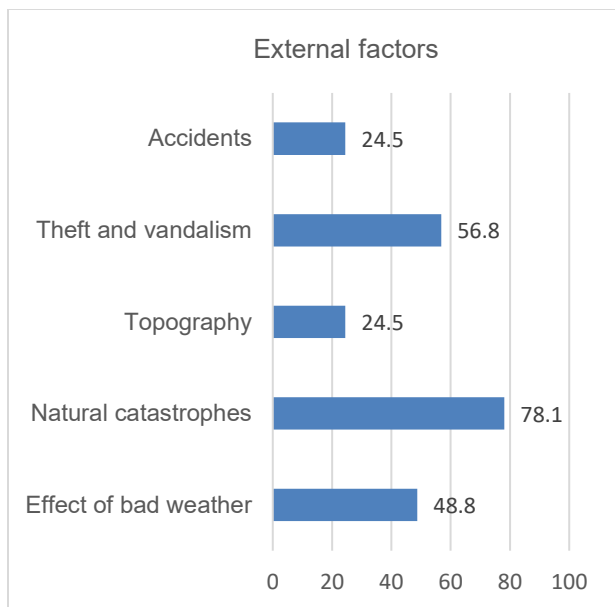
Figure 7 presents the respondents' rankings of site condition factors, comprising seven categories, that contribute to construction material waste.



**Figure 7:** Significance of site conditions factors

The results indicate that remaining materials on-site and waste generated from packaging are the primary contributors to construction waste, each with a significance rate of 72.8%. Poor site conditions rank second, with a rate of 56.2%. The least influential factors include inadequate lighting, interference from other crews on-site, and difficulties accessing construction sites, all rated at 22.9%.

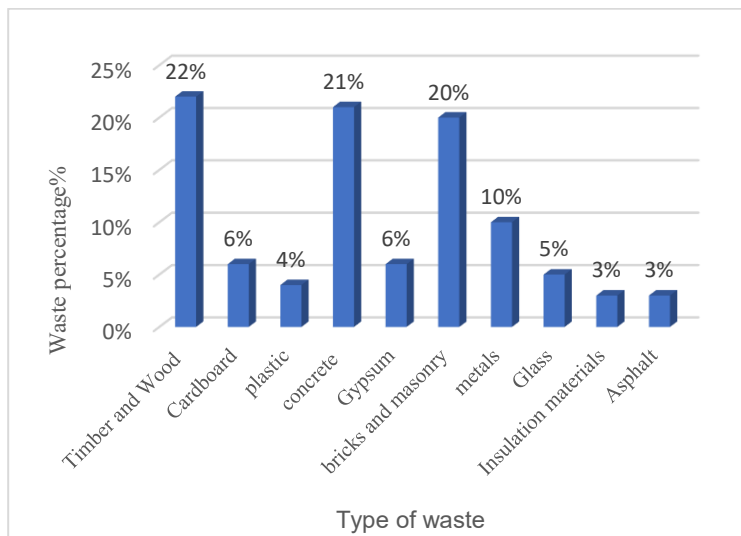
Figure 8 presents the respondents' rankings of external construction factors, comprising five categories that are beyond direct control.



**Figure 8:** External conditions factors

Natural catastrophes are identified as the most influential external factor contributing to construction waste, with a significance rate of 78.1%, followed by theft and vandalism at 56.8%. Figure 9 illustrates the respondents' estimated waste rates generated from different materials during construction.

Topography and accidents have the least impact in this category, each accounting for 24.5%.



**Figure 9:** The average percentage of waste

Respondents identified timber and wood, bricks and masonry, and concrete as the primary sources of construction waste, contributing 22%, 21%, and 20% of the total waste, respectively. Collectively, these materials accounted for 63% of the overall waste generated. Smaller quantities of waste were reported for asphalt, insulation materials, plastic, glass, gypsum, and cardboard, contributing 3%, 3%, 4%, 5%, 6%, and 6% of the total waste, respectively. Metal waste accounted for approximately 10% of the total. Given that metals and wood are generally recyclable, these materials should be prioritized in waste recovery efforts. Notably, there was substantial variation in respondents' perceptions regarding the composition and proportions of waste materials, suggesting the absence of a formal waste management plan and limited awareness of actual waste composition. Furthermore, waste management practices have not been prioritized in these construction projects.

Table 3 summarizes the current waste disposal practices for different types of construction waste.

**Table 3: Source of waste and method of disposal**

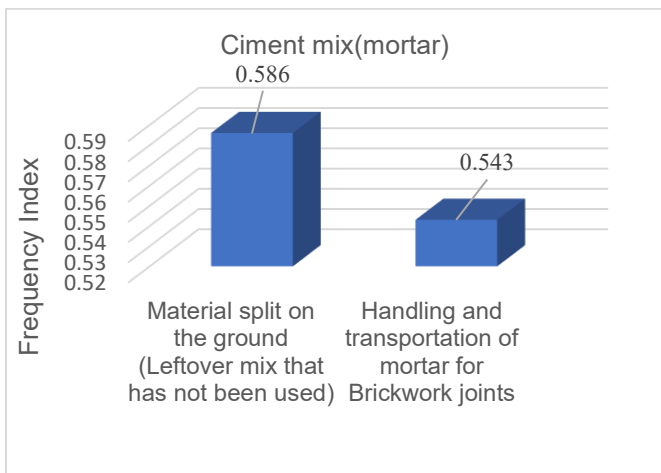
	Type of waste	Practiced process	Practice percentage
1	Cement mix (Mortar)	Crusted for recycled sand	0%
		Disposed of by throwing in a remote area	100%
2	Bricks and blocks	Crushed into fine aggregate.	15%
		Disposed of by throwing in a remote area	85%
3	Concrete	Used as a base course in garages and pathways.	10%
		Disposed of by throwing in a remote area	90%
4	Metal waste,	Sold	92.35%
		Disposed of by throwing in a remote area	7.65%
5	Wood	Recycled and used for papers or furniture	0%
		Burned	15.87%
		Disposed of by throwing in a remote area	83.53%
6	Cardboard	burned	2.34%
		Thrown with other waste	90.76%
7	plastic	Recycled and reused	0%
		Disposed of by throwing in a remote area	100%
8	Glass	Recycled	0%
		Disposed of by throwing in a remote area	100%
9	Gypsum	Disposed of by throwing in a remote area	100%
10	asphalt	Crushed into fine aggregate	2.94%
		Disposed of by throwing in a remote area	97.06%
11	Insulation materials	Disposed of by throwing in a remote area	100%

According to respondents, approximately 15% of brick waste is crushed and reused as fine aggregate, while 10% of concrete waste is repurposed as a base course for garages and pathways. Although the reuse of concrete has not gained widespread adoption, it remains a highly effective strategy for resource conservation. Most metal waste is sold, whereas 7.65% is illegally disposed of in remote areas. The data further reveal that 15.87% of wood waste and 2.35% of cardboard waste are incinerated, with the remaining quantities similarly dumped in remote locations. Only 2.94% of asphalt waste is processed into fine aggregate. In contrast, cement mix, plastic, glass, gypsum, and insulation materials are predominantly discarded at unauthorized dumping sites. These findings underscore that a substantial proportion of construction waste is improperly managed, despite its considerable potential for reuse and recycling.

Many construction waste materials possess significant potential for recycling or repurposing. For example, crushed concrete and bricks can be utilized as aggregates in road base layers, new

concrete production, or landscaping applications. Metals and wood are highly recyclable and should be prioritized for recovery; additionally, treated wood can be incinerated in waste-to-energy facilities. Metals may be melted and reintroduced into manufacturing processes, while larger plastic items such as sheeting and pipes can often be reused directly on-site. Certain plastics can also be reprocessed into new products. Similarly, reclaimed asphalt can be crushed and incorporated into new mixtures, glass can be melted and remanufactured, and gypsum can be processed into new drywall panels.

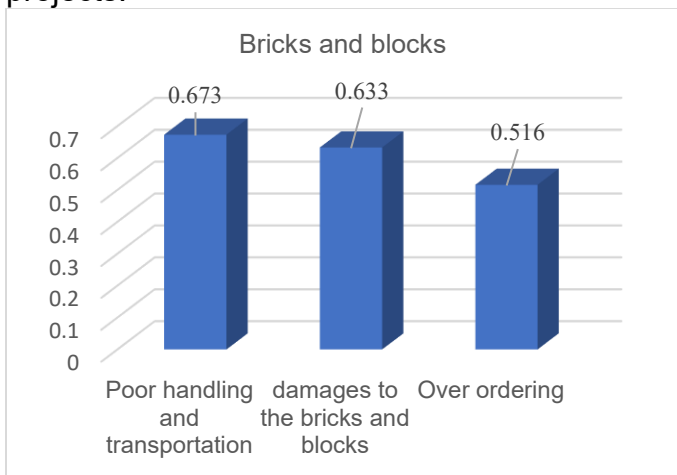
Figure 10 illustrates the respondents' rankings of the frequency of cement waste sources generated during the construction phase of the projects.



**Figure 10:** Cement mix waste sources

The results presented in Figure 10 indicate that the most frequent source of cement waste is leftover mix, ranked first with a rate of 0.586, followed by waste generated during the handling and transportation of mortar for brickwork joints, with a rate of 0.543.

Figure 11 illustrates the respondents' rankings of the frequency of waste generated from bricks and blocks during the construction phase of the projects.

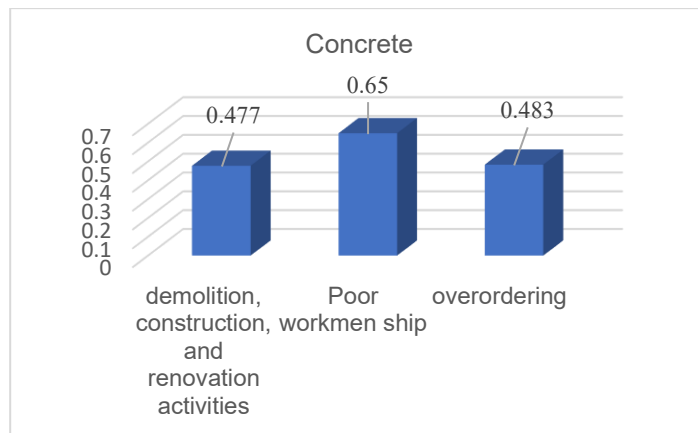


**Figure 11:** The bricks and blocks waste sources

The most frequent sources of brick and block waste, as shown in Figure 11, are poor handling and transportation, ranked first with a rate of 0.673; damage to bricks and blocks, ranked second at 0.633; and overordering, ranked third with a rate of 0.516.

The results presented in Figure 12 show the respondents' rankings of the frequency of

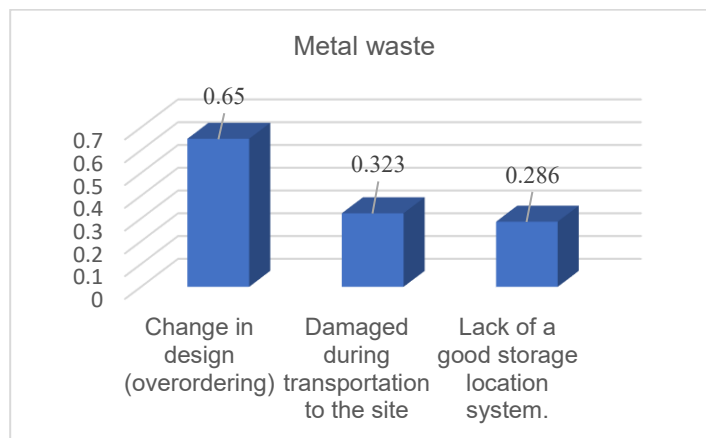
concrete waste sources generated during the construction phase of the projects.



**Figure 12:** Concrete waste sources

The most frequent sources of concrete waste, as shown in Figure 12, are poor workmanship, ranked first with a rate of 0.650; overordering, ranked second at 0.483; and demolition, construction, and renovation activities, ranked third with a rate of 0.477.

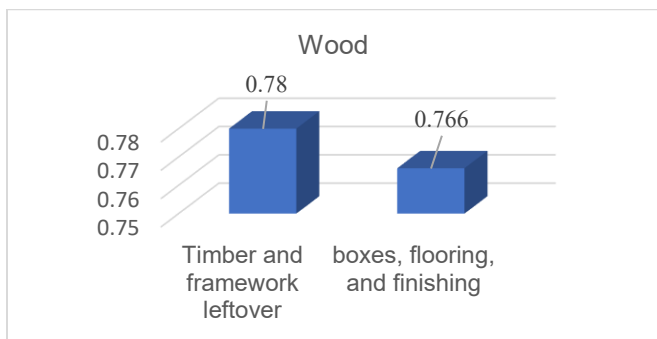
The results presented in Figure 13 illustrate the respondents' rankings of the frequency of metal waste sources generated during the construction phase of the projects.



**Figure 13:** Metal waste source

The most frequent sources of metal waste, as shown in Figure 13, are design changes, ranked first with a rate of 0.650; damage during transportation, ranked second at 0.323; and inadequate storage location systems, ranked third with a rate of 0.286.

The results presented in Figure 14 illustrate the respondents' rankings of the frequency of wood waste sources generated during the construction phase of the projects.



**Figure 14:** Wood waste sources

The results illustrated in Figure 14 show that the most frequent sources of wood waste are timber and framework leftovers, ranked first with a rate of 0.780, followed by boxes, flooring, and finishing materials, ranked second with a rate of 0.766.

Figure 15 presents the respondents' rankings of the frequency of gypsum waste sources generated during the construction phase of the projects.



**Figure 15:** gypsum waste sources

The results presented in Figure 15 indicate that the primary sources of gypsum waste are drywall, plaster, and other wallboard products, ranked first with a frequency rate of 0.683, followed by leftover mix, ranked second with a rate of 0.563.

**4. Conclusion**

This study highlights the critical issue of construction waste generation in residential complex projects within Erbil Governorate and underscores its environmental, economic, and

social implications. The findings reveal that management-related factors, particularly poor planning, inadequate site management, lack of waste management plans, and insufficient supervision, are the most significant contributors to waste generation. Design-related issues, such as frequent changes and errors, along with improper handling, poor workmanship, and worker-related mistakes, further exacerbate the problem. The results also demonstrate that the majority of construction and demolition waste is still disposed of in unauthorized locations, with very limited reuse or recycling. Wood, bricks, and concrete collectively account for the largest portion of generated waste, yet their potential for reuse as aggregates or secondary materials remains largely untapped. Metals, while mostly recycled, represent one of the few materials with relatively efficient recovery practices. To improve construction waste management in Erbil, stronger regulations and enforcement mechanisms, including landfill taxes and mandatory waste management plans, are essential. Emphasis should be placed on reducing waste at the source through better planning, accurate procurement, and modern construction methods such as prefabrication. To mandate on-site waste sorting and establish centralized collection points for recyclables, creating a market for them. Establishing recycling facilities, promoting on-site segregation, and encouraging the reuse of materials like concrete, metals, and wood can significantly reduce landfill dependency. Training programs, awareness campaigns, and the adoption of digital tools such as BIM will further enhance efficiency. Finally, collaboration among government, contractors, and communities is key to building a sustainable, circular construction industry.

**Acknowledgment:** Not applicable.

**Financial support:** No financial support.

**Conflict of interest**

The author acknowledges that there are no conflicts of interest regarding the publication of this article.

**References**

AIGUOBARUEGHIAN, I., MONICA ADANMA, U. & KUPA, E. 2024. Impact of biodegradable plastics on US environmental conservation: A comprehensive review, exploring the effectiveness, challenges, and broader

- implications of bioplastics in waste management and eco-preservation. *Eng. Sci. Technol. J*, 5, 2157-2185.
- AJAYI, S. O. & OYEDELE, L. O. 2018. Waste-efficient materials procurement for construction projects: A structural equation modelling of critical success factors. *Waste management*, 75, 60-69.
- AJAYI, S. O., OYEDELE, L. O., BILAL, M., AKINADE, O. O., ALAKA, H. A. & OWOLABI, H. A. 2017. Critical management practices influencing on-site waste minimization in construction projects. *Waste management*, 59, 330-339.
- AL-HAJJ, A. & HAMANI, K. 2011. Material waste in the UAE construction industry: Main causes and minimization practices. *Architectural engineering and design management*, 7, 221-235.
- AL-RIFAI, J. A.-R. & AMOUDI, O. 2016. Understanding the key factors of construction waste in Jordan. *Jordan Journal of Civil Engineering*, 10.
- BEKR, G. A. 2014. Study of the causes and magnitude of wastage of materials on construction sites in Jordan. *Journal of Construction Engineering*, 2014, 283298.
- CHOWI, S., MAHARJAN, N. & MANANDHAR, R. 2024. IDENTIFICATION OF CAUSES OF CONSTRUCTION WASTE MATERIALS GENERATION: A CASE STUDY OF TRIBHUVAN INTERNATIONAL AIRPORT. *JOURNAL OF TRANSPORTATION SYSTEMS Управління: MAT Journals*, 9, 32-41.
- ENOBBIE, B. K., OKWANDU, A. C., ABDULWAHEED, S. A. & IWUANYANWU, O. 2024. Effective waste management in construction: Techniques and implementation. *Int. J. Appl. Res. Soc. Sci*, 6, 1642-1652.
- FITRIANI, H., AJAYI, S. & KIM, S. 2022. Analysis of the underlying causes of waste generation in Indonesia's construction industry. *Sustainability*, 15, 409.
- FOO, L. C., RAHMAN, I. A., ASMI, A., NAGAPAN, S. & KHALID, K. I. 2013. Classification and quantification of construction waste at housing project site. *International Journal of Zero Waste Generation*, 1, 1-4.
- HITTINI, B. Y. & SHIBEIKA, A. I. 2019. Construction waste management in UAE: An exploratory study. *WIT Transactions on Ecology and the Environment*, 238, 679-686.
- KABIRIFAR, K., MOJTAHEDI, M., WANG, C. & TAM, V. W. 2020. Construction and demolition waste management contributing factors coupled with reduce, reuse, and recycle strategies for effective waste management: A review. *Journal of cleaner production*, 263, 121265.
- LATIF, Q. B. I. 2020. Oman construction industry prospective on cause of construction material waste. *INTERNATIONAL JOURNAL OF INTEGRATED ENGINEERING VOL. 12 NO. 1 (2020) 243-252*.
- LEE, J. C., THEDY, W. H., CHONG, Z., NG, J. L., MOON, W. C., HONG, X. & LEE, S. 2023. A Study on Recycling Waste Materials in Construction Industry. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, 59, 227-241.
- MARUF, S. M. 2017. Construction waste management in kurdistan reigon. *Polytechnic Journal*, 7, 10.
- MOHAMMED, A. J. 2016. A study for the causes of variation orders in different sectors of construction projects in Erbil governorate from the point of view of the involved parties. *Journal of Engineering and Sustainable Development*, 20, 30-54.
- MOHAMMED, A. 2023. Evaluation of the procurement management system for residential complex projects in Erbil Governorate. *Journal of Engineering and Sustainable Development*, 27(1), pp.54-67.
- MOHAMMED, A. J. 2024. Evaluation Of the Safety Management System of Building Construction Projects: A Case Study of Erbil Governorate. *Zanco Journal of Pure and Applied Sciences*, 36.
- NAGAPAN, S., RAHMAN, I. A., ASMI, A., MEMON, A. H. & ZIN, R. M. 2012. Identifying causes of construction waste-Case of central region of Peninsula Malaysia. *International Journal of Integrated Engineering*, 4.
- NAGAPAN, S., RAHMAN, I. A. & ASMI, A. 2012. Factors contributing to physical and non-physical waste generation in construction industry. *International Journal of Advances in Applied Sciences*, 1, 1-10.
- NAOUM, S. G. 2012. *Dissertation research and writing for construction students*, Routledge.
- OLANREWAJU, S.D. & Ogunmakinde, O.E., 2020. Waste minimisation strategies at the design phase: Architects' response. *Waste Management*, 118, pp.323-330.
- SINOH, S. S., OTHMAN, F. & ONN, C. C. 2023. Circular economy potential of sustainable aggregates for the Malaysian construction industry. *Sustainable Cities and Society*, 89, 104332.
- TAFESSE, S., GIRMA, Y. E. & DESSALEGN, E. 2022. Analysis of the socio-economic and environmental impacts of construction waste and management practices. *Heliyon*, 8.
- TENNY, S., BRANNAN, J. M. & BRANNAN, G. D. 2022. 'Qualitative' studies. *StatPearls [Internet]*, StatPearls Publishing, FL, pp.93-187.
- WANG, J. Y., KANG, X. P. & WING-YAN TAM, V. 2008. An investigation of construction wastes: an empirical study in Shenzhen. *Journal of Engineering, Design and Technology*, 6, 227-236.
- WOODARD, R., 2021. Waste management in small and medium enterprises (SMEs): compliance with duty of care and implications for the circular economy. *Journal of Cleaner Production*, 278, p.123770.
- YaANG, Y., GUAN, J., NWAOGU, J.M., CHAN, A.P., CHI, H.L. & LUK, C.W., 2022. Attaining higher levels of circularity in construction: Scientometric review and cross-industry exploration. *Journal of Cleaner Production*, 375, p.133934.
- ZADA, A., KHAN, M., KHAN, M.A., KHAN, Q., HABIBI-YANJGE, A., Dang, A. & MAQBOOL, M., 2021. Review on the hazardous applications and photodegradation mechanisms of chlorophenols over different photocatalysts. *Environmental Research*, 195, p.110742.