Understanding the key factors of construction waste in Jordan

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Abstract — Waste of construction materials has been recognized as a significant problem for different stakeholders involved in construction projects. This waste has negative impacts on the efficiency of the construction industry, the country economy at large and the environment. Thus, the minimization of construction wastes has become a pressing issue. This paper aims to investigate the main factors and causes contributing to material waste in the construction industry in Jordan. In order to achieve the aim of this study, a survey was carried out, employing semi-structured interview, to gather information from construction professionals about causes of waste in construction materials. The results show that the most significant factors contributing to construction waste can be categorized mainly into two groups: management related and workforce related. Examples of these are: 'Lack of skilled workers and subcontractors' and 'Lack of quality management system'. Decision makers and construction professionals can use the findings of this study as inputs to build their strategies concerning construction waste management.

Keywords; Material wastages, Construction projects, Environmental Impact, Jordan

I. INTRODUCTION

The construction industry in Jordan represents approximately 5% of the Gross Domestic Product (GDP) (Bank Audi 2014). This contribution is a result of the demand for construction from other sectors of the economy. The construction industry supplies the infrastructure to enable other organizations in other economic sectors to operate. Such infrastructure includes both the national infrastructure (power, water, transport, etc…) and the infrastructure specific to an organization (its factories, offices and so on).

The construction sector is large, complex and diverse covering a wide range of business activities. Construction projects can be classified in several ways. A common classification is as either building or civil engineering projects (Hillebrandt 2000). These could be further divided into housing, industrial and commercial building, and infrastructure projects and services (Cox and Townsend 1998; Pottier et al. 2006). Alternative classifications which are often used are repair and maintenance, and new work (Pottier et al. 2006). Construction industry in Jordan could be categorized into two main categories:

Category I: Small and Medium Company. This type of company - family company - is owned and managed by one person and who's own interest to get a maximum profit from his investment with a short period of time. Companies fall into this category plays the roles of client and contractor and sometimes the designers with no intention into construction waste management.

Category II: Large Size Company. This type of companies is multimillion dollar project, where the management is concerned with cost, quality and time.

It can simply be recognized that the construction industry is a major consumer of natural resources. Examples of these are cement, sand and aggregate, wood, steel and energy. Moreover, the construction industry is generally project based (Bassioni et al. 2004), and these projects are specially made according to client requirements. Thus, from the above, it can be said that these conditions and characteristics within the construction industry can result in a serious waste of construction materials, which in turn will have major impacts on the country's economy and the environment.

The construction industry in Jordan is not an exception. It generates tons of construction wastes per year, making construction waste a pressing issue for in-depth investigation. Until now, there is no study in Jordan that has investigated this issue and addressed the main causes and factors that contribute to construction wastes. Therefore, there is a necessity to study this issue. This paper aims to identify the main factors causing waste in construction materials, quantifying waste ratios in various construction materials, and producing suggestions to help decision makers and construction stakeholders to manage and minimize the negative impacts of construction waste on the economy and environment in Jordan.

In order to achieve this aim, an intensive literature review was carried out to identify causes behind construction waste in various countries. Following this, a survey with Category II Company was conducted to gather relevant data about the

study. Then, data was analyzed and the results are discussed. At the end, a set of recommendations and suggestions are provided to deal with the construction waste issue in Jordan.

II. LITERATURE REVIEW

Waste is a popular term in the industry world-wide (Ekanayake and Ofori 2000). Therefore, it will be necessary to know what is meant by construction waste in this study. Construction waste means 'any substance or object (such as bricks, concrete, and steel) which is generated as a result of construction work and should be discarded as it no longer can be used as part of the construction processes'. In term of money, construction material waste can be understood as the difference between the value of materials delivered and accepted on site and those properly used as specified and accurately measured in the work (Shen & Tam 2002).

Construction material waste can also be recognized and classified as follows:

- Waste of materials as a result of damage which cannot be repaired and utilized anymore
- Waste of materials as a result of loss during construction process
- Waste of materials as a result of errors in construction and excess of actual quantities comparing to theoretical quantities in drawings

Construction and demolition waste materials consist mainly of concrete, masonry, limestone, sand, metal and wood depending on the construction type (Bossink and Brouwers, 1996).

Construction waste and its management have been widely investigated in many countries, and from various points of view. For example, Rogoff and Williams (1994) stated that 29% of solid wastes in the USA are construction waste. Kartam et al (2004) reported that construction and demolition waste in Kuwait represents about 15-30% of all solid waste by weight. Similarly, it was reported by Lu and Yuan (2011) that construction activities contributed to approximately 40% of China's municipal solid waste. It will be necessary to recognize the construction waste issue and the factors contributing to waste generation. Therefore, management of construction waste is of a great potential for sustainable construction for society, economy and the environment.

A large number of studies have investigated the construction waste management, including waste reduction, waste recycling, waste reuse and waste disposal (Yuan 2013; Kartam et al. 2004; Al-Hajj and Hamani, 2011; Coelho and Brito, 2012; Lu and Yuan, 2011). The obstacles behind construction waste management were intensively investigated in the literature (Yuan, 2013; Kartam et al. 2004; Ling and Nguyen 2013; John and Itodo 2013). These obstacles were classified into groups in China, involving weak awareness of project stakeholders, insufficient support from local government, immature waste recycling market, economic consideration, low waste despoil fee and barriers related to site activities (Yuan 2011).

A large number of studies around the world have investigated construction waste and the factors behind it (Bossink and Brouwers 1996; Kartam et al. 2004; Yuan 2013; Al-Moghany 2006; Al-Hajj and Hamani 2011). The most important factors extracted from relevant literature were considered for this study.

III. RESEARCH METHODOLOGY

A survey was conducted between March 2014 and May 2014 to collect information on the causes / factors of construction material wastage and their ambit contribution into this waste. Semi-structured interview was employed to collect data from construction professionals. Ten interviews were carried out with project managers working for Category II companies.

Interview questions were designed as structured questionnaire. It consists of three parts:

In the first part, the interviewee was asked to give information about his/her position, experience, project size and company grade (see Table 1).

TABLE I. GENERAL INFORMATION ON INTERVIEWS

Job position	**Percentage**	**Experience in years**	**Percentage**
Company Manager	10	Less than 5	0
Project Manager	60	5-10	20
Site Engineer	30	10-20	30
Supervisor	0	More than 20	50
Company age in years	**Percentage**	**Project size in thousand JD**	**Percentage**
Less than 5	0	Less than 250	10
5-10	20	250-1000	20
10-20	30	1000-10,000	50
More than 20	50	More than 10,000	20
Contractor Grade according to contractors syndicate	**Percentage**	**Size of the company Number of employees**	**Percentage**
First	60	1 – 50	0
Second	0	51 - 100	20
Third	40	101 - 250	20
Fourth	0	>250	60

The second part, questions were concerned with presence of waste management system at their company. Thirty nine factors were selected from literatures to cover the main causes that might contribute to construction waste as shown in Table 2. An interviewee was asked to give his/her opinion on the degree of contribution of each factor to the waste based on a Likert scale (1-4).

TABLE II. RANKING OF FACTORS CONTRIBUTING INTO CONSTRUCTION WASTE

Class	Factor description	Average	SD
High	*Lack of skilled workers and subcontractors*	3.70	0.67
	Rework required because of workers errors	3.50	0.53
	Lack of quality management system	3.50	0.71
	Design changes and change orders during construction stage	3.40	0.84
	Selection of low quality materials	3.40	0.70
	Damage to work due to subsequent tasks	3.40	0.70
	Unsuitable cutting for building materials	3.30	0.95
	Bad storage	3.30	0.48
	Damage due to wrong transportation of materials	3.30	0.67
	Poor construction techniques	3.30	0.82
Medium	*Using more quantities than required*	3.20	0.92
	Lack of waste management system by contractor	3.20	0.63
	Changes of specifications by client	3.10	0.74
	Manufacturing defects	3.10	1.10
	Lack of on-site materials management	3.10	0.74
	Use of incorrect materials	3.10	0.99
	Over-ordering or under-ordering due to mistake in quantity surveys	3.00	1.25
	Poor Coordination between project participants	3.00	0.47
	Purchased materials that don't comply with specifications	2.90	1.20
	Damage of materials on site	2.90	1.29
	Lack of good site planning and management (Difficulty of mobility)	2.90	0.99
	Poor project control by general contractor	2.90	0.88
	Lack of contractor's professional team	2.90	0.88
	Poor management of project resources	2.90	0.88
	Theft and vandalism	2.80	1.03
	Over-sized of building components during construction	2.70	1.16
	Frequent transportation of materials on site	2.70	1.06
	Bad weather	2.70	0.67
	Breakdown of construction plants/equipment and poor selection	2.70	0.95
	Interactions between various construction activities	2.50	1.18
Low	*Designers use high security factors in design*	2.30	0.95
	Ineffective planning and scheduling	2.30	0.67
	Difference between site conditions and project documents	2.20	0.79
	Delay of consultant engineer's response to contractor inquiries	2.10	0.88
	Delay of consultant engineer's acceptance on work done and inspection	2.10	0.88
	Delay in construction according to schedule	2.10	0.57
	Ambiguities and errors of information in project documents	2.00	1.05
	Lack of information in drawings and project documents	1.90	1.10
Very Low	*Ambiguous, errors in drawings*	1.60	0.84

The third part was designed to compare between expected percentage of waste and actual waste for different items such as steel, concrete & painting.

IV. RESULTS

A. Interviewees details

Table 1 shows general information that represents the first part of the questionnaire. It demonstrates that all of interviewees are in management positions and should be aware of the waste. It shows that 80% of the interviewees have more than 10 years experience, and that 70% of each contract is more than one million JD.

B. Factors behind construction waste

The interviews demonstrate that 40% of companies have no waste management system at all. In contrast, 50% of companies that have waste management systems only investigate waste for some important items of projects. In general, the results illustrate that the construction industry in Jordan, even for large companies, do not pay considerable attention toward waste management. This is because that there is no legislations concern about waste in the construction sector.

Table 2 shows 39 factors which were selected from literatures considering their raking according to their contribution to waste. Following the data collection, the average and the standard deviation were computed for each factor based on values given by the Likert scale. The factors ranked were based on their average; a factor with high score means that it has a high contribution to construction material waste. In order to classify these factors into various classes according to their importance, it was decided to determine ranges for each class. Based on the Likert scale, 1 represents very low impact factor and 4 represents high impact factor. The range between the maximum and minimum values is 3. This range is divided by 4 to represent the four classes shown in Likert scale (High impact factors, medium, low, and very low). The calculated interval for each class is 0.75 as follows:

- Very low: 1 + 0.75 = 1.75 (Range from 1 to 1.75)
- Low: 1.75 + 0.75 = 2.5 (Range from 1.75 to 2.5)
- Medium: 2.5 + 0.75 = 3.25 (Range from 2.25 to 3.25)
- High: 3.25 + 0.75 = 4 (Range from 3.25 to 4)

It can be seen from Table 2 that the highest factor has a score (3.70) and the lowest has a score (1.60). According to the above class ranges, it can be seen that 10 factors fall within the high impact class, 20 factors are in medium class, and the others fall within low and very low classes.

In the following sections, only high and medium factors will be discussed and other factors are ignored due to minor contributions to the waste.

1) High Impact Factors

It can be seen that the factors 'Lack of skilled workers and subcontractors' and 'Rework required because of workers

errors', which are relevant to workers and subcontractors, have the highest contribution to construction waste due to unskilled labors. Additionally, contractors and subcontractors employ these workers for temporary periods as required for work based on daily wages. This in turn encourages the contractor and subcontractors to ignore their own accountability for training them to build up their skills. This finding is similar to other studies in various countries (Yuan 2013; Al-Moghany 2006; Al-Hajj and Hamani 2011, Ling and Nguyan 2013). On the other hand, Jordanian workers are either have low skills or unwilling to work in the construction sector as they prefer services administration / office jobs. Moreover, when the interviewees were asked to state the major obstacles facing construction sector, they were mainly concerned with shortage of skilled workers. However, the Jordanian government established several training and education centers to cover the skills shortage in the construction market. Despite of the active construction market, the high demand for such skills, considerable income comparing to other administration jobs and the government efforts to build up skills, the problem 'shortage of skills' is still existing.

The results in Table 2 also demonstrate that the factors 'Lack of quality management system' and 'Selection of low quality materials' have significant roles in construction waste. This means that the lack of quality management system (QMS) in construction activities may lead to errors and poor quality work. This in turn will enforce the contractor to rework and as a consequence waste occur in terms of materials and time. On the other hand, selecting low quality materials is directly related to quality management system as the QMS should identify the procedures for selecting required materials that meet contract specifications. This factor strongly shares other factors contribution, such as 'Purchased materials that don't comply with specifications' and 'Manufacturing defects', into poor quality work.

The factor 'Design changes and change orders during construction stage' is directly related to client requirements. This factor is out of control by the contractor or his management team. However, its contribution to waste is highly dependent on the level of design changes required.

The results also show that the factor 'Damage to work due to subsequent tasks' has high impact on construction waste. This might occur at finishing stage of project comparing to structure work. Examples of these tasks are painting, tiling and plumping. This factor is related to lack of workers awareness and schedule pressure.

It can be seen that the factor 'Unsuitable cutting for building materials' contributes to waste especially for some construction elements such as tiles, ceramic and steel bars. The interviewees have emphasis that impact of this factor is dependent on various causes, mainly lack of constructability consideration by design team, lack of management team awareness and poor workers skills. Some interviewees reported that waste in some construction components such as steel and tiles can be recycled within the project. Furthermore, all interviewees stated that steel waste is sold as scrap at 20% of its original purchasing price. This agrees with the study conducted by Kartam et al (2004) in Kuwait as they reported that metal / steel is the highest recycled material in construction. Whereas materials as ceramic and tiles cannot be sold as scrap and are considered as waste.

The results demonstrate that waste related to raw materials is mainly occurred by two factors 'Bad storage' and 'Damage due to wrong transportation of materials'. This can be correlated to both management and workers awareness. In similar way, the management and workers awareness might be the main causes to waste resulted from 'Poor construction techniques'. This is based on company policy and technology availability in addition to capability of workers to use advanced technology.

2) Medium impact factors

The results in Table 2 show that more than 50% of medium impact factors which contribute to waste are relevant to management tasks. Examples of these factors are 'Lack of waste management system by contractor', 'Lack of on-site materials management' and 'Poor coordination between project participants'. Other factors seem to be related to both management and labour tasks, such as 'Damage of materials on site' and 'Interactions between various construction activities'. Also, it can be seen that there is a shared responsibility between contractor management team, labour and other stakeholders for some factors, such as 'Theft and vandalism' and 'Breakdown of construction plants/equipments and poor selection'. Other factors can be seen in Table 2.

C. *Expected and actual waste percentage*

The results shown in Table 3 present the expected and the actual waste percentage. The middle columns demonstrate the percentage of interviewees' answers about the expected waste percentage for each item of the total material purchased. In the last column, the range of the actual waste percentage is presented. The waste percentage in this paper is considered as a quantity measure. A summary of data in Table 3 is illustrated in Table 4 showing a comparison between the actual and expected waste percentage and possible causes beyond waste.

TABLE III. EXPECTED AND ACTUAL WASTE PERCENTAGE

Building items	Expected waste percentage %				Range of actual waste percentage
	< 2	2 – 5	5 - 10	> 10	
Concrete	*20*	*80*	*0*	*0*	*2-12*
Steel	*80*	*20*	*0*	*0*	*2-10*
Formwork	*0*	*0*	*20*	*80*	*10-40*
Sand and Aggregate	*20*	*80*	*0*	*0*	*3-15*
Cement	*20*	*80*	*0*	*0*	*3-20*
Bricks	*0*	*40*	*40*	*20*	*5-10*
Stone	*10*	*50*	*20*	*20*	*5-20*
Tiles	*0*	*80*	*20*	*0*	*3-11*
Ceramic	*0*	*60*	*40*	*0*	*3-11*
Pipes	*80*	*20*	*0*	*0*	*3-7*
Paint	*60*	*20*	*20*	*0*	*3-7*

TABLE IV. COMPARISON BETWEEN THE ACTUAL AND EXPECTED WASTE PERCENTAGE AND POSSIBLE CAUSES

Building items	Actual vs. Expected waste percentage	Possible causes
Concrete	***higher than expected***	over-sized of building components during construction lack of management team and labour awareness Lack of quality management system
Steel	***higher than expected***	unsuitable cutting lack of proper supervision team Poor construction techniques
Formwork	***Within the range***	frequent cutting of formwork to shape various types of structure elements lack of constructability in design lack of labour awareness
Sand and Aggregate	***higher than expected***	over-sized of building components during construction bad storage damage during to transportation on site Lack of on-site materials management
Cement	***higher than expected***	bad storage Frequent transportation of materials on site Lack of on-site materials management
Bricks	***Within the range***	unsuitable cutting Lack of skilled workers and subcontractors damage during to transportation
Stone	***Within the range***	Similar to bricks Selection of low quality materials
Tiles	***Within the range***	unsuitable cutting Lack of skilled workers and subcontractors Manufacturing defects Forced cutting to match required dimensions Selection of low quality materials
Ceramic	***Within the range***	Similar to tiles
Pipes	***Within the range***	unsuitable cutting
Paint	***Within the range***	lack of labour awareness Damage to work due to subsequent tasks Rework required because of workers errors Selection of low quality materials

D. Potential benefits of construction waste management

Considering and adopting waste management strategy in construction could bring many benefits to construction companies. These may include:

- Reduce project cost and enhance profit
- Enhance their competitive advantages in the market
- Demonstrate their clients about waste management and environmental protection
- Enhance quality and performance within the construction industry at large
- Reduce resources and energy consumption and decrease soil and air pollution
- Save last user money because of cost saving resulted from minimizing construction waste.
- Promote workforce skills and productivity
- Enhance sustainability aspects (economic, environmental and social)

V. SUGGESTIONS AND RECOMMENDATIONS

Two types of recommendations will be presented in this section. Firstly, a set of recommendation based on the findings of this study, these are:

- Enhancing skills of construction workers and management team through attending some training courses
- Encouraging contracting companies to allocate a considerable budget for enhancing their workers and management team skills.
- Encouraging the governmental bodies concerned with the construction sector to issue a set of legislations concerning with quality and waste management.

Secondly, a strategy for construction waste management is proposed for future consideration. It is suggested to develop a waste management strategy by main stakeholders involved in the construction industry. This may include governmental bodies, Syndicate of Engineers, Syndicate of Contractors and material suppliers and environmental organizations. The proposed strategy initially may involve the following issues:

- Develop clear solid waste management regulations to deal with construction waste
- Identifying the responsibility of each party towards applying the waste management framework
- Identifying types and quantities of waste that could be generated from construction activities
- Implementing onsite construction waste sorting procedures
- Adopting prefabricated building components to enhance quality and reducing waste onsite
- Improve project contractors' onsite construction management (Onsite coordination of various construction activities, onsite management and planning, enhance resource use efficiency)
- Identifying necessary training required for project stakeholders to recognize the importance of waste management and how they should minimize it
- Measuring waste and comparing it with ex-determined targets to identify and handle with potential sources of waste.
- Reviewing the results and updating the strategy for continuous improvement.

VI. CONCLUSIONS

This paper presents the main findings from a survey conducted in the construction industry in Jordan, aiming to investigate the concept of construction waste and identify the main factors contributing to it. Ten interviews were carried out with construction professionals. The findings of this study serve as the basis for making the following conclusions:

- Most of construction companies do not seem to be concerned about material waste.
- The most significant factors contributing into construction waste can be categorized mainly into two groups: management related and workforce related. This means that a considerable emphasis should be placed on the management factors of greater importance, so that the management effects can be maximized to enhance their practices. Furthermore, significant attention should be paid on building up workforce skills through training and education courses and encouraging permanent employment.
- The actual waste in some construction items such as concrete and steel are higher than expected. Therefore, managing such factors that cause this waste is of great importance in minimizing construction waste.

The findings revealed in this study can be useful for decision makers to formulate their strategies to enhance construction waste management in Jordan and other countries.

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