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RESEARCH PAPER

An Investigation into the Factors Influencing the Reduction of Construction Materials Wastage in Erbil City- KRG-Iraq

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A B S T R A C T:
The aim of this study is to identify the factors affecting the construction material waste generation and to determine the magnitude of construction waste material in Erbil city. To achieve this study, a form of a questionnaire was prepared comprised of the factors influencing the waste generation of construction material, and assessment of seventeen different construction materials was selected to examine the approximate magnitude of their waste. The survey data was analyzed by adopting the relative important index (RII) method. The result of the analysis revealed that the top significant causes of wastage of materials on construction projects were due to the lack of on-site waste management plans; frequent changes to design, lack of supervision, improper storing of materials; lack of possibilities to order small quantities; lack of skilled workers. Also the study found that the waste percentage of materials used ranged from 3.3% to 8.5%., and the waste percentage of fine aggregate, coarse aggregate, and timber were in a range of 6% to 7% while the waste of cement, steel reinforcement, concrete, concrete block and brick in a range of 5% to 6%, whereas the waste in gypsum reached 8.5%. Furthermore, the study found that poor planning and rework contributing as a significant aspect of waste generation in Erbil city.

KEY WORDS: Wastage Reduction; Factors Influencing; Construction Materials; Waste Management.
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1. INTRODUCTION

Waste reduction of construction materials in the construction industry is essential aspect not only from the view of efficiency of project management related to the financial return, since, the environmental impact is also growing in recent years in the sense of the adverse impact of the waste generation of building materials on the society and environment. The waste of construction materials accounts for between 15 and 30% of urban waste, and building materials wastage is difficult to recycle due to high levels of pollution and contamination due to the availability of insufficient space and lands for its disposal in large cities (Bossink and Brouwers, 1996). For the production of building materials require of using large amounts of nonrenewable resources of energy, since the resources that are in danger and risk of depletion, including timber, sand, and crushed stone (Wyatt, 1978). Although construction waste occurs and accumulates during the actual construction process, there is an understanding that it is caused by events and actions at the design stage, materials procurement handling, and during the construction stages of project and delivery processes (Kavithra et al., 2017). According to modern production philosophy, waste should be understood as any inefficiency that results in the use of equipment, materials, labor (Koskela, 1992).

The construction waste was defined as “quality costs, rework, unnecessary transportation trips,

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long distances, improper choice of management methods and poor constructability" (Alarcón et al., 2002). The physical wastage is included loss of construction materials and damages whereas, cost and time overrun refer to non-physical waste. Hence, the waste can be defined as the difference between the total quantity of material brought to the project site and the actual amount used (Enshassi, 1996).

Furthermore, waste is defined as "any losses that generate a direct or indirect cost but do not add any value to the product." Moreover, the construction waste can be defined as any inefficiency activities that result in the use of equipment, labor, materials, or capital in larger quantities other than those considered in the production of a building (Formoso et al., 1999).

A study focused on waste management stated that the production of waste could be displaced and reused. Materials like glass, plastic, and PVC, and paper products are collected and recycled into new materials and products (Davis et al., 2006).

A study identified two case studies of construction projects to reduce construction waste generation in the UAE construction sites by a literature review of research, and concluded that people are lack of awareness, less importance towards the waste management on sites and showed that contractors consider that waste management is an extra cost of the project (Al-Hajj and Iskandarani, 2012).

Another study focused on the economic aspects of waste minimization of construction waste materials in terms of cost savings of construction projects in India. In addition, they found that due to lack of site waste management systems, lack awareness of waste minimization in the Indian construction industry cause of generation of large quantities of material waste (Jain, 2012).

It is necessary to reduce waste generation and increase the reuse and recycling process to overcome the shortage of aggregate from natural sources being discovered in many parts of the country, so now recycled aggregate can use in construction processes. The government Municipal waste laws are required to modify and prepare effective plans, and strict rules and regulations are essential to forget out of this problem (Bansal and Singh, 2014). The mechanism of handling the construction materials will contribute to improving the efficiency and cost-effectiveness on the construction site. The study revealed that minimization of the amount of wastage of construction materials during the construction phases helps reduce the cost of the project (Singh, 2015).

A research study indicated that the management of construction materials waste plays an essential factor in the reduction of project costs(Sawant Surendra et al., 2016).

A study suggested that waste planning and management practices could be important for reducing waste generation like strict construction waste management, project drawings, no design changes during the construction process. Moreover, concluded poor knowledge, poor design documentation, and lack of awareness towards waste minimization would increase construction waste generation. Site supervisors should be with the understanding of waste minimization, which could reduce waste generation on sites (Ajayi et al., 2017).

The main aims of this study are to assess the perception of construction professionals, towards the efficient performance of construction activities related to the reduction of construction material wastes and as follows:

To identify the most critical factors that influence the construction material waste produced during construction activities, and to determine the magnitude of waste generated in construction projects in Erbil city.

2. MATERIALS AND METHODS

2.1 Preparation of questionnaire

The questionnaire designed to be self-administered and to facilitate conducting on-site interviewed survey conducted. The primary form

of the questionnaire subjected to correction and revisions by the feedback received during the pilot study conducted to review and assess the feasibility of the survey. The final form of the questionnaire comprises three parts as follows:
The first part investigated the necessary personal information of the respondent profiles and working category and the type of construction projects. The second part of the questionnaire devoted to studying the factors effect on a waste generation was distributed on seven significant groups, such as factors related to design, worker, management process, site condition, procurement, and factors related to external conditions. The third part of the questionnaire focused on the investigation of the respondent's perception of the waste percentage generated on construction site for seventeen types of materials. The respondents were requested to reply to require enquires based on their previous professional experience and skills in the execution of construction projects to score their perception related to the magnitude of construction materials waste. Various types of construction materials selected, such as; cement, fine sand, coarse aggregate, steel reinforcements, concrete, concrete blocks, brick, gypsum, glass, roofing materials, paint, PVC water pipes, mosaic tile, ceramic tiles, marble tiles, and electrical items. A total of 110 questionnaires were distributed for this survey, of which 43 were completed with a valid response, and this indicated a response rate of 40%.

2.2 Study Area

The current study involved surveying the construction materials waste generation in twelve project sites under construction in Erbil city, as presented in Table 1.

Table 1: The Study Area in Erbil City

No.	Project Name and location
1.	Cristal Hotel 2-100m Road Near Empire
2.	Runaky Towers- Runaky Neighborhood
3.	Zanyari Apartments-60m Road Near Stadium
4.	Majdi Mall 2- Masif Salahaddin Road
5.	Empire Wings Apartments-100m Road
6.	4 Towers – Bahirka Road- Bahrka Road
7.	Justice Tower- Opposite Sami Abdurahman Park
8.	Majdi Hospital- Masif Salahaddin Road
9.	Erbil International Hospital-100m Road Near Hogr Fuel Station
10.	Construction of 7 Multi-Stories Apartment In Erbil (280 Units)- Near Majdi Mall 120m road
11.	Mnw Tower-40m Road Opposite Dream City
12.	Department of Construction of Schools-Erbil Governorate

2.3 Statistical Analysis Techniques

The collected data were statistically analyzed by calculation of Relative Important Index (RII) conducted in terms of quantitative and qualitative analysis of data collection in this study using questionnaires, interviews, field observation, and documentary sources. To calculated and the RII by using equation (1) (Fadiya et al., 2013).

$$RII = \sum_{i=1}^{5} \frac{i}{5}\, x \frac{n_i}{N} \qquad (1)$$

Where; $\mathbf{n_i}$ is referred to the number of respondents that chose **i** for the frequency.
While **N** is the total number of responses, and **i** is the weight of category **i**.
To demonstrate the procedure for calculation RII by using Equation (1) as an example for the first factor (frequent design change) which listed in Table. 4, and as follows:

$$\boldsymbol{RII}_{(\boldsymbol{Frequent\ design\ change})} = \frac{(1*1+2*8+3*16*4*11+5*7)}{(5*43)}$$
$$= 0.6698$$

2.4 Reliability Test

The Cronbach's alpha results give value ranged from 0 to 1, and it was calculated to estimate the internal consistency of reliability of measurement scale, and the closer to 1 indicate the high degree of reliability range, thus Cronbach's alpha coefficient should fall within a range of 0.7 to 1.0 (Yockey, 2018). The Cronbach's alpha was estimated by using the SPSS package; the result of calculating the Cronbach's alpha was 0.91; this value indicates that the collected data is very reliable, as shown in Table2.

Table 2: Cronbach's Alpha Value

Cronbach's Alpha	No. of Items
0.910	38

3. RESULTS and DISCUSSIONS

3.1 Respondents Profile

The questionnaires distributed to various professionals, engineering, and technical staff involved in construction projects in Erbil city, to investigate the respondent's profiles. Table 3. shows that among the respondents working in building construction accounting for 49% and 49% in other types of projects such as dams, water supply, sewage, etc. and only 2% in road construction.

Table 3: Summary of Respondents Personal Information and Background

CHARACTERISTICS		Frequency	Percent (%)
Type of construction	Building Construction	21	49
	Road Construction	1	2
	other construction types	21	49
Total		43	100
Type of Project	Public	28	65
	Private	15	35
Total		43	100
Respondent's Qualification	Primary Education	1	2
	Diploma Degree	3	7
	Bachelor's Degree	33	77
	Master Degree	4	9
	Ph.D. Degree	2	5
Total		43	100
Specialization	Civil	36	84
	Architect	4	9
	Other	3	7
Total		43	100.0
Category	Consultant	4	9
	Project Manager	19	44
	Site Engineer	18	42
	Contractor	2	5
Total		43	100.0

3.2 Identification the Factors Influencing the Materials Waste Generation

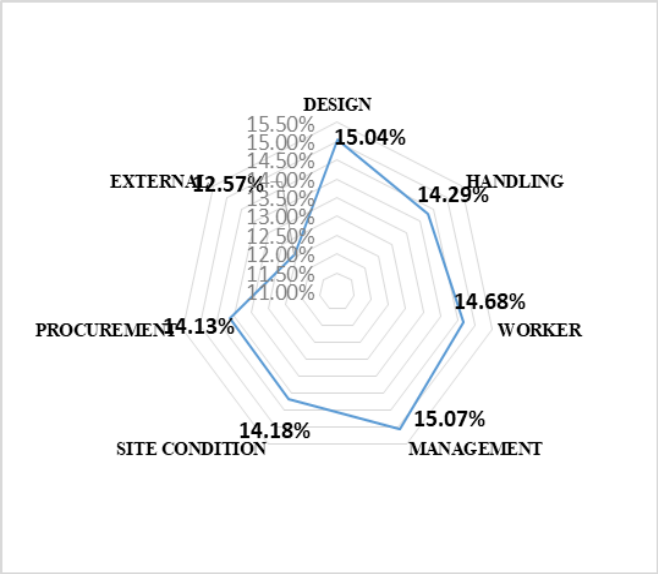
From the results presented in Table 4, showed that the factors influencing the materials waste generation analyzed in terms of relative importance index (RII) for seven aspects in terms of groups (design, handling, worker, management, site condition, procurement, and external factors), and each group divided to sub-items. The analysis of RII indicates that the in design aspect the highest RII of 0.6698 related to frequent design change, while in handling issue a poor quality of materials comes in highest RII of 0.6047. Whereas, in worker the shortage of skilled worker reached to 0.6372, and in management

aspect the poor planning and in the procurement aspect the ignorance of specifications are both recorded the RII at rate of 0.6279.

Table 4: RII for Significance Causes of Waste in Construction Projects

GROUP	No.	CAUSE OF CONSTRUCTION WASTE	Weight					RII Of Causes
			1	2	3	4	5	
DESIGN	1	Frequent design changes	1	8	16	11	7	0.6698
	2	Design errors	8	5	12	10	8	0.6233
	3	Lack of design information	2	12	16	7	6	0.6140
	4	Complicated design	6	8	15	7	7	0.6047
	5	Inexperience designer	6	10	12	8	7	0.6000
	6	Conflect between design and other contract documents.	7	10	13	7	6	0.5767
HANDLING	1	Wrong material storage	2	13	17	8	3	0.5860
	2	Poor material handling	4	15	12	9	3	0.5628
	3	Damage during transportation	6	10	14	11	2	0.5674
	4	Poor quality of materials	5	8	16	9	5	0.6047
	5	Delay during delivery	4	7	20	9	3	0.6000
WORKER	1	Workers mistakes	2	16	17	7	1	0.5488
	2	Incompetent worker	3	15	17	6	2	0.5488
	3	Damage caused by workers	2	8	21	9	3	0.6140
	4	Lack of experience	2	6	18	15	2	0.6419
	5	Shortage of skilled workers	2	7	18	13	3	0.6372
	6	Inappropriate use of materials	3	9	16	13	2	0.6093
MANAGEMENT	1	Poor planning	3	11	14	7	8	0.6279
	2	Poor site management	6	9	10	10	8	0.6233
	3	Poor supervision	7	9	11	7	9	0.6093
	4	Inappropriate construction methods	4	9	17	11	2	0.5907
	5	Lack of coordination among parties	1	12	15	12	3	0.6186
	6	Poor information quality	3	16	11	8	5	0.5814
	7	Rework	2	7	16	12	6	0.6605
SITE CONDITION	1	Leftover materials on site	3	15	12	5	8	0.6000
	2	Poor site condition	2	9	17	12	3	0.6233
	3	Waste resulting from packaging	2	12	20	7	2	0.5767
	4	Crews interference	6	12	17	6	2	0.5349
	5	Change order Occurrence.	6	11	14	9	3	0.5628
PROCUREMENT	1	Ordering errors	5	13	15	7	3	0.5535
	2	Error in shipping	7	12	17	7	0	0.5116
	3	Mistakes in quantity surveys	9	5	14	11	4	0.5814
	4	Ignorance of specifications	3	12	9	14	5	0.6279
	5	Difficulties of ordering small quantities.	3	14	11	7	8	0.6140
EXTERNAL	1	Effect of weather	5	11	7	11	9	0.6372
	2	Theft	14	12	10	5	2	0.4558
	3	Vandalism	13	9	11	8	2	0.4930
	4	Lack of legatitive enforcement	14	8	14	6	1	0.4698

Further analysis conducted to evaluate the effects of overall causes contributed to the waste generation on a group basis as illustrated in Fig.1. Which shows that the management and design aspects had the most significant impact on waste

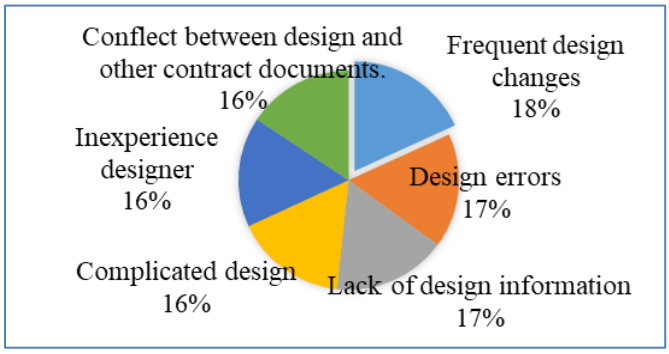


generation in a rate of 15.07% and 15.04% respectively, while the external factors received minimum rate of 12.57%.

Figure 1. Factors Contribution to Wastage as groups

3.2.1 Factors related to Design

Analysis of the causes related to the design aspect



showed that the frequent design changes in the design process contributes to highest rate of 18% in construction waste, as shown in Figure 2**.**

Figure 2: Factors affecting wastage in the design

3.2.2 Factors related to Handling of Materials

Handling factors are one of the essential elements, which affect construction waste generation. Figure 3 shows the most effective source was the poor quality of the material and delay during delivery at a rate of 21 %.

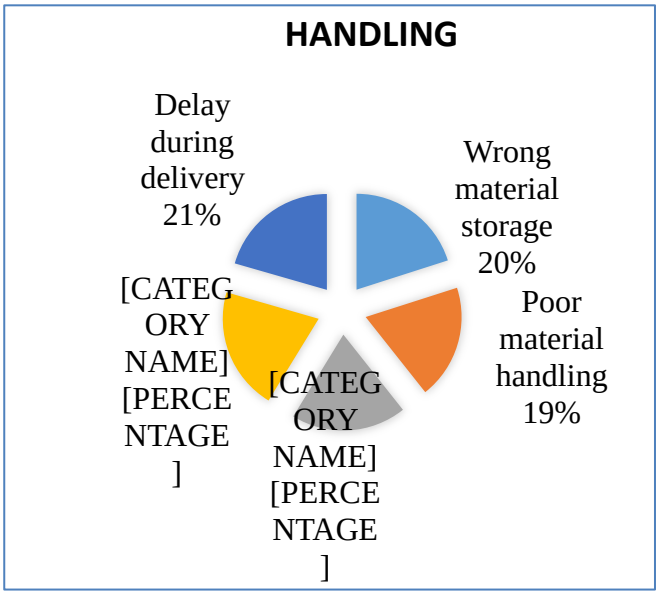


Figure 3: Factors affecting wastage in handling group

3.2.3 Factors related to Workers

The factors related to workers group, which produce wastes indicating that the significant sources of debris in this group are lack of experience of workers and shortage of skilled workers at a rate of 18% as be observed in Figure 4.

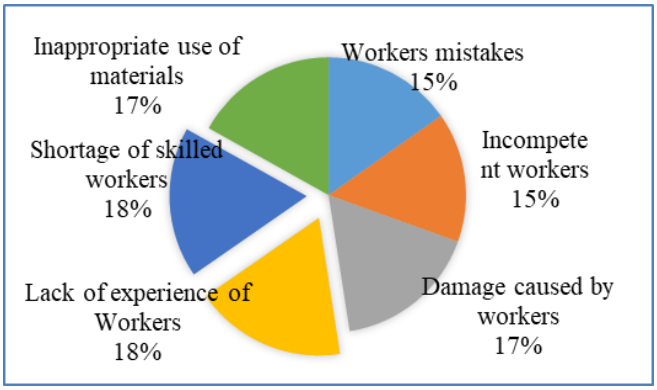


Figure 4: Factors affecting construction materials waste in workers group

3.2.4 Factors related to Management

Figure 5 illustrates the factors related to management have a crucial role in reducing construction waste. Seven causes devoted to management studied in this study showed that poor planning and rework were the most effective source of waste at a rate of 15%.

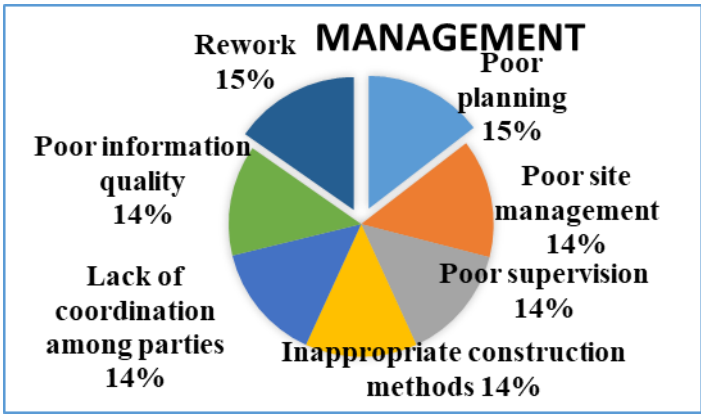


Figure 5: Factors affecting wastage in management.

3.2.5 Factors related to Site Condition

The condition of the site has a direct effect on construction waste because the construction materials generally packaged and stored on the project site the study showed that the most effective cause was the poor site condition, leftover materials and packaging at a rate of 22%, 21%, and 20% respectively as shown in Figure 6**.**

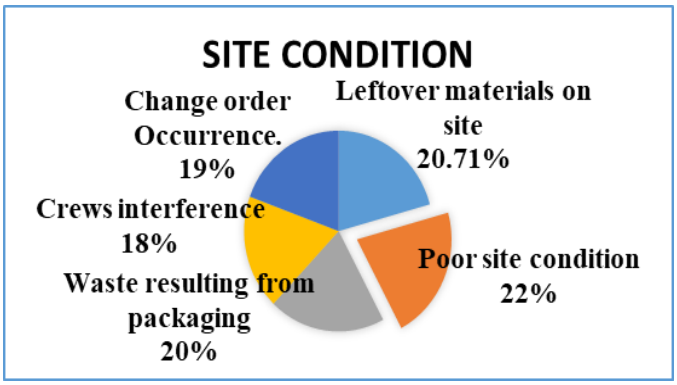


Figure 6: Factors affecting wastage in site conditions.

3.2.6 Factors related to Procurement

The procurement process of the delivery of the material to the site also examined and showed that the most effective source was the ignorance of Specifications at a rate of 22%, as seen from Figure7.

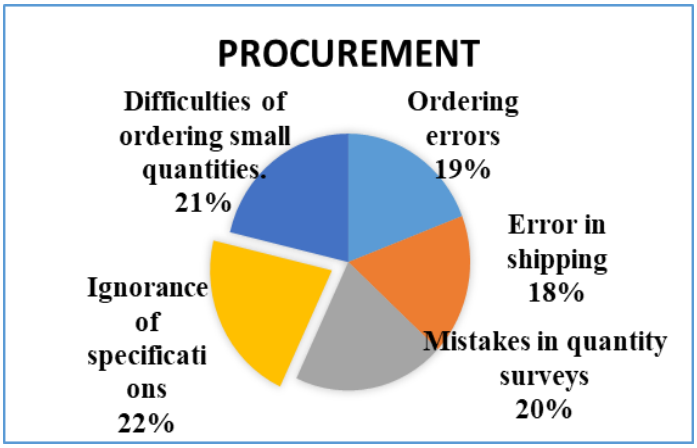


Figure 7: Factors affecting waste in procurement.

3.2.7Factors related to External

Figure 8 shows the most significant source in external factors that contribute to the waste generated during construction was the effect of weather at a rate of 31%.

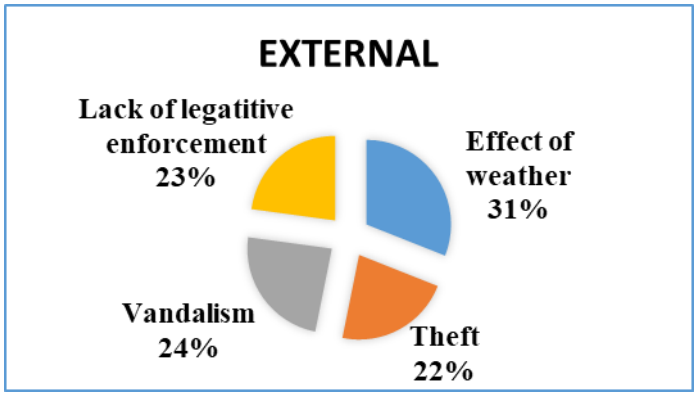


Figure 8: External factors affecting waste generation.

4.3 The Magnitude of Construction Materials Waste Generation

In the third part of the questionnaire examined the magnitude of construction materials waste generation where seventeen materials selected as detailed in Figure 9, which showed that the highest percentage of

waste generated in Gypsum at a rate of 8.5%, while the waste in gravel and sand at a rate of 7.7% and 7.2% respectively. Whereas 7.4% in ceramic tiles.

4.4 Identification of factors influencing on the magnitude of waste generation

Concerning the causes of waste generation related to the quantity of waste of selected materials that the top significant factors influencing the waste generation due to lack of experience and improper operation in the project site in dealing with the following construction materials summarized in Table 5.

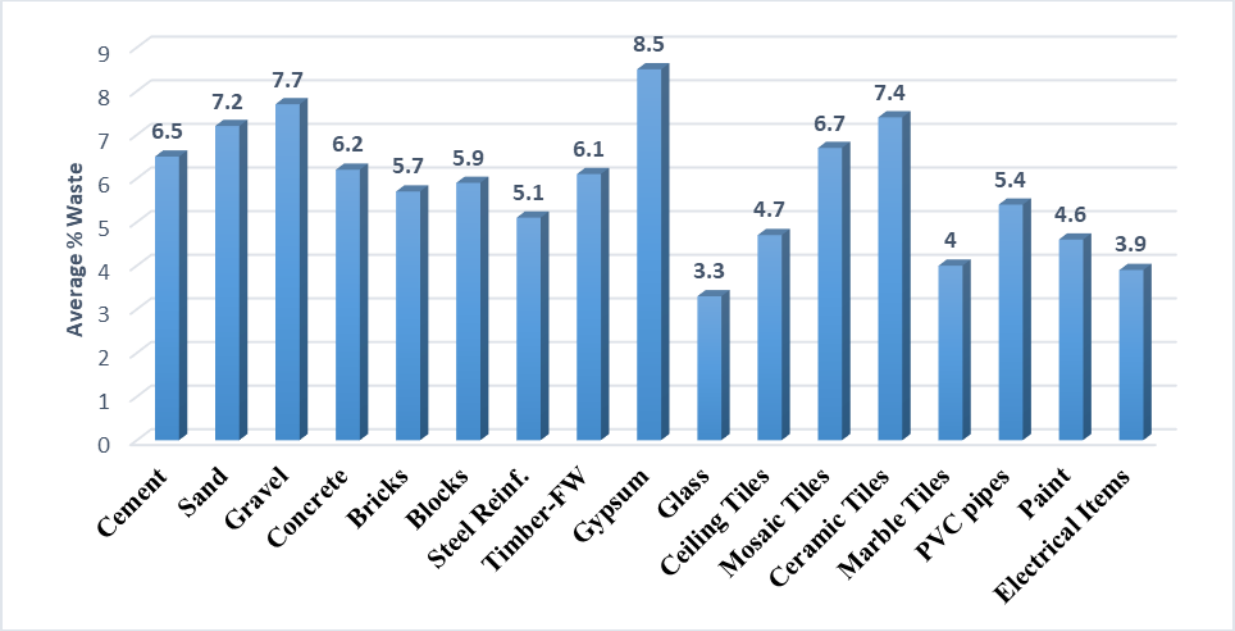


Figure 9: Average percentage of construction waste materials

Table 5. The Causes of Construction Materials waste generation

No.	Material	Top significance causes of wastages
1.	Cement	❖ Excessive or unnecessary consumption of mortar ❖ Improper storage method ❖ Mixing in unsuitable places ❖ Mixing of amounts more than the required ❖ Inappropriate way of transportation
2.	Sand	▪ Excessive or unnecessary consumption of sand ▪ Damaging the remained quantities in the workplace ▪ Improper storage method
3.	Gravel	✓ Mixing excessive amounts greater than required ✓ Far distance between the place of mixing and casting ✓ Wrong handling ✓ Losing the aggregate while passing the equipment on it
4.	Concrete	➢ Insufficient estimation of the amount of concrete required

		➢ Requiring an extra allowance of concrete ➢ Flaws in the framework assembling process ➢ Inadequate use of vibration which causes problems in concrete ➢ Use of insufficient equipment's and tools ➢ Far distance between the place of mixing and casting
5.	Blocks& Bricks	• Defects from the manufacturing of block • Lack of halves and quarters of blocks • Excessive cutting of blocks • Damaging of blocks during the process of cutting • Damaging of blocks during unloading and transportation
6.	Steel bars	✚ Improper cutting of bars ✚ Using lengthier bars than required ✚ Type of reinforcement method (bend bar, cut bar) ✚ Overlapping because of incorrect the length of bars ✚ Lack of skilled workers ✚ Damage during storage and rusting
7.	Timber	✓ No optimized cutting of timber boards ✓ low durability and reusability of formwork ✓ Cutting for interior fittings and finishing ✓ Wrong storage ✓ Use of low-quality wood ✓ Breaking of timber boards during the removal of the frames
8.	Gypsum	❖ Mixing amounts more than the required ❖ Ordering excessive quantities of gypsum ❖ The damaging result from severe weather conditions ❖ Poor storage method ❖ The excessive thickness of gypsum plastering
9.	Ceiling Tiles	○ Wastages from the necessary cutting process ○ Ordering additional quantities more than required ○ Unsuitable storage leading to deterioration or damage ○ Damage from handling or transportation
10.	Ceramic, Marble& Mosaic Tiles	✚ Damaging the tile during the process if necessary cutting ✚ Damage during transportation ✚ Excessive quantities of tiles, over-ordering ✚ Damage during finishing ✚ Inadequate skill workers
11.	PVC Pipes	➢ Ordering additional quantities more than required ➢ Cutting the pipes inappropriately ➢ Poor storage method ➢ Theft and vandalism
12.	Paint	▪ Paint damage under weather conditions ▪ Directly exposing the paint area to dust ▪ Inappropriate cleaning of walls and slabs prior painting process ▪ The damaging result from the addition of other materials to paint ▪ Wrong storage
13.	Electrical Items	✓ Excessive quantities required, over-ordering ✓ Excessive cutting of wires at ends ✓ Using additional amount more than required

5.CONCLUSION and RECOMMENDATIONS

This study has identified the primary sources and causes of construction materials wastages in construction projects in Erbil city from the perspective and views of construction practitioners. The analysis of survey data showed that the most effective source of waste generation was in the management aspect comes in the first rank in contributing to the waste generation, particularly poor planning and rework at a rate of 15% among seven factors tested in the area of management. While the design aspect comes in the second rank comes, particularly the cause of frequent design change that was contributing to the waste generation at a rate of 18%. The analysis extended to determine the magnitude of construction materials waste generation of sixteen types of materials. It was found that top highest percentage of waste generation was in gypsum at a rate of 8.5%, 7.7% in gravel, 7.4% in ceramic tiles, whereas in the sand, mosaic tiles, cement and concrete were 7.2%, 6.7%, 6.5%, 6.2% respectively.

Therefore, it is recommended to focus on the following issues to reduce the waste generation in construction projects:

- To adopt lean construction principles to minimize waste generation and maximize the value of project.
- To adopt a precise mechanism in management area to detect waste generation, by setting up clear waste management procedures and guidelines on identifying waste and that adopting a system to determine waste is essential since this will help in minimizing waste as well as discouraging the generation of waste by employs involved in construction development.
- Establishing a waste minimization plan is to encourage operators to be aware of the threat and negative impact of waste on society, environment.
- Encouraging recycling and reuse policies
- Diffusing the culture of understanding of the concept of waste generation management system and its implication to overrun the project cost and profitability among the workers and professionals in the construction sector in Erbil city.

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