# 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 at investigating 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 benefit from the findings of this study as input to build their strategies concerning construction waste management.

**KEYWORDS:** Material wastage, Construction projects, Environmental impact, Jordan.

## 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 buildings as well as 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 usually owned and managed by one person who has an own interest to get maximum profit from his/her investment in a short period of time. Companies falling under this category play the roles of client and contractor and sometimes that of the designers with no concern in construction waste management.

Category II: *Large Size Company*. This type of company is usually a multimillion dollar project, where the management is concerned in cost, quality and time.

It can simply be recognized that the construction

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

Construction industry in Jordan is not an exception. It generates tons of construction wastes per year, making construction wastes 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 at identifying 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 manage and minimize the negative impacts of construction wastes on economy and environment in Jordan.

In order to achieve this aim, an intensive literature review was carried out to identify causes behind construction wastes in various countries. Following this, a survey with Category II Companies was conducted to gather relevant data about the study. Then, data was analyzed and the results were discussed. At the end, a set of recommendations and suggestions are provided to deal with the construction waste issue in Jordan.

## LITERATURE REVIEW

Waste is a popular term in industry world-wide (Ekanayake and Ofori, 2000). Therefore, it is 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 terms 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 and 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 the construction process.
- Waste of materials as a result of errors in construction and excess of actual quantities compared to theoretical quantities in the 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 wastes. 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 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 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 considerations, low waste deposit fee and barriers related to site activities (Yuan, 2011).

**Table 1. 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 Association of Contractors** | **Percentage** | **Size of the Company According to Number of Employees** | **Percentage** |
| First | 60 | 1 – 50 | 0 |
| Second | 0 | 51 - 100 | 20 |
| Third | 40 | 101 - 250 | 20 |
| Fourth | 0 | >250 | 60 |

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 and are given in Table 2.

## RESEARCH METHODOLOGY

A survey was conducted between March and May 2014 to collect information on the causes/factors of construction material wastage and their contribution to this wastage. 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 in the form of a 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).

In the second part, questions were concerned with the presence or absence of a waste management system

at their company. Thirty nine factors were selected from literature to cover the main causes that might contribute to construction waste as shown in Table 2. Interviewees were asked to give their opinions on the degree of contribution of each factor to construction waste based on a Likert scale (1-4).

The third part was designed to compare the expected percentages of waste with the actual ones for different items such as steel, concrete and paint.

**Table 2. Ranking of factors contributing to construction waste**

| Class | Factor Description | Average | S.D. |
|---|---|---|---|
| **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 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's inquiries | 2.10 | 0.88 |
| | Delay of consultant engineer's acceptance of work done and inspection | 2.10 | 0.88 |
| | Delay in construction according to schedule | 2.10 | 0.57 |
| | Ambiguities and errors in information in project documents | 2.00 | 1.05 |
| | Lack of information in drawings and project documents | 1.90 | 1.10 |
| **Very Low** | Ambiguity and errors in drawings | 1.60 | 0.84 |

## RESULTS

### Section 1: Details of Interviewees

Table 1 shows general information that represents the first part of the questionnaire. It demonstrates that all of the 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.

### Section 2: Factors behind Construction Waste

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

Table 2 shows 39 factors which were selected from literature considering their ranking 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 the Likert scale (high, medium, low and very low impact factors). 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 2.5 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 of (3.70) and the lowest has a score of (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 the medium class and the other factors fall within the low and very low classes.

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

### 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

labor. Additionally, contractors and subcontractors employ these workers for temporary periods as required for work based on daily wages. This in turn encourages the contractors and sub-contractors to ignore their own accountability for training them to build up their skills. This finding is similar to those of 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 either have low skills or are unwilling to work in the construction sector as they prefer services, administration and office jobs. Moreover, when the interviewees were asked to state the major obstacles facing the 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. In spite of the active construction market, the high demand for such skills, considerable income compared to other administration jobs and the government's 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 systems (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 occurs 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 the contract specifications. This factor strongly shares contribution with other factors, such as 'purchased materials that don't comply with specifications' and 'manufacturing defects', in poor quality work.

The factor 'design changes and change orders during the 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.

**Table 3. 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 Aggregates | 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 |

The results also show that the factor 'damage to work due to subsequent tasks' has a high impact on construction waste. This might occur at the finishing stage of the project compared 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 emphasized that the 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 findings of the study conducted by Kartam et al. (2004) in Kuwait who 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 mainly occurred as a result of two factors: 'bad storage' and 'damage due to wrong transportation of materials'. This can be correlated to both management and workers' awareness. In a similar way, management and workers' awareness might be the main causes of waste resulting from 'poor construction techniques'. This is based on the company's policy and technology availability in addition to capability of workers to use advanced technology.

**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 labor 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, labor and other stakeholders for some factors, such as 'theft and vandalism' and 'breakdown of construction plants/equipment and poor selection'. Other factors can be seen in Table 2.

**Section 3: Expected and Actual Waste Percentages**

The results shown in Table 3 present the expected and actual waste percentages. The middle columns demonstrate the percentage of interviewees' answers on the expected waste percentage for each item of the total materials 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 percentages and possible causes beyond waste.

**Table 4. Comparison between the actual and expected waste percentages and possible causes**

| Building Items | Actual *vs.* Expected Waste Percentage | Possible Causes |
|---|---|---|
| Concrete | higher than expected | • over-sized building components during construction<br>• lack of management team and labor awareness<br>• lack of quality management system |
| Steel | higher than expected | • unsuitable cutting<br>• lack of proper supervision team<br>• poor construction techniques |
| Formwork | within the range | • frequent cutting of formwork to shape various types of structure elements<br>• lack of constructability in design<br>• lack of labour awareness |
| Sand and Aggregates | higher than expected | • over-sized building components during construction<br>• bad storage |

| | | |
|---|---|---|
| | | • damage during to transportation on site<br>• lack of on-site materials management |
| Cement | higher than expected | • bad storage<br>• frequent transportation of materials on site<br>• lack of on-site materials management |
| Bricks | within the range | • unsuitable cutting<br>• lack of skilled workers and subcontractors<br>• damage during to transportation |
| Stone | within the range | • similar to bricks<br>• selection of low quality materials |
| Tiles | within the range | • unsuitable cutting<br>• lack of skilled workers and subcontractors<br>• manufacturing defects<br>• forced cutting to match required dimensions<br>• selection of low quality materials |
| Ceramic | within the range | • similar to tiles |
| Pipes | within the range | • unsuitable cutting |
| Paint | within the range | • lack of labor awareness<br>• damage to work due to subsequent tasks<br>• rework required because of workers' errors<br>• selection of low quality materials |

## Potential Benefits of Construction Waste Management

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

- reduce project costs and enhance profit.
- enhance the competitive advantages of construction companies in the market.
- demonstrate waste management and environmental protection to the clients of construction companies.
- enhance quality and performance within the construction industry at large.
- reduce resource and energy consumption and decrease soil and air pollution.
- save last user's money because of cost saving resulting from minimizing construction waste.
- promote workforce skills and productivity.
- enhance economic, environmental and social sustainability aspects.

## Suggestions and Recommendations

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

- enhancing skills of construction workers and management team through attending training courses.
- encouraging contracting companies to allocate a considerable budget for enhancing the skills of their workers and management team.
- encouraging the governmental bodies concerned with the construction sector to issue a set of legislations concerned 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 the main stakeholders involved in the construction industry. This may include governmental bodies, Association of Engineers, Association of Contractors,

as well as material suppliers and environmental organizations. The proposed strategy may initially involve the following issues:

- Developing 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 on-site construction waste sorting procedures.
- Adopting prefabricated building components to enhance quality and reducing on-site waste.
- Improve project contractors' on-site construction management (on-site coordination between various construction activities, on-site management and planning, enhancement of resource use efficiency).
- Identifying necessary training required for project stakeholders to recognize the importance of waste management and how waste should be minimized.
- Measuring waste and comparing it with ex-determined targets to identify and handle potential sources of waste.
- Reviewing the results and updating the strategy for continuous improvement.

## CONCLUSIONS

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

- Most of construction companies do not seem to be concerned with the issue of material waste.
- The most significant factors contributing to 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 to building up workforce skills through training and education courses and the encouragement of permanent employment.
- The actual waste in some construction items, such as concrete and steel, is 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 and professionals to formulate their strategies to enhance construction waste management in Jordan and other countries.

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