Jordan Journal of Civil Engineering, Volume **15**, No. **2**, **2021**

Understanding the Causes of Material Wastage in the Construction Industry

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ABSTRACT

Recent studies have recognized material waste from construction projects as a serious problem for both economies and the environment. This research aims to identify the major causes of material waste in construction projects, determine the level of wastage for some selected materials and suggest strategies to manage and minimize wastage. In order to facilitate the application of this research, Jordan was taken as a case study. The results from 61 returned surveys suggested 49 factors which were then analyzed to identify the main causes of material wastage; the main factors are as follows: design changes during the construction phase, rework due to labor mistakes, purchases not complying with specifications, improper cutting of materials and poor site layout. The study concluded that the most important advantages of managing and minimizing material wastage are minimizing time and cost overruns and helping in determining the required quantities, thus leading to improved project performance.

KEYWORDS: Material wastage, Construction waste, Construction industry, Causes of waste, Minimizing waste.

INTRODUCTION

Evidence shows that the construction industry is a comprehensive waste-generator sector due to its tremendous consumption of resources, which makes it a critical target for environmentalists when it comes to environmental sustainability (Ajayi et al., 2015; Faniran and Caban, 1998; Ekanayake and Ofori, 2000). Construction and demolition (hereafter C&D) waste is a mix of rigid and non-rigid materials that is produced in different construction activities, such as excavation, renovation, roadwork and demolition (Yu et al., 2013). Recently, attention has been focused on this issue from the viewpoint of efficiency as well as the adverse impact of waste on the environment (Formoso et al., 2002). A previous study in Egypt showed that waste generated from different materials has a negative effect on the national economy and the environment (Garas et al., 2001). According to Stukhart (1995), the total cost of materials can reach a half or more of the total project cost, which rings the bell on the importance of managing materials carefully. Excessive quantities of materials cause critical problems to project managers and increase the total cost of projects. On the other hand, unavailability of materials when needed can affect productivity and cause delays until the required materials are available. However, very few contractors have made efforts to develop and implement strategies to manage and minimize wastage.

The construction industry is one of the most productive activities in Jordan and plays a major role in the national economy (Assbeihat, 2005). In fact, it is the backbone of the country in terms of employment. Any

Received on 17/7/2020.
Accepted for Publication on 23/1/2021.

fluctuations in this sector are directly reflected on the national income (Sweis, 2013). Waste generated from C&D activities in Amman was nearly 2.6 million m^3 per year according to the Country Report on Solid Waste Management in Jordan for the year 2014. Owing to material wastage, rising cost of energy and unwise consumption, Jordan's total oil bill accounts for more than a half of its budget (Alshboul and Abu Ghazaleh, 2014).

This research focuses only on contracting companies, since the contractor is directly involved in construction activities (Assbeihat, 2005). In this research, the population covers contracting companies classified within the top three grades out of the six classification grades that are specialized in buildings' construction. The building sector shares a large workload compared to other sectors in the construction industry.

The main objectives of this study are as follows:

- Identifying the major causes of material wastage in the Jordanian construction industry.
- Presenting a comprehensive analysis of these causes and determining the severity of each cause.
- Assessing the level of wastage for 10 selected materials and providing a comparison with other countries.
- Providing practical suggestions and recommendations to minimize construction waste.

It is anticipated that minimizing material wastage would improve project performance in terms of time and cost, reduce environmental pollution, increase profits and greatly influence the national economy (Ajayi et al., 2015; Durana et al., 2006).

LITERATURE REVIEW

Construction Material Wastage: Most practitioners in the construction industry typically relate waste with any rubbish removed from a site and disposed off in landfills. Perhaps the main reason for this narrow view is the fact that such waste is relatively easy to see and measure (Formoso et al., 2002). The construction industry has always been considered as one of the major producers of solid wastes in comparison with other economic activities and this is obvious from environmental and statistical reports in several countries (Al-Hajj and Hamani, 2011; Durana et al., 2006). Llatas (2011) acknowledged that up to 35% of solid wastes worldwide come from construction activities; yet, the highest consumers of resources are construction projects.

Literature reviewed reveals that there is no consensus for defining construction waste. Perhaps the European Council Directive 91/156/EEC gives one of the most public definitions of construction waste as "any substance or object which the holder discards, intends to discard or is required to discard". McDonald and Smithers (1998) define material wastage as the difference between the amount of materials delivered and accepted on site and the amount of materials used as per standards and exactly re-measured. Furthermore, material wastage can be defined as any material that needs to be transported elsewhere from the construction site or even used within the construction site (Ekanayake and Ofori, 2000). Formoso et al. (2002) considered indirect wastage to be caused by variations in the dimension of the structural components of the building, such as slabs, beams and walls. Formoso et al. (1999) made a distinction between avoidable and unavoidable wastage. In the case of unavoidable or natural wastage, the cost of reducing it is higher than the value of the wastage. In contrast, in the case of avoidable wastage, the cost of wastage is higher than the cost of preventing it. In addition, Al-Rifai and Amoudi (2016) concluded that the most significant factors contributing to construction waste can be categorized into management-related and workforce-related. This means that the role of managerial factors should be maximized. Furthermore, the manpower skills should be enhanced through several training strategies to encourage the workforce.

Causes of Material Wastage: Construction waste results during the lifecycle of buildings; starting from design, going through construction, modifications and ending with demolition (Llatas, 2011). A number of studies concluded that the design phase is one of the primary causes of construction waste. Osmani et al. (2007; 2006) stated that poor design models and decisions are among the main factors that make the design phase responsible for early waste in construction materials. According to Jayamathan and Rameezdeen (2014), causes of construction material wastage can be divided into two categories: *non-site based* and *site-*

based. Non-site-based wastage largely occurs due to overordering of materials (Poon et al., 2004), design errors (Bossink and Brouwers, 1996) and design changes (Faniran and Caban, 1998). According to Esin and Cosgun (2007), good specifications, clear design and effective procurement strategy can reduce wastage. Site-based wastage is the actual loss of materials during site operations. According to Lu et al. (2011), careful transportation, handling, storage and coordination can reduce site-based material wastage. Site-based material wastage can be further divided into two categories: upstream and downstream (Jayamathan and Rameezdeen, 2014). Upstream wastage is generated prior to the construction phase. It is mainly caused by improper material handling and storage (Bossink and Brouwers, 1996).

Al-Ani and Al-Adhmawi (2011) showed the importance of the monthly material wastage report in order to compare it with the allowable waste to maintain the quality management system.

Downstream wastage is generated at the construction phase. It is mainly caused by material cutting (Faniran and Caban, 1998). Cosgun and Esin (2007) found that the main causes of downstream wastage are unskilled workers, inadequate tools and poor working conditions. According to Poon et al. (2004), steel reinforcement, timber formwork, tiles and blocks are subjected to frequent cutting. The two main reasons behind downstream wastage are workers' belief that wastage is unavoidable and lack of supervision (Tam et al., 2015). On the other hand, the model fitness of the effectiveness of the implementation of lean construction techniques for construction wastes in building construction was accepted (Ahmed and Wong, 2020), However, Wong and Ahmed (2018) indicated that the construction industry is less impacted by lean production thinking than founded in manufacturing sector with regard to the overwhelming amount of waste in construction processes. Table 1 shows the causes of construction wastage in the Netherlands, UAE, Turkey, Brazil, Australia and Egypt; according to Bossink and Brouwers (1996), Al-Hajj and Hamani (2011), Polat and Ballard (2004), Formoso et al. (1999), Alwi et al. (2000) and Garas et al. (2001), respectively.

Table 1. Main causes of material wastage in several countries

Countries	The Netherlands	UAE	Turkey	Brazil	Australia	Egypt
Causes	Changes in design	Rework and variations	Workers' mistakes	Overproduction	Slow drawing revision and distribution	Overordering
	Waste from application process	Poor design leading to excessive off-cuts	Lack of on-site material control	Inventories	Unclear specifications	Design changes

Level of Selected Material Wastage: In Dubai, records for the year 2007 show that the total construction waste dumped in landfills was 27.7 million tons; this was three times higher than the volume generated in 2006 (Al-Hajj & Hamani, 2011). In 2007, the generated waste from the construction industry in Norway was about 1.25 million tons (Bergsdal, 2007). According to a Eurostat report, 2 billion tons of waste are generated every year in the European Union (EU-15) and the share of construction waste is 31% (DEFRA, 2007). A study in Malaysia indicated that the percentages of material wastage are as follows: aggregate 65.80%, soil 27%, wood 5%, blocks 2% and steel 3% (Begum et al., 2007). Based on a statistical analysis of existing C&D landfill sites in Kuwait, the annual amount of building waste is ~3 million tons. Assuming that 50% of this amount is from excavation, 1.5 million tons of building waste is generated every year (Kartam et al., 2004). The US Environment Protection Agency (USEPA, 2004) recorded that 1900 C&D landfills were operating to receive 170 million tons of disposed materials generated in the US in 2003.

In Hong Kong, block wastage has been noted in all processes, such as loading, unloading and storing (Poon et al., 2004). According to Al-Moghany (2006), the main source of block wastage in Palestine was cutting. Furthermore, a sample of 40 sites in Brazil indicates that nearly 18% of the total number of blocks are cut pieces (Formoso et al., 2002). Block work has the highest level of material wastage in the Nigerian construction industry in comparison with other materials (Odusami et al., 2012).

The main sources of cement wastage are summarized below as observed by Formoso et al. (2002):

- Production process of mortar.
- Handling and transportation process of mortar, unmeasurable in some cases.
- Production of brickwork owing to the excessive consumption of mortar in joints.
- Plastering process due to the exceeded thickness over the specifications.

The main sources of stone wastage are cutting, poor quality, overordering and transportation methods (Bossink and Brouwers, 1996).

Lack of detailed design can increase levels of waste. For instance, short pieces produced when cutting pipes is a main source of wastage and it is caused by lack of design details; this results in many changes in the routing of pipes during installation as well as the replacement of elements by others that have high performance (Formoso et al., 2002).

The main source of tile wastage was cutting; on average, 35% of the pieces on floors and 27% of the pieces on walls had to be cut (Formoso et al., 2002). Timber is usually used at least three times as formwork before it is disposed of. The main sources of wastage in timber are cutting and poor site layout (Bossink and Brouwers, 1996). According to Poon et al. (2004), 49% of the volume of timber ends up as waste.

Formoso et al. (2002) claimed that the main causes of wastage in sand are basically related to lack of control in the delivery operation, inclement weather, poor storage and damages due to equipment movement.

A recent study in Malaysia by Ikau and colleagues in 2016 took another perspective. In their study of factors influencing waste generation, they listed the causes of waste based on design, procurement, material handling and construction. By understanding their sources, further concentration and control on the wastage material and construction material would reduce the amount of material damage and rework (Ikau et al., 2016).

The rising costs of construction projects remain the greatest problem that construction industry in Gaza Strip is currently facing. Factors such as waste affect negatively the architecture, engineering and construction industry (Enhassi, Abu Hamra and Alkilani, 2018).

RESEARCH DESIGN

Research Strategy and Variables

Naoum (1998) defined strategy as the way in which a study reaches its objectives. It is mainly classified into two types: qualitative and quantitative research. The most widely used data collection technique for conducting surveys to extract facts, views and opinions is through a structured questionnaire (Naoum, 1998). In this study, a quantitative approach is selected, because it is an objective measurement of the problem.

Another study in Palestine indicated 92 factors affecting time and material wastage in Gaza (Al-Moghany, 2006). Polat and Ballard (2004) identified 14 factors in their study to determine the main causes of material wastage from the Turkish construction industry. A study in Hong Kong identified 13 main causes of material wastage (Poon et al., 2004). In Indonesia, Alwi et al. (2000) considered 35 factors contributing to wastage. Ekanayake and Ofori (2000) measured 27 factors resulting in construction waste. In the Netherlands, Bossink and Brouwers (1996) looked at 31 factors to determine the sources of wastage.

Research Methodology

A quantitative approach was adopted for this study. It is mainly used to investigate facts and establish relationships between them. Based on previous studies, this research considered 49 factors that generate wastes from construction materials. Furthermore, these factors were distributed into five groups: design and contract documents, materials' handling and storage, project staff, site management and supervision and external factors and conditions. The objectives of this research have been achieved through a survey questionnaire distributed to a random sample of contracting companies. The collected data from the questionnaire was analyzed using the Statistical Package for Social

Sciences (SPSS) program to rank the causes of material wastage. Finally, the relation between the answers and the variation in participants was checked by analysis of variance (ANOVA) to compare the mean values within groups for the overall factors.

According to the Jordanian Construction Contractors Association (JCCA), there are 1620 contracting companies in Amman alone. This represents 61% of all contracting companies in Jordan (Annual Report, 2014). In this study, the population includes contracting companies of the first three grades, as discussed above, that have a valid registration by JCCA and are specialized in buildings. The rationale behind selecting these grades is based on experience and financial capacity of such companies. First-grade companies formed 51% of the total population of this study.

For the purpose of accuracy and economy, sampling is used in a wide range of survey studies (Weisberg et al., 1996). A very small sample reduces the utility of the results; in contrast, a very large sample implies a waste of resources. Cochran (1977) used the sample size formula shown in Equation 1:

$$\{ n_o = [t^2 \times p \times q]/d^2 \} \quad \text{.......... (1)}$$

where,

t: value of selected alpha level; α = 0.025 (1.96 for 95% confidence level).

p: percentage of selecting a choice (expressed in decimals, equal to 0.5).

q: p -1; p and q are estimates of variance.

d: acceptable margin of error for proportion being estimated (confidence interval, expressed as decimals, equal to 0.1).

$$\therefore\ no = [1.96\verb|^|2 \times (0.5 * 0.5)]/0.01 = 96.$$

However, as this sample size exceeds 5% of the population, Cochran's (1977) correction formula should be used to calculate the final sample size:

$$n1 = \frac{no}{1 + \frac{no}{N}}$$

$$\therefore no = 96/(1 + 96/301) = 72.79 \approx [\mathbf{73}].$$

The geographic domain of the survey is Amman, the capital city of Jordan. Random sampling is considered the most direct form of probability sampling. In this method, each participant has an equal opportunity to be selected (Weisberg et al., 1996). According to Naoum (1998), the two main steps for performing a random sample are: choosing a list of names and addresses and making a random numbering technique. A list of contracting companies' contact info and numbers was obtained from JCCA and the sample companies were selected randomly from that list.

In this research, nondirective interviews, related studies, site visits and a structured questionnaire will be used for data collection. To identify and pinpoint the most frequent onsite factors affecting material wastage in construction projects, five nondirective interviews were carried out with project managers who have more than ten years of experience with various on-going field projects; thus, the collected data reflects the interviewees' experience. Furthermore, the following materials were selected to be included in the questions to cover the main causes of wastage: steel reinforcement, cement, blocks, concrete, aggregate, pipes, timber, sand, stones and tiles. Site visits showed that activities, such as cutting, material rejection and labor mistakes, represent a complete image of the construction companies' performance in terms of material wastage.

The questionnaire design was undertaken to determine the contractors' viewpoint regarding the factors affecting material wastage. The questionnaire was of the closed type, where the questions are straightforward and require no additional clarification by the respondent (Naoum, 1998). The questionnaire was divided into the following four sections to fulfill the study objectives: company profile, factors affecting material wastage, percentage of material wastage in construction projects and advantages of managing and minimizing material wastage. The factors and questions regarding material wastage in the questionnaire were extracted from previous studies (Agyekum et al., 2012; Begum et al., 2007; Al-Moghany, 2006; Polat and Ballard, 2004; Poon et al., 2004; Formoso et al., 2002; Garas et al., 2001; Ekanayake and Ofori, 2000; Alwi et al., 2000; Bossink and Brouwers, 1996).

Validity is a measure of the accuracy to which any test fulfills its objectives (Dessler, 2013). To ensure the validity of the survey, available literature was used. Then, a chosen sample of four project managers with more than ten years of experience in the construction field was invited to complete the questionnaire. As a result, 28 causes of wastage were deleted because of repetition. Also, one section from the questionnaire was deleted; namely, factors affecting selected construction materials. Then, a final revision of the questionnaire by two experts from the academic staff of the Faculty of Engineering and Technology at the University of Jordan was made to ensure technical accuracy and clarity resulting in improvement to the questionnaire in terms of its format, layout, wording of statements and overall content.

The pilot study provides a trial run for the questionnaire, which involves testing the technique used to collect data and testing the wording of the questions (Naoum, 1998). The 49 factors causing wastage were pretested in a pilot study to assess their applicability to the research objectives. Six selected experienced consultants (four project managers and two quantity surveyors) with more than ten years of experience participated in the test. They all agreed with the pertinence of the selected factors to the current study and suggested modifications and rewording for some factors; for example, “lack of handling instructions” was reworded as “methods of unloading,” and “problems between the main contractor and his sub-contractors” was reworded as “poor work ethics”. In summary, 73 questionnaire forms were printed to be distributed to the contracting companies.

The data coding process consists of recording the responses to all questions and then transferring them to a sheet (usually an Excel sheet) in order to summarize them; this prevents any repetition in the answers (Weisberg et al., 1996). The collected data from the questionnaire was analyzed using the SPSS program to rank the causes of material wastage. The relation between the answers and the variation in participants was checked by using ANOVA to compare the mean values within groups for the overall factors.

DATA ANALYSIS

In total, 73 questionnaire forms were distributed as follows; 19 companies of 1st grade (26%), 23 companies of 2nd grade (31.5%) and 31 companies of 3rd grade (42.5%). Moreover, the response rates from the 1st, 2nd and 3rd grades were: 79%, 78% and 90%, respectively. It turns out that the total response rate is 84%.

The majority of respondents were site engineers constituting 46% of the total respondents. Project managers accounted for 31% of the respondents. Quantity surveyors and general managers accounted for 13% and 10% of the respondents, respectively. In terms of years of experience, results show that 51% of the respondents have less than 5 years of experience, while 6.6% have spent more than 20 years in the industry. Almost 80% of the respondents have completed their B.Sc., while 3 respondents have M.Sc. and 3 respondents have a Ph.D. degree. More importantly, only 16 companies (26%) that have been surveyed acknowledged record keeping of wastage from previous projects. This means that the majority of companies are not aware of the amount of waste generated by their previous projects. 12 out of the 16 companies which keep records of wastage are 1st-grade companies. This indicates that 1st-grade companies have a material management department which improves their reputation.

None of the companies surveyed use “special construction material estimating software” and “approximate estimate by experience”; rather, the majority used “AutoCAD and Excel sheets” (58%) and “hand calculations” (42%). Furthermore, the responsibility for calculating the required construction materials was distributed among project managers (34%), site engineers (12%) and quantity surveyors (54%). This implies a common dependency on both project managers and quantity surveyors in calculating material quantities and the vital role they play, which leads to project success or failure.

As mentioned earlier, the survey questionnaire considers 49 factors that cause wastage, as classified by their groups. Table 2 illustrates the means and ranks of these groups. The survey concluded that the “design and contract documents” group has the highest rank; as it causes material wastage with a mean of 3.62. On the other hand, the “external factors and conditions” group has the lowest rank, with a mean of 2.69.

Table 2. Ranking of main groups

Group Number	Group Name	Mean	Rank
1	Design and contract documents	3.62	1
3	Project staff	3.59	2
2	Material handling and storage	3.44	3
4	Site management and supervision	3.36	4
5	External factors and conditions	2.69	5

Each of the main groups was analyzed in terms of its factors under each group category and its group number.

"Design changes during the construction phase" is the most important factor causing wastage in the highest-ranked group, with a mean of 4.28. The average rating of "design changes during the construction phase" is 4.28 and indicates that the average opinion among respondents to this factor is that it is highly influencing material wastage. The average rating was calculated based on the degree of influence (from very low influence to very high influence) and the Likert scale (1 to 5) as the sum of the frequency of the responses times the weighting for each category divided by the total number of responses. The high rank of the "design changes during the construction phase" factor is attributed to rework, which leads to material wastage. On the other hand, "poor stakeholder involvement" was the least important factor, with a mean of 2.14, which implies little or negligible effect on wastage.

"Purchases not complying with specifications" is the most important factor in the "materials handling" group. "Difficulties for delivery vehicles to access the site" has the lowest ranking, with an average of 2.83. Furthermore, "poor storage" is ranked sixth. On the other hand, "existence of unnecessary materials on site" and "difficulties for delivery vehicles to access the site" show little effect on material wastage, with an average of 2.86 and 2.83, respectively.

The mean and ranking of the "project staff" group showed that "rework due to labor mistakes" has the highest ranking, with a mean of 4.16. On the other hand, "lack of skilled technicians" has the lowest ranking, with an average of 3.10.

"Poor site layout" has the highest ranking for the "site and management" group, with a mean of 4.06. "Delay in payments to the contractor" is the least important factor, with an average of 2.04.

The mean and rank of each factor from the "external factors and conditions" group are displayed in the appendix. It is concluded that "severe weather conditions" has the highest mean of 3.39, whereas "theft and vandalism" have the lowest ranking.

Severe weather conditions are a major reason that affects material wastage in comparison with other factors in this group. "Theft and vandalism" constituted the lowest-ranked cause among the 49 causes; this is directly related to the stable environment in Jordan and the safety and security conditions in the country, despite the ongoing conflicts in other Middle-Eastern countries.

According to the results and the ranking of the mentioned main groups, Table 3 shows the overall ranking of factors affecting material wastage, indicating that the highest factor is "design changes during the construction phase," with an average of 4.28, while the lowest factor is "delay in payments to the contractor" with an average of 2.04.

RESULTS AND DISCUSSION

To obtain the relationships between sample characteristics and the five main groups; one-way ANOVA is considered reliable to test the null hypothesis that all means are equal. It was found that there is no significant statistical relationship between the groups at P-value > 0.05.

Table 3. Overall ranking of all factors

Factor	Group Number	Mean	Rank
Design changes during the construction phase	1	4.28	1
Rework due to labor mistakes	3	4.16	2
Purchases not complying with specifications	2	4.15	3
Improper cutting of materials	2	4.14	4
Poor site layout	4	4.06	5
Poor coordination between subcontractors	3	4.02	6
Incomplete contract documents	1	4.01	7
Poor monitoring and controlling of materials	2	3.98	8
Time as a project priority over cost and quality	1	3.97	9
Design without considering material dimensions	1	3.95	10
Selecting contractors based on the lowest price	1	3.94	11
Complexity of drawings	1	3.94	11
Lack of possibility of ordering small quantities	2	3.94	11
Delay in decision-making	4	3.81	12
Selecting subcontractors based on the lowest price	4	3.81	12
Production of a quantity greater than necessary	2	3.66	13
Poor work ethics	3	3.61	14
Preparing BOQ without considering wastage	1	3.60	15
Lack of using first in the first out method	2	3.59	16
Poor storage of materials	2	3.59	16
Lack of training for workers	3	3.59	16
Lack of experienced project manager	4	3.59	16
Poor communication between clients/contractors	4	3.56	17
Lack of quality control	4	3.55	18
Using wrong construction methods	3	3.55	18
Lack of material management plan	4	3.47	19
Accidents due to lack of awareness	3	3.44	20
Poor communication between contractor and staff	4	3.44	20
Severe weather conditions	5	3.39	21
Absence of quantity surveyor at the construction site	3	3.26	22
Errors in contract documents	1	3.25	23
Selection of poor-quality products	1	3.16	24
Increase in material prices during construction	2	3.12	25
Lack of skilled technicians	3	3.10	26
Poor planning by contractor	4	3.09	27
Manufacturing defects	2	3.09	27
Production of a quantity earlier than necessary	2	3.09	27
Inadequate storage area	2	3.05	28
Methods of unloading	2	3.05	28
Late response from consultant	4	3.01	29
Lack of risk management plan	4	2.88	30
Existence of unnecessary materials on site	2	2.86	31
Difficulties for delivery vehicles to access site	2	2.83	32
Equipment breakdown	5	2.52	33
Poor infrastructure	5	2.43	34
Poor stakeholder involvement	1	2.14	35
Effect of subsurface site conditions	5	2.09	36
Theft and vandalisim	5	2.05	37
Delay in payments to contractor	4	2.04	38

This indicates the same viewpoint regarding the severity of the factors affecting material wastage in construction projects. Regardless of who filled the questionnaire, whether a general manager, a project manager, a site engineer or a quantity surveyor, the same viewpoint on the severity of the factors affecting material wastage in construction projects resulted. The results refer to accepting the null hypothesis, which means that all levels are equal and that there is no statistically significant difference between the means of the levels. Table 4 compares the level of material wastage in Jordan with other countries.

Table 4. Percentage of material wastage in Jordan in comparison with other countries

Material	Jordan	UAE	USA	Egypt	Hong Kong		Brazil	Palestine	Malaysia
					Private	Public			
Sand	14.04	NA	NA	NA	NA	NA	40.70	10.50	27
Aggregate	11.94	NA	NA	NA	8.00	5.00	NA	8.90	NA
Tiles	11.05	7.40	6.5	5.00	7.00	7.00	14.40	4.40	NA
Stones	10.00	NA	NA	NA	NA	NA	NA	NA	NA
Blocks	10.00	11.30	3.50	NA	4.00	6.00	7.70	5.40	2.00
Steel	10.02	3.90	NA	5.00	4.50	4.50	10.60	5.40	3.00
Cement	9.99	7.80	3.50	5.00	12.00	4.00	45.20	4.40	NA
Pipes	9.04	NA	NA	NA	NA	NA	14.80	2.10	NA
Concrete	7.98	4.10	7.50	7.00	4.50	4.50	8.60	5.40	65.80
Formwork	5.94	13.90	10.00	13.00	15.00	5.00	NA	7.00	5
Reference		Al-Hajj and Hamani (2011)	Chen et al. (2002)	Garas et al. (2001)	Poon et al. (2004)		Formoso et al. (2002)	Al-Moghany (2006)	Begum et al. (2007)

These results are higher than the nominal figures assumed by construction companies in their cost estimates. This is in line with the results obtained by Formoso et al. (2002).

The percentage of the total range of material wastage in the Jordanian construction industry was (5.87%-11.84%). Figure 1 depicts the percentage of each material wastage with respect to the whole project's material wastage.

Table 5 explains the causes of wastage for these materials.

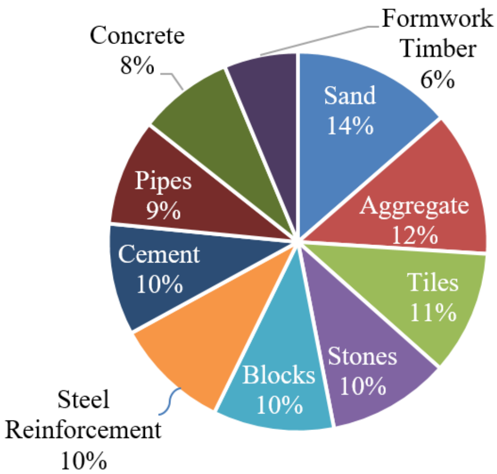

Figure (1): Percentage of material wastage in the Jordanian construction industry

The main causes of the material wastage are explained as follows:

- Sand: Excessive consumption of sand, purchases without measuring the exact quantities required, poor storage and bad weather.
- Aggregate: Poor storage and overordering.
- Tiles: Rework as a result of mistakes, using materials that do not comply with specifications.

Table 1. Main causes of waste for selected materials

Materials	Main Causes
Sand	Excessive consumption of sand, purchases without measuring the exact quantities required, poor storage and bad weather
Aggregate	Poor storage and overordering
Tiles	Rework as a result of mistakes, using materials that do not comply with specifications
Stone	Cutting and incapability of ordering small quantities
Blocks	Damage during cutting; damage caused during delivery, storage and transit to the work location
Steel	Using diameters that are larger than required, using bars that are longer than required, poor bar bending schedules and poor storage
Cement	Reworking plastering, excessive thickness due to deviations in the structural elements' dimensions, losses due to mortar falling on the ground during plastering and bad weather
Pipes	Damages during cutting
Concrete	Poor performance leading to rework, ordering additional concrete, supply is lower than demand and imperfection in formworks
Timber	Cutting, using low-quality timber, damaging timber boards during the removal of formworks, using timber for other needs and poor storage

To understand the perception of the construction industry on the management of construction waste, respondents were asked to rank the importance of managing and minimizing material wastage, as displayed in Table 6.

Table 6. Ranking the importance of minimizing material wastage

Importance	Mean	Rank
Minimizes time and cost overruns	4.67	1
Helps determine the exact required quantities	4.53	2
Preparing accurate BOQ	4.46	3
Reduces environmental pollution	4.13	4
Helps contractors to price tenders more accurately	4.06	5
Supports contractors to have a better chance to win the tender	3.72	6
Contributes to an increase in national income	3.18	7
Increases chances of obtaining project finance	3.02	8

The results indicate that the optimization of material wastage would greatly impact the time and cost overruns in construction projects with a mean of 4.46. It has been noted that the least important factor was increasing the chance of obtaining project finance with a mean of 3.02. Most contractors in the UAE considered cost savings and increased profits to be the most important benefits and incentives for material waste minimization, while protecting the environment was seen as the least important one (Al-Hajj and Hamani, 2011). According to Al-Moghany (2006), the main advantages of managing and minimizing wastage were knowing the exact required quantities for the project and serving contractors in pricing bids.

CONCLUSION AND RECOMMENDATIONS

Owing to its significant utilization of resources, the construction industry faces serious challenges to manage construction wastes. Despite significant studies on construction waste in terms of identification, causes and minimization strategies, developing countries lack the diagnosis of the *status quo* when it comes to construction waste. This study filled this gap by identifying the main causes of construction waste along with most materials that need efficient utilization.

This paper indicated that "design changes during the construction phase" was the main cause of material wastage. On the other hand, "poor infrastructure" was the least important source of material wastage. The average percentages of material wastage in Jordan for concrete, cement, tiles and sand were in good agreement with those of recent studies from other developing countries. The results indicated that sand showed the highest percentage of waste among the selected materials. On the other hand, formwork timber showed the lowest waste percentage among the materials. The results indicated that ~74% of contracting companies do not have any records on material wastage for their previous projects. Waste minimization is not considered a priority, which, if implemented, would improve project performance by reducing time and cost overruns and preparing an accurate BOQ.

By understanding the main causes of construction waste, stakeholders (mainly clients and contractors) will be able to better identify where improvements can be made to reduce construction wastes in a country that is in dire need to utilize its very limited resources and faces economic challenges. Further studies are needed to investigate the current status and future trends of waste management strategies on recycling and reusing technologies for construction materials, with emphasis on developing countries.

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