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MATERIAL WASTE IN THE UAE CONSTRUCTION INDUSTRY: MAIN CAUSES AND MINIMISATION PRACTICES

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Abstract

The United Arab Emirates (UAE) is facing the challenge of achieving sustainability on construction sites. One of the main barriers lies in the increasing amounts of material waste generated from construction activities and dumped in landfills. This research examined previous studies about the sources of waste and the recommended measures to minimise. The significance of these causes and frequency of implementation of adequate measures in the UAE construction sites were examined. Four construction projects were visited before a survey was conducted of the perceptions of contractors on the problem and causes of material waste; waste minimisation measures and their benefits. This research revealed that the main causes of material waste are lack of awareness; excessive off-cuts resulting from poor design; and rework and variations. The most frequent measures practiced to minimise material waste are: staff training; adequate storage; and just- in time delivery of materials. Waste measurement and waste segregation are areas that need more efficient implementation to achieve material waste minimisation targets. Moreover, contractors' perceptions towards the benefits of material waste minimisation revealed that this waste is primarily considered a financial problem and its minimisation a cost cutting activity. In contrast, the environmental dimension was neglected by surveyed companies.

Keywords: construction, material waste, waste management, waste minimisation, sustainability, UAE

1. Introduction

In pursuing the mission of sustainable development, many countries are working towards maintaining a balance between developing the built environment and protecting the natural environment. This balance can only be achieved by shifting from the traditional linear production process to a cyclic process based on prevention, reuse and recycling of material waste (Miyatake, 1996, Du Plessis, 2002). Although solid waste is generated by different household and economic activities the construction industry has always been considered as one of the major producers of waste. This is clearly reflected in statistical and environmental reports in several countries. The U.S. Environmental Protection Agency (USEPA, 2004) reported that 170 million tonne have been generated in the US in 2003 and that 1900 Construction and Demolition (C&D) landfills are operating in the US to receive disposed material waste. According to Eurostat report, 2 billion tonnes of waste is generated every year in European Union (EU-15) and the share of construction waste is 31% (DEFRA, 2007). In Honk Kong, 3158 tonne per day of material waste is disposed of at landfills representing 23% of total solid waste (EPD, 2008). The UAE is no exception and it is considered as one of the biggest producers of waste, 75% of which is from construction waste (UAE Interact, 2007) and it is ranked second to USA in waste share per capita among the world countries (Al-Qaydi, 2006). The amount of construction waste dumped in Dubai's landfill for the year 2007 has reached 27.7 million tons which is almost three times the volume generated in 2006 (10.6 million tons). In 2008, it was reported that the construction waste from the first half of 2008 is already double that produced in 2007 with 35000 tons of sites' debris discarded daily (Alkhafaf, 2008). These figures show the urgent need for a revolution in the way the country is handling waste; adopting other waste management practices instead of disposal should be the way forward.

This research seeks to contribute to the implementation of this change by investigating the causes of material waste in the UAE construction sites and examining the current practices implemented by the contractors to minimise material waste.

2. Construction waste: definition and measurement

Many categorisation models have been applied to classify the types of waste. Wastes can be classified by their state (solid, liquid or gaseous); by their characteristics (inert, combustible, bio-degradable, hazardous or nuclear); or by their origin (processing, household, emission treatment, Construction & Demolition or energy conversion). Demolition and Construction (D&C) waste can then be defined and studied separately.

Construction waste has been defined in various ways. The Building Research Establishment (1978) defined waste as 'the difference between materials ordered and those placed for fixing on building projects'. In 1981 another definition emerged from BRE stating that waste is 'any material apart from earth materials, which needed to be transported elsewhere from the construction site or used on the site itself other than the intended specific purpose of the project'. In the 1990's the Environmental Act (1990) defined waste as: 'scrap material or an effluent or other surplus substance arising from the application of any process.' In Hong Kong, the definition by HK Polytechnic made it clear what construction waste is defining it as: 'The by-products generated and removed from construction, renovation and demolition workplaces or sites of building and civil engineering structures'.

Koskela (1992) and Alarcon (1993) studied other types of waste in construction. Time and process waste is generated from activities that take time, resources or space without adding value. Formoso et al. (1999) added that defined time and process related waste as: 'any losses produced by activities that generate direct or indirect costs but do not add value to the product from the point of view of the client'. Non adding value activities and how to minimise the waste they generate are the basis of the lean construction philosophy. Although inefficiency related waste has greater economic loss than material waste (Formoso et al., 1999), it is widely recognised that the latter is more important from an environmental perspective (Miyatake, 1996; Formoso et al., 199; Du Plessis, 2002; Mora,2005,).

Similarly to the definition of waste, waste measurement has been also viewed and implemented in different ways. Treloar et al. (2003) suggest the measurement of waste in terms of embodied energy of materials. Bossink and Brouwers (1996) reported 3 case studies where waste of each type of material was measured in different ways: i) as a percentage of the total amount of construction waste; ii) as a percentage of purchased materials; and iii) as a percentage of the total waste's cost. These methods are all illustrative of the level of waste generated and they can be used simultaneously. However, in order to calculate these percentages, the identification of waste streams and volume/weight of waste generated for each one is necessary.

In addition to the fact that recording and measuring waste is a prerequisite to its management (Wrap, 2007b), knowing how much waste is generated can be used as a benchmarking tool against other projects; other companies; or against good practice. The next step is then to explore the gap between what is achieved and good practice. Reducing the gap can be attained by looking at the sources of waste and analyzing the causes behind its generation.

3. Sources of material waste in construction

Many factors contribute to the generation of material waste. These factors have been grouped by Ekanayake & Ofori (2000) under four categories: (1) design; (2) procurement; (3) handling of materials; and (4) operation. They have concluded that most of the causes of waste are due to design issues. This finding has also been reported by a number of other studies (Ekanayake and Ofori, 2004; Innes, 2004); Keys et al., 2000; Rounce, 1998). It is, thus, agreed that the process of waste minimisation must be started at the early stages of the project. A survey conducted by Saunders and Wynn (2004) showed that improper design resulting in excessive cut-offs is one of the major causes of material waste.

The UAE construction industry is witnessing an unprecedented boom. A lot of mega projects are underway and contractors are enjoying high profit margins in a tax free economy (El-Sayegh, 2008). Therefore it is important to focus on contractors' attitudes towards waste and on waste generated as a result of construction site activities. In addition to excessive cut off resulting from improper design, the three aspects to be investigated in detail are Procurement, Operation and Handling. It is worth noting that waste generation is not only a technical issue but a behaviouristic one as well. Teo et al. (2000) stated that "the labour intensive nature of construction activity suggests that behavioural impediments are likely to influence waste levels significantly". This statement was supported by Lingard et al. (2000) who pointed out that effective waste minimisation depends on the extent to which participants to the construction process change their behaviour in relation to waste issues. Therefore, sources of waste revolve around four factors namely: procurement, handling, operation and culture. A review of the main origins of material waste belonging to each category is summarised in figure 1.

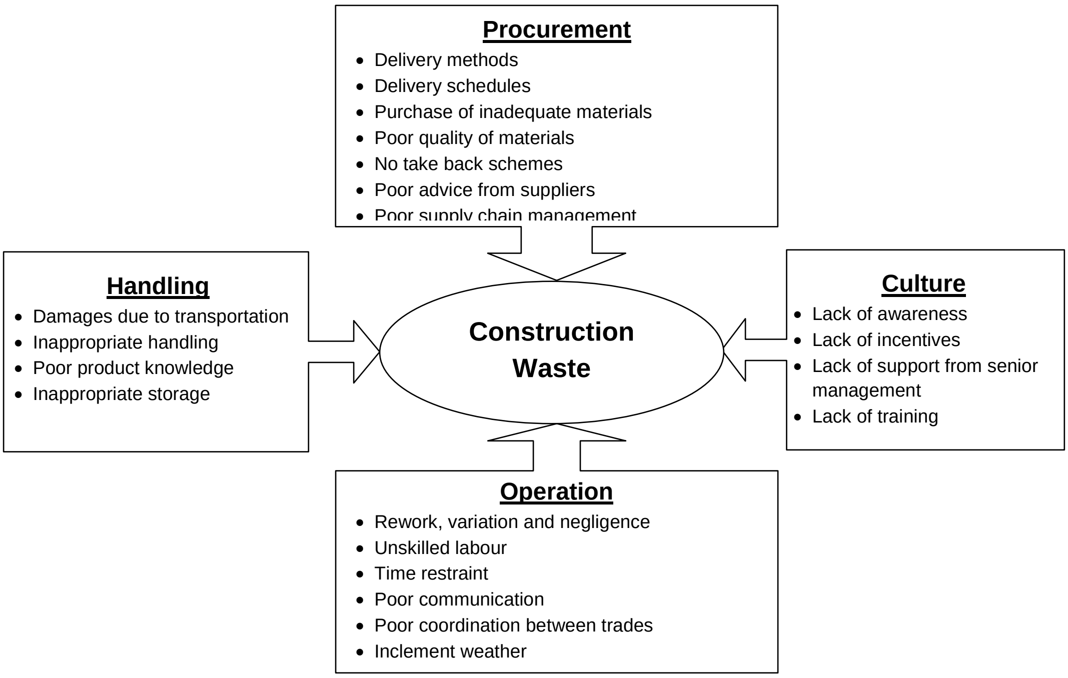

Figure 1: Origins of construction waste
(Source: Lingard et al. (2000))

4. Material waste minimisation measures

Waste minimisation, prevention and management are sometimes used interchangeably. Jacobsen and Kristofferson (2002) in their report on waste minimisation practices in Europe gave a clear distinction between the three concepts and defined waste minimisation as a set of three options prioritized according to the waste hierarchy. The first priority is waste prevention; the second is waste re-use while the third priority is waste recycle. Reducing the waste generated at source is considered as the first option to be implemented for better protection of the environment, and for better economic savings. A review of the literature suggests the following measures as the main solutions for efficient prevention of material waste on construction sites:

Logistics management: It has been the subject of many reports published by the Waste and Resources Action Programme in the UK where they emphasise the importance of implementation of a sophisticated Material Logistics Plan (MLP) on site for better waste reduction. In fact, logistics management is proven to prevent double handling and ensure the adequate handling of equipment to minimise damage to materials on site (WRAP, 2007a).

Supply chain management (SCM): It is based on long-term commitment with suppliers and subcontractors and on the win-win arrangements (Ofori, 2000). A good SCM can help to achieve Just-in-Time delivery in order to avoid waste due to long storage or to ordering unneeded materials (DEFRA, 2008; Wrap, 2007a; CIOB, 2004; Mc Donald, 1997).

Modern construction methods: A study published by WRAP (Waste & Resources Action Programme) in January 2007 shows that "the substitution of some modern methods of construction for traditional building methods resulted in a net reduction in waste levels" (Wrap, 2007c, p77). Dainty and Broke (2004) have reported the same finding in their survey of waste minimisation measures implemented in the UK; they stated that there is an increase use of off-site prefabrication to control waste and damage on site.

Training and incentivising: a number of studies and government guides insist on staff training as one of the first steps in dealing with construction waste. Increasing the awareness could be through using toolbox talks or waste posters about the benefits and rules of waste on site (WRAP, 2007b). In addition, incentives for good performers can contribute to meet the waste targets (Lingard et al., 2001).

Reuse and recycling are usually treated together in the literature. Both of these two practices require a separation of waste streams in order to be accomplished (CIRIA, 1995). In fact, the good practice of waste minimisation involves segregation of key waste streams namely: timber, plasterboard, packaging, general waste, inert waste, metal and hazardous by using clearly labelled skips or bins (Wrap, 2007b). Once the waste material is segregated, the possibilities of reuse or recycling on-site must be investigated before considering any off-site recovery or disposal (DEFRA, 2008).

5. Drivers for material waste minimisation

According to Osmani et al. (2006), the drivers for waste minimisation can be categorised into four main groups: environmental, industry, economic issues and legislation. From these broad categories, the followings can be considered as the key drivers:

Government policies and contractual terms: The reluctance to implement effective waste management has incited many governments to decree waste management laws and policies. The most common regulation is related to the landfill tax which is applied in many countries in the world. In addition to these regulations, contract document can stipulate the required levels of waste segregation and minimisation and also specify some "punitive measures for non-compliance"(Macozoma, 2002: 6).

Environmental standards and Assessment tools: Environmental Management System standards have emerged after the Rio de Janiero Summit in 1992. The world’s first standard BS7750 was developed by the BSI in 1992 followed by the Eco- Management and Audit scheme (EMAS) published by the European Union (EU) in 1993(Kein et al., 1999).The ISO 14001 for Environmental Management System (EMS) first published in 1996 has been adopted by many countries including the UAE (ISO, 2006). ISO 14001 is considered as a vehicle for organisations to minimise the impact of their activities on the environment. One of the main requirements of the ISO 14001 is waste minimisation and the development of a waste management plan as part of the EMS (Greenwood, 2004; Poon et al., 2004; Powell et al., 2001).

In addition, Environmental assessment systems for sustainable buildings such as LEED(US), BREAM (UK), CASBEE (Japan) and GLOBE (Canada) are considering construction waste management as one of the main criteria for granting credits (Shafii et al., 2006). Estidama, the bespoke rating system developed by Abu Dhabi, allocates 5 credits for waste management in construction projects (ESTIDAMA, 2008).

Financial benefits: Envirowise (2007) have proved through case studies that the true cost of waste disposal is more than the cost of paying a waste contractor to remove a skip from site and a number of researchers have highlighted the financial benefits of waste minimisation (eg. Osmani et al., 2006; Begum et al., 2006; Tam et al., 2005; Shen et al., 2005). But, the true cost of waste is still underestimated by contractors (Wrap, 2007b).

Many surveys and studies have been carried out in different countries to identify the causes of waste and assess current practices. However, no such studies have been found in the literature for the case of the UAE. By building on the findings in other countries and taking into consideration the characteristics of the UAE in terms of culture and legislation, this research aims to fill this gap by means of a carefully selected research method.

6. Research methodology

In order to investigate the causes of material waste in construction sites and to assess the current material waste minimisation practices implemented by the UAE contractors two sets of information were gathered. First, four projects with different locations; sizes, types and at different stages of construction were visited to audit material waste management on construction sites and to find out from project managers about the processes used to minimise construction waste. The results obtained from this stage were analysed and combined with the literature findings to design and to analyse the questionnaire survey. In the second stage a non random sampling approach was adopted and only medium and large companies having construction and general contracting as their primary business were targeted.

The analysis of the questionnaire was mainly based on the calculation of weighted average values and the standard deviation according to the following formulas:

(A): $$AS_i = \frac{\sum_{j=1}^{n} X_j N_{ij}}{N}$$

(B): $$\delta_i = \sqrt{\frac{\sum_{j=1}^{N} (X_j - AS_i)^2}{N}}$$

(C): $$IV_i = AS_i + \frac{AS_i}{\delta_i}$$

AS_i: the average score of the attribute (i)

X_j: the rank given to the attribute (i)

N_{ij}: the number of respondents who gave the attribute (i) the rank Xj

n: the number of possible ranks given

δ_i: Standard deviation of the attribute (i)

IV_i : Index Value of the attribute (i)

The same method has been used by Begum et al. (2006) in assessing the significance and levels of practice of waste minimisation factors in Malaysia; and by Shen and Tam (2002) in their study of the benefits of and barriers to the implementation of Environmental Management System in Hong Kong.

7. Findings and analysis

Table 1 shows general information on the four projects in the study including, project type, location, the stage it is at at the time of the study and the designation of the member of staff providing the information. Also, table 1 shows the type of waste found on site, possible causes and the measures taken to reduce material waste. Finally, general observations were provided on each project. The information about causes of waste and waste minimisation practices implemented in each project were obtained from observations during site walks and interviews with main contractors' employees.

Table 1:

	PROJECT 1	PROJECT 2	PROJECT 3	PROJECT 4
Type	Industrial zone	**Residential**	**Office**	**Residential**
Location	Abu Dhabi	**Dubai**	**Dubai**	**Dubai**
Stage	Foundation	**Finishing**	**Structure**	**Foundation**
Staff interviewed	Construction Manager Civil engineer 9 years experience	Project Director, Mechanical engineering, 35 years experience in construction	Senior Safety Advisor/ HSE Manager, 6 years experience in construction	Construction manager, civil engineers, 10 years of experience
Type of Waste	• Steel off-cuts • Wood off-cuts • Wood after repetitive use • Concrete (from temporary work) • Packaging	• Concrete, • Paint, • Plasterboard off-cuts • Cables off-cuts • Wood off-cuts • Packaging	• Wood (from off-cuts) • Steel (from off-cuts) • Concrete (during pouring) • Plastics and • Packaging	• Steel off-cuts • Wood off-cuts • Wood after repetitive use • Concrete (from temporary work) • Packaging
Waste Minimisation Measures Used	• waste segregation; • adequate storage; • recycling steel off-site (selling steel to scrap contractors); • reuse of wood and; • just in time delivery in order to minimise storage on site. • storage area was well protected and organised	• Segregation mainly for steel and wood. • Segregating other types of waste were not carried out since waste will not be recycled and will, at the end, be remixed in the landfill.	• A segregation area is available on this site especially for removing nails and preparing wood for reuse. • Using metallic reusable formwork systems to minimise wood waste. • Take back schemes were arranged for these systems but not for other materials or for packaging.	• Adequate storage • On-site segregation of waste • Bar bending lists were also used to minimise steel off cuts and the take back arrangements were made for some materials

	PROJECT 1	PROJECT 2	PROJECT 3	PROJECT 4
General observations	• The interview took place during a sustainability audit undertaken by the project management consultancy. Despite the inexistence of contractual terms about waste management, some waste minimisations measures were implemented on site. • The segregation of waste was observed during the site walk and it was noticed that only three streams of waste were separated: steel, wood and what was called by the interviewee 'construction waste'. This latter stream contains concrete, bricks, unused metal, damaged wood, plastics inter alia. • The skips intended for waste were neither labelled nor contained any indication of their content. • Specific problems faced in the UAE regarding waste minimisation: the interviewee stated that the poor quality of products is a main cause of damage particularly for wood; he further pointed out that the market conditions impose sometimes an over ordering of materials in order to avoid shortage. • No formal waste management plan was implemented on site although the interviewee stated that waste minimisation is part of their cost control and of their value management activity. • The benefits of minimising waste are related to cost savings and increased profit	• Waste management was part of the Project Director duties. • The main streams of waste at this stage of the project were: off-cuts due to standard sizes in the market (e.g. plasterboard) lack of awareness; poor quality of materials; and fast track method of construction leading to design errors and rework • Waste minimisation is considered having both economical and environmental benefits. In addition, it is believed that protecting the environment is important; but cost savings must be achieved in order to have the support of senior managers. • The main problem in the UAE, is unskilled labour and their awareness of waste minimisation and management culture.	• Waste management responsibility was formally assigned to Safety Senior Advisor. • Waste management plan is part of the health and safety plan. • The benefits of waste minimisation are the improvement of environmental and health conditions on site • Cost savings came second.	• Site is governed by a waste management plan which was submitted with the tender • No measures were undertaken for packaging waste • Three types of storage practiced as per the type of materials: uncovered, shuttled and air conditioned. • The major difficulties faced in the UAE were: lack of policies and incentives for minimising waste in addition to the price escalations that make just in time delivery impossible for some materials. • Improving the corporate image of the company and saving costs of transport and waste disposal were the benefits sought by the company through waste minimisation according to the construction manager.

Table 2: Summary of projects analysis

Projects	1	2	3	4
Causes of waste				
Poor design leading to excessive Off-cuts	✓	✓	✓	✓
Poor quality of products	✓	✓		✓
Lack of awareness		✓		
Rework and variations		✓		
Temporary works	✓			
Waste minimisation measures				
Segregation of waste	✓	✓	✓	✓
Reuse of off-cuts (wood)	✓	✓	✓	✓
Just in time delivery	✓	✓		✓
Adequate storage	✓			✓
Take back schemes			✓	✓
Bar bending lists				✓
Waste Management Plan			✓	✓
Segregation area			✓	✓
Reusable formwork			✓	
Waste minimisation benefits				
Cost savings	✓	✓	✓	✓
Environmental protection		✓	✓	
Health and safety improvement			✓	
Enhancing the corporate image of the company				✓

All the interviewees agreed that most of the waste is due to off-cuts as the sizes of materials in the market are usually different from the sizes in the design drawings. Two of them mentioned the poor quality of products as one of the main sources of damages to materials especially the quality of wood. Two further causes are reported to be the lack of awareness and design errors and variations.

The above opinions show that material waste in these projects is caused by parties other than those directly involved in the construction stage. Similar findings were reported by Ofori (2000) when he stated that waste on site is directly related to problems "on which the site personnel have very little or no influence". However, it was observed during the site walks that there are some problems of storage and handling that can eventually engender material waste. In addition, the waste minimisation measure claimed to be implemented by all the contractors particularly the segregation of waste needs more attention. Only two types of material waste are separated. These are, wood and steel. This was justified by interviewees by the fact that these two types of material are valuable and their wastage cannot be allowed. The same idea is supported by the statement of one interviewee that waste minimisation for them is part of their cost control and value engineering activities. Furthermore, the major benefit of waste minimisation considered by all interviewees is related to cost savings.

All the facts cited above lead to the conclusion that material waste minimisation is not construed as a mean to achieve sustainable construction and to save natural resources but as a financial solution to increase profit. Therefore, there is a large scope for changing the attitude of construction companies towards the problem of material waste in construction.

Industry survey on material waste measurement

56 responses were received from 120 questionnaires distributed giving a 46% response rate.
The survey helps collecting information on the existence of systems for recording and measuring waste. It also provides a measure of the waste levels of the most common waste streams used in the construction industry.

It was asked to choose between 5 intervals: 1-5%; 6-10%; 11-20%; 21-50% in addition to the 0% waste. The results showed that 62% of the companies have a system of recording and measuring waste on site. This is an encouraging result for the promotion of waste minimisation in the UAE construction industry. However, this does not give a clear idea about the methods of measurement and the accuracy in measuring waste. Hence, the question about the rates of different streams of waste.

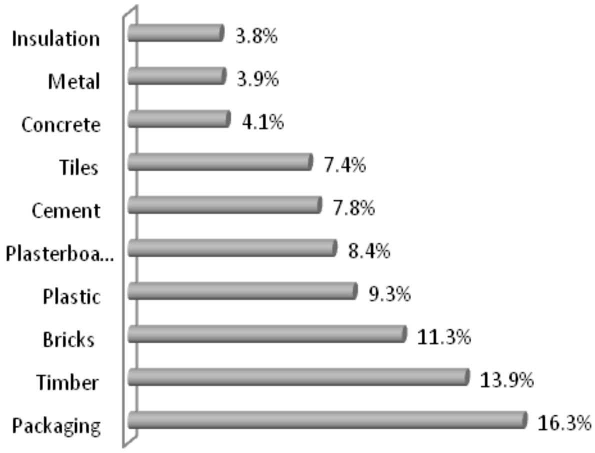

Figure 2: Waste rates

Table 3: Waste levels: standard deviations

Waste category	**Mean**	**Standard deviation**
Insulation	3.8%	2.1%
Metal	3.9%	2.6%
Concrete	4.1%	2.3%
Tiles	7.4%	3.6%
Cement	7.8%	6.7%
Plasterboard	8.4%	8.7%
Plastic	9.3%	6.6%
Bricks	11.3%	10.1%
Timber	13.9%	10.9%
Packaging	16.3%	12.2%

The results illustrated in figure 2 were obtained by calculating the averages of the medians of each interval (i.e. 1-5% is replaced by 3%; 6-10% by 8%; etc). The results obtained look realistic as most of them fall within or close to the ranges provided as findings of several case studies undertaken by WRAP (2007b). However, the waste rate of packaging is less than the range given and this can be due to possible misunderstanding by respondents (11 respondents put 0% waste for this category) or the underestimation of packaging as an important waste stream of construction and its exclusion from measurement and recording. Moreover, it is noteworthy that the responses exhibit significant deviations as it is illustrated in table 2. In fact the high variation in waste rates proves that there is great difference in the practices used to measure and manage waste on site. More extended and detailed case studies are needed to assess the degree and the sources of such significant differences.

Furthermore, as it was highlighted in the literature review that waste measurement is one of the pillars of an efficient waste minimisation. In order to assess the impact of such tool on the waste levels generated on site; a t-test for two samples will be used. The null hypothesis is set as: "there is no difference between the waste levels of respondents who have a system of waste measurement and the respondents who don't have that system". The results for the different categories are shown in table 3 below.

Table 4: T-test results for waste rates

	Mean		**Variance**		**t-stat**	**P(T<=t) one-tail**	**t Critical one-tail**
	Sample1	Sample2	Sample1	Sample2			
Concrete	3.97	4.19	5.44	4.76	**-0.35**	0.36	**1.68**
Timber	11.40	18.10	58.48	198.19	**-2.01**	0.03	**1.70**
Metal	3.20	5.00	5.22	7.50	**-2.53**	0.01	**1.69**
Bricks	18.11	15.52	115.81	76.86	**0.98**	0.17	**1.68**
Plasterboard	6.66	11.43	23.76	150.86	**-1.70**	0.05	**1.71**
Packaging	15.09	18.29	142.32	162.51	**-0.93**	0.18	**1.68**
Tiles	7.66	7.10	11.53	16.49	**0.53**	0.30	**1.69**
Insulation	3.54	4.19	3.90	4.76	**-1.11**	0.14	**1.68**
Plastic	9.91	8.24	57.67	19.69	**1.04**	0.15	**1.67**
Cement	7.06	9.10	41.70	48.79	**-1.09**	0.14	**1.68**

From the results, it can be concluded that although the percentage of companies using a system of measuring waste is relatively high, no difference was found between the mean values given by the two categories of respondents for most of the waste streams. The two waste categories for which there was a significant difference in waste levels were metal and timber. These two materials are indeed highly considered by contractors because of their high monetary value as it was concluded from the projects in table 1. This is why they are separated and measured to keep their wastage to a minimum.

Causes of material waste

The list of causes of material waste given in the questionnaire was derived from the literature review and the projects visited. Respondents were asked to estimate the amount of waste generated in their projects between the ranges of no contribution (1) to significant contribution (4).

An analysis of the responses is shown in Table 5. Three factors have been identified with a mean greater than 3 (more than a moderate contribution). These factors are namely: (i) Lack of workers' awareness, (ii) Poor design, resulting in excessive off-cuts, and (iii) Unskilled labour and rework. Poor design is clearly outside the contractors' control. It may be the case that 'lack of awareness' in the construction industry workforce could be considered as a general issue, related to the culture of the construction industry in the UAE, where sustainable practices and environmental impact are not a priority and hence, are out of the contractors' control. However, contractors have a responsibility and a role to play in raising environmental awareness, particularly in relation to minimising construction material waste on site. Factor 3, Unskilled labour and rework, was considered by Smith (2008) to be a cause of off-cuts, as a result of the construction boom in the UAE, and the increasing demand for workers regardless of their level of experience and competence. Although this description summarises the 'status quo' in the UAE construction industry, it should not acquit the contractors from their responsibilities towards waste production and management. It is the contractor's obligation to raise awareness and provide a suitably trained workforce to reduce waste produced on site.

Table 5 ranks an additional six factors related to the procurement category of sources of waste. (Ranking 8-13 in table 5 in order of significance).

1. Damages during delivery and transport
2. Poor quality of products
3. Purchase of inadequate materials
4. Over-ordering of materials
5. Poor advice from suppliers
6. Inadequate packaging

The six factors listed above have a weighting of less than 2.5 and therefore have been identified as making a minimal contribution to waste production. They are all part of the procurement process, which is an area directly controlled by the contractor. This analysis agrees with the findings of the study undertaken by Ekanayake and Ofori (2000) who reported that contractors did not consider procurement-related factors as major contributors to site waste generation.

Table 5: The ranking of direct causes of waste

	4	3	2	1	Weighted Average	Standard deviation	Index value	Rank
Lack of workers' awareness	38	18	0	0	3.68	0.47	11.48	**1**
Poor design (resulting into off-cuts)	17	30	8	1	3.13	0.72	7.50	**2**
Unskilled labour and rework	17	26	13	0	3.07	0.74	7.25	**3**
Time Pressure	10	27	16	3	2.79	0.80	6.26	**4**
Problems of handling	2	26	25	3	2.48	0.66	6.24	**5**
Inappropriate storage	3	20	30	3	2.41	0.68	5.95	**6**
Inclement weather	7	22	24	3	2.59	0.78	5.90	**7**
Damages during delivery and transport	0	5	42	9	1.93	0.50	5.79	**8**
Poor quality of products	3	10	37	6	2.18	0.69	5.33	**9**
Purchase of inadequate materials	1	26	17	12	2.29	0.82	5.06	**10**
Poor advice from suppliers	6	16	25	9	2.34	0.88	5.00	**11**
Over ordering of materials	3	13	21	19	2.00	0.89	4.24	**12**
Inadequate packaging	1	2	3	51	1.13	0.43	3.75	**13**

Four indirect causes of waste were identified through interviews. Answers were given in the range of strongly disagree (1) to strongly agree (5). The results presented in table 6 demonstrate that the majority of respondents consider the lack of government legislation and policies as the main barrier to the reduction of material waste generated in construction sites in the UAE. Furthermore, 55% of respondents agree that contractual terms can be used as an incentive to minimise material waste on construction sites. The lack of local recycling facilities (ranked third) was considered as a real barrier to reducing material waste in projects. Lack of support from Company management was not currently considered a critical cause towards waste generation, according to this study. The other factors in this category have taken precedence, and this can be demonstrated by the differential in the weighted average score between ranking 3 and 4.

Table 6: Ranking of indirect causes of waste

	5	4	3	2	1	Weighted Average	Standard deviation	Index value	Rank
Lack of government legislation and policies	32	20	4	0	0	**4.50**	**0.63**	**11.62**	**1**
Lack of contractual incentives	14	31	11	0	0	**4.05**	**0.67**	**10.09**	**2**
Lack of local recycling facilities	28	19	7	2	0	**4.30**	**0.83**	**9.49**	**3**
Lack of support from the company managers	4	17	0	22	13	**2.59**	**1.33**	**4.53**	**4**

Material waste minimisation measures

The analysis on material waste minimisation measures was based on rates of frequency of implementing Waste Management Plan on site. The range of frequency ranged from Never (1) to Always (4).

Table 7: Frequency of implementation of material waste minimisation measures

	4	3	2	1	Weighted average	Standard deviation	Index value	Rank
Adequate storage of material	45	10	0	1	3.77	0.54	10.76	**1**
Ordering just what is needed of material	11	41	3	1	3.11	0.56	8.64	**2**
Staff training and awareness	31	17	7	1	3.39	0.78	7.75	**3**
Recording and measuring different streams of waste	20	26	8	2	3.14	0.80	7.09	**4**
Using mechanical handling of materials	19	21	13	3	3.00	0.89	6.35	**5**
Segregation of waste on site	27	11	14	4	3.09	1.01	6.14	**6**
Prefabrication of components off-site	1	7	38	10	1.98	0.62	5.19	**7**
Ordering material to size	0	11	20	25	1.75	0.77	4.03	**8**
Take-back arrangement with suppliers	0	7	21	28	1.63	0.70	3.94	**9**
Reuse on site of off-cut material	0	6	21	29	1.59	0.68	3.92	**10**
Incentives to site personnel	0	7	19	30	1.59	0.71	3.83	**11**
Recycling on site	0	3	9	44	1.27	0.56	3.55	**12**
Recycling off-site	1	11	6	38	1.55	0.87	3.33	**13**
Appointment of waste manager on site	2	6	9	39	1.48	0.83	3.27	**14**

Scale: Always (4); Sometimes (3); Rarely (2); Never (1)

12% of the respondents affirm that they always implement a Site Waste Management Plan (SWMP). Of the remaining 88%, 29% never used it and 59% used it rarely or sometimes.

Studies undertaken in different countries (e.g. Poon et al., 2004; Shen and Tam, 2002; Mcdonald and Smithers, 1998) have proven the effectiveness of the SWMP approach as an important measure in reducing waste generation on construction sites. This analysis shows that there is a poor implementation of the technique on construction sites in the UAE. An increase in the use of SWMP in UAE projects will have an immediate impact in the level of material waste generated on site. However, some measures, such as those highlighted in table 7, can be applied without a SWMP in place.

The analysis presented in table 7 shows that the top three measures of waste minimisation fall within the first level, which is waste prevention, as explained in Section 4. These measures are (i) adequate storage of material, (ii) ordering just what is needed and (iii) staff training and awareness. Obviously, this is a preferred option to most if not all companies. It is better to prevent waste from the outset rather than dealing with it after it is generated.

The three measures that the analysis shows to be less frequently implemented in the industry are namely (i) recycling on-site, (ii) recycling off-site and (iii) appointment of waste manager on site. It is important to note that recycling off site is rarely carried out because of the lack of recycling facilities, as previously stated. Furthermore, recycling on site and the appointment of a waste manager would be the least preferred option for contractors because it would be a cost item.

For this purpose, the existence of relationship between the ranking of causes of waste obtained from table 5 and the ranking of the preventive measures in the table 7 was tested. According to Naoum (2007), the most appropriate statistical test when assessing ordinal data that are related to more than one attribute is the Spearman Rank Correlation test and; so a critical value for 56 subjects was set at 0.4433 at the level of $p > 0.005$. The value of rho was obtained by using the CORREL statistical function in Excel. The null hypothesis was set as: “there was no significant relationship between the ranking of the preventive waste minimisation measures and the correspondent causes involving these measures". Table 8 shows the results found for the three firstly ranked measures.

Table 8: Correlation test between causes and preventive measures

Preventive measure	**Cause of waste**	**ρ**
Waste minimisation training and awareness	Lack of awareness	**+0.65**
Adequate storage of material	Inappropriate storage	**-0.56**
Ordering just what is needed of material	Delivery schedules	**-0.69**

The following conclusions can be drawn from the analysis table 8: All the coefficients in absolute value exceeded the critical value of 0.4433 and it was concluded that the null hypothesis should be rejected. In addition, the positive correlation between the ranking of 'Waste minimisation training and awareness' and 'Lack of awareness' can be interpreted in two ways: 1) this measure is frequently used because lack of awareness is considered as a high contributor to waste or 2) Lack of awareness is still considered as a significant factor because the training and awareness activities were not sufficiently efficient. Finally, The negative correlation between the rankings of 'adequate storage on site' and 'inappropriate storage'; and between 'ordering just what is needed of materials' and 'delivery schedules' indicate that the two factors are considered of minimal contribution to the generation of material waste because of the frequent implementation of the appropriate measures.

It cannot be easily concluded that the other preventive measures are used with less frequency because their correspondent causes were overlooked by respondents. This can be due to financial considerations such as in the case of 'ordering material to size' or to the rules of the market as it can be the case of 'take back arrangements with suppliers' as it was mentioned by the interviewees in the sites visited. For example, an investigation of a correlation between 'using prefabricated components' and 'off-cuts' gave a coefficient of 0.09 which indicates that there is no significant correlation between the two attributes. This can be interpreted by the fact that this measure of using prefabricated components can be for other purposes such as time saving and quality improvement and not necessarily to reduce off-cuts.

Benefits of material waste minimisation

The analysis on the benefits material waste minimisation in table 9 shows that the material waste minimisation is currently driven by the immediate financial benefits, not legislations or care for the environment. Similar conclusions were drawn on the four projects included in this study and in the literature.

Table 9: Ranking of waste minimisation benefits								
	4	**3**	**2**	**1**	**Weighted average**	**Standard deviation**	**Index value**	**Rank**
Increased profit	33	20	2	1	3.52	0.66	8.85	**1**
Cleaner and safe site conditions	24	26	5	1	3.30	0.71	7.95	**2**
Saving cost of disposal and transport	8	30	13	5	2.73	0.82	6.06	**4**
Enhancing the image of the company as a green contractor	18	23	8	7	2.93	0.99	5.89	**5**
Protection of the environment	10	17	12	17	2.36	1.10	4.50	**6**

Scale: Very important (4); Moderately important (3); Slightly important (2); Not alt all important (1)

The second important benefit in the ranking is getting a ‘cleaner and safer site conditions’ with a mean value of 3.30. This indicates that the health and safety issues are more than moderately important for the industry and that it is climbing the ladder to become a priority. This finding is evidence of the increasing interest and awareness in health and safety issues in the UAE. This is reported by Alkaabi et al. (2003) and observed during the projects site visits. The next financial benefit is related to saving cost of disposal and transport, has a mean of 2.73 which supports the finding in table 4 that the costs of disposal to landfill are not very high in the UAE and represent a minimal incentive for material waste minimisation.

The environmental benefits of waste minimisation are ranked last by respondents, yet the mean of 'enhancing the image of the company as green contractor' is 2.93 indicating that it is almost moderately important for them. In contrast, the mean value of 'protection of the environment' is relatively low and 30% of the respondents perceive this benefit as being not important at all for them. It can be concluded then that while economical and health and safety benefits are strong drivers for waste minimisation, the environmental benefits are still overlooked by most of the contractors.

8. Conclusions

This paper examines the various causes of material waste and waste minimisation practices implemented in UAE construction sites. The perceptions of contractors on the benefits of waste minimisations have also been investigated.

The following conclusions can be drawn from this study:

1. The main direct causes of material waste in the UAE construction sites are: workers' lack of awareness; poor design resulting in excessive off-cuts; and the rework and variations. In contrast, the factors emanating from poor logistics management and procurement problems were considered as being of low significance.
2. The indirect causes of material waste were found to be the lack of legal and contractual incentives.
3. The current practices implemented by contractors to minimise material waste on construction sites are: adequate storage, staff training and awareness, and ‘just- in time’ delivery.
4. Material waste recycling is rarely practiced. In addition, waste measurement and waste segregation are two practices that need to be implemented more efficiently in UAE construction sites.
5. Cost savings and increasing profits are considered, by most contractors in the UAE construction projects to be the most important benefits and incentive for material waste minimisation.
6. The environmental benefits are neglected, overlooked and considered as less important by contractors in the UAE construction sites.

The effectiveness of the waste minimisation measures implemented could be further investigated based on the content of this research. In addition, construction waste in order to be managed should be integrated and taken into consideration at the planning and design stages of the project.

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