

MATERIAL WASTE IN THE NORTHERN IRELAND CONSTRUCTION INDUSTRY: ON-SITE MANAGEMENT CAUSES AND METHODS OF PREVENTION

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The construction industry in Northern Ireland is one of the major contributors of construction waste to landfill each year. The aim of this research paper is to identify the core on-site management causes of material waste on construction sites in Northern Ireland and to illustrate various methods of prevention which can be adopted. The research begins with a detailed literature review and is complemented with the conduction of semi-structured interviews with 6 professionals who are experienced and active within the Northern Ireland construction industry. Following on from the literature review and interviews analysis, a questionnaire survey is developed to obtain further information in relation to the subject area. The questionnaire is based on the key findings of the previous stages to direct the research towards the most influential factors. The analysis of the survey responses reveals that the core causes of waste generation include a rushed program, poor handling and on-site damage of materials, while the principal methods of prevention emerge as the adequate storage, the reuse of material on-site and efficient material ordering. Furthermore, the role of the professional background in the shaping of perceptions relevant to waste management is also investigated and significant differences are identified. The findings of this research are beneficial for the industry as they enhance the understanding of construction waste generation causes and highlight the practices required to reduce waste on-site in the context of sustainable development.

Keywords: construction planning, design management, recycling, waste management.

INTRODUCTION

It is an unquestionable fact that the construction industry makes a valuable contribution to the competitiveness and prosperity of the country's economy accounting for 8% of Gross Domestic Product and providing employment for around 3 million workers (HM Government, 2008). However, the official UK government statistics reveal that the construction sector is also the largest contributing sector to the generation of waste, with more than 100 million tonnes per year. Construction waste is a mixture of inert and non-inert materials arising from various construction activities and could include materials such as soil and sand, brick and blocks, concrete and aggregate, wood, metal products, roofing materials, plastic materials and packaging of products (Begum *et al.* 2006).

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The influential report “*Rethinking Construction*” by Egan (1998) highlighted the fact that there is plenty of scope for improving efficiency and quality of UK construction simply by taking waste out of it. Furthermore, reducing waste is a high priority issue in the European and UK recent years' sustainability agenda. For example, in the 2008 Strategy for Sustainable Construction the Government included the target to halve construction, demolition and excavation waste going to landfill by 2012. Moreover, the European Union with its 2008/98/ EC Directive establishes the legal framework for the treatment of waste within the Community and defines prevention as the top of the waste hierarchy and the number one priority for waste management. It also identifies reuse and recycling as the next acceptable levels in the waste management hierarchy and urges all Member States to take measures for the appropriate treatment of their waste. In this context, construction is under increasing pressure to improve performance, reduce waste and increase recycling.

Specifically for Northern Ireland, landfilling has historically been the main disposal route for construction and demolition waste, often under the guise of agricultural land improvement at authorised sites which are exempt from licensing (DOENI 2013). The current estimate is that around 4 million tonnes of construction and demolition waste are produced annually, of which only 1.3 million tonnes (33%) is currently reused or recycled while up to 1.7 million tonnes (42.5%) per year is illegally dumped (DOENI 2010). In fact, in Northern Ireland there is a shortage of legal landfill space and this will become more severe in future years. It is therefore vital to minimise waste on construction sites (Dep. of Finance and Personnel 2010). The ambitious future target included in the 2006-2020 N. Ireland Waste Management Strategy is to achieve the 75% of construction and demolition waste being recycled or reused by 2020 which means that 3 million tonnes should be reused or recycled every year (DOENI, 2006).

The results of a survey on the waste management practices and perceptions of construction industry practitioners in Northern Ireland are presented in this paper, aiming to enlighten the major waste generation causes and highlight the most effective methods of waste prevention.

LITERATURE REVIEW

Waste is a major issue for the construction industry both from the perspective of efficiency and protection of the environment. Currently in the UK, slightly more than 100 million tonnes of construction and demolition waste ends up as landfill – of which 16% apparently is material delivered and then thrown away unused (Myers 2013).

Difficulties inherent in construction waste management process have been highlighted in the literature. Kwan *et al.* (2001) note that commonly on construction sites the responsibility for the waste generated on-site is not clear and cannot be allocated to one specific group of people therefore leaving it extremely hard to enforce. In addition, Teo *et al.* (2000) highlight the fact that the labour-intensive nature of construction activity suggests that behavioural impediments are likely to influence waste levels significantly. Teo and Loosemore (2001) provide relevant evidence exploring people's attitudes to waste and notice that a lack of managerial commitment and support for the issue of waste often, results in inadequate resources, manpower and time being devoted for waste management activities.

Many surveys and studies have been carried out in different countries to identify the causes of construction waste and assess the relevant minimisation practices in the industry. Al Hajj and Hamani (2011) focused on practices implemented in UAE

construction sites and concluded that the factors contributing the most to the generation of material waste are the workers' lack of awareness, poor design, rework requirements and lack of legal and contractual incentives. Furthermore, they highlighted the important role of adequate storage, staff training and Just-In-Time (JIT) delivery to the minimization of waste. The study by Formoso *et al.* (2002) encompassing 74 building sites in Brazil demonstrated that a large proportion of material waste occurs because of poor material delivery, transportation and handling as well as due to poor detailing and coordination in design and lack of site layout planning. Cha *et al.* (2009) investigated waste management practices in the Korean industry and highlighted the importance of factors like the contractor's commitment, the use of standardized materials and the appointment of labourers solely for waste disposal.

In the UK, the Department for Environment, Food and Rural Affairs sets the context of a resource efficient approach and suggests careful choice of materials and methods of construction during the design phase, proposes the incorporation of waste management targets into tender specifications, encourages the introduction of regular toolbox talks with workers and highlights the role of adequate ordering, delivery and storage of materials (DEFRA 2008).

The Site Waste Management Plans (SWMPs) are also considered as an important tool for construction companies and their clients, to improve their environmental performance and reduce costs of disposing of waste. A SWMP details the amount and type of waste that will be produced on a construction site and how it will be reused, recycled or disposed of. The plan is then updated during the construction process to record how the waste is managed and to confirm the disposal of any materials that cannot be reused or recycled at a legitimate site. The use of SWMP has been associated not only with environmental benefits, but also with economic benefits. A cost-benefit analysis conducted in the context of the UK-wide Waste and Resources Action Programme (WRAP) specified that the average saving for the 15 case studies (including housing, public and commercial projects) was about 0.8% of the construction value, which however can equate to a large saving. Furthermore, evidence from a detailed questionnaire survey suggested that using a SWMP has been beneficial to the majority of organisations and most achieved significant cost savings (WRAP 2009). SWMPs have been used in the construction industry for several years and in April 2008 they became a legal requirement for construction and demolition projects over £300,000 (exc VAT) in England. The implementation of a SWMP is not currently compulsory within N. Ireland.

INVESTIGATION OF WASTE MANAGEMENT PRACTICES IN N. IRELAND

Qualitative Research

Six semi-structured interviews were conducted with relevant professionals ranging from Project Managers and Site Managers to Trade Foremen with an average construction experience of 16.5 years. Each of them lasted about 20 minutes and was conducted in person. These interviews enabled first-hand knowledge to be obtained from people who are experienced and active within the Northern Ireland construction industry and deal with the situation of material waste on-site on a daily basis.

The first three interviewees were the sustainability manager, the assistant construction manager and a site foreman of a large company with a large number of employees and

sub –contractors, based in Enniskillen. When asked about the waste generation causes, the sustainability manager highlighted the rushed programme and the poor handling, the assistant construction manager emphasized on inadequate storage facilities and design related issues and the site foreman highlighted the role sub-trades in excessive construction waste generation along with over ordering of materials.

The same interviewees also highlighted a number of key methods of prevention of material waste. The sustainability manager suggested good planning and the use of segregated skips to deal with waste recycling on-site. He also mentioned the idea of designing out waste i.e. the designers analysing, controlling and reducing the waste implications of their solutions. The assistant construction manager detailed the reuse of materials as a prevention method along with the adherence to the SWMP which was considered a crucial element of the waste reduction process. The site foreman suggested JIT deliveries and good site management as key factors in SWMP adherence and the prevention of material waste. Furthermore, the use of segregated skips to ensure efficient recycling and tool box talks to increase awareness on site were also mentioned as efficient methods to reduce material waste.

The rest three people interviewed on-site were a Project manager, a site manager and a site foreman of a smaller scale construction company in Belfast.

The project Manager detailed that large skips caused increased amounts of waste to be disposed with the workforce just simply ignoring the reuse of materials. He also stated that providing adequate storage facilities helped prevent materials damage and also detailed that sufficient disposal facilities encourage effective recycling and therefore prevent waste on-site. The site manager additionally suggested ensuring adequate time is set aside for material waste management systems on-site while the site foreman highlighted the criticality of good crew coordination and having adequate space for segregation, especially on confined sites.

The summary of the key issues most commonly mentioned by the 6 interviewees with regards to the waste generation and prevention are presented in Table 1. These concepts along with other secondary ones which were also mentioned (e.g. tool box talks, the role of subtrades) were used to produce the questions included in the detailed questionnaire.

Table 1: Key findings of interviews

	1	2	3	4	5	6
Design related issues	✓	✓		✓	✓	✓
Materials handling, management and on-site storage	✓	✓	✓	✓	✓	
Reuse / recycle of materials and use of proper skips	✓	✓	✓	✓		✓
SWMP implementation		✓	✓			✓
Rushed program / Time management	✓				✓	

Quantitative Research

In order to further the topic of on-site management and material waste on construction sites within the Northern Ireland industry, a questionnaire survey incorporating the

key findings of the interview process detailed previously, was also undertaken. The questionnaires were sent out via email to a wide range of different people spanning over different professions to encourage a more widespread feedback from all perceptions.

The questionnaire consisted of 3 different sections. Section A included four general multiple-choice questions in relation to the particulars of the respondents (job title, years of experience in the industry, type and size of organization they work in). Sections B and C included a range of statements in relation to the causes of construction materials waste and the methods of prevention, respectively. The respondents were asked to indicate their level of agreement/disagreement with the statement, choosing a number from 1 to 5, according to the following scale:

- (1) Disagree
- (2) Slightly disagree
- (3) Neither agree nor disagree
- (4) Slightly Agree
- (5) Agree

Section C also allowed the people questioned to make additional comments relevant to the research in a separate column.

Results Analysis

Section A - Respondents particulars

70 questionnaires were sent out and 45 responses were received in total (response rate 64.3%). According to the details that the respondents provided regarding their job title, they can be broken down as follows; 6 Project Managers(13%), 10 Construction/Site Managers (22%), 7 Site Engineers (16%), 8 Quantity Surveyors 18%, 8 Architect/Designers (18%), 5 Health and Safety Officers (11%) and 1 Other (2%).

With regards to the type of their organisation, 23 respondents (51%) worked with main contractors, 16 (36%) with sub-contractors and 6 (13%) in a public body. The 45% of the organisations (20 in total) was medium-sized (25-75 people), 33% (15 organisations) of large size (>75 people) and 22% (10 organisations) of small size (<25 people).

With regards to the work experience of the respondents in the construction industry, 18 (40%) had less than 5 years of experience, 6 (14%) had experience between 6 and 10 years, 5 (11%) between 11 and 15 years, 10 (22%) between 16 and 20 years and 6 (13%) had experience greater than 20 years. The considerable percentage of respondents with little experience (0-5 years) may have been beneficial to the research, as the younger generation of construction workers, is probably more aware of the importance of incorporating material waste management systems into design and construction.

Section B- Construction waste causes

In this section the respondents were asked to indicate their level of agreement / disagreement with different statements directly connecting the waste generation with the following factors: Rushed program, Design issues, Damaged materials, Packaging waste, Sub trades, Poor handling, Odd sized components, Over ordering of materials, Lack of sufficient time for waste management and Poor scheduling of deliveries.

The weighted average values of the respondents' level of agreement (ALA) with each statement and the standard deviation (SD) were then calculated using the formulas (1) and (2),

$$ALA_i = \frac{\sum_{j=1}^n LA_j N_{ij}}{N} \quad (1)$$

$$SD_i = \sqrt{\frac{\sum_{j=1}^n (LA_j - ALA_i)^2}{N}} \quad (2)$$

where ALA_i is the average level of agreement for the factor i , LA_j the level of agreement chosen (1-5) for the factor i , N_{ij} the number of respondents who chose the j th level of agreement (LA_j) for the factor i , n the number of different available agreement levels, SD_i the standard deviation of the acceptance level for the factor i , N the total number of respondents.

According to Shen and Tam (2002) the commonly recognized weakness involved in using the weighted average as a ranking criterion is that it does not consider the degree of variation between individual responses. The typical technique used to mitigate this weakness is to apply the Coefficient of Variation (CV), obtained through dividing the weighted average by the standard deviation, as in formula (3).

$$CV_i = \frac{ALA_i}{SD_i} \quad (3)$$

Thus the different factors ranking should result from the Index Value for each factor IV_i , easily determined after considering both the weighted average and the coefficient of variation, according to the formula (4).

$$IV_i = ALA_i + CV_i \quad (4)$$

The views of the respondents in relation to the main causes of construction waste generation on site are presented in Table 2.

It can be seen that the average level of agreement for the 5 out of 10 statements is equal or greater than 4, which denotes wide acceptance of the rushed program, design issues, damaged materials, poor handling and odd-sizes components as waste generating causes. The statements correlating waste to poor scheduling, lack of time, over ordering of materials and packaging were also accepted by the respondents but at a lower average level of agreement. Finally, the statement linking waste with sub trades was rejected as the relevant ALA was below 3. Taking into account the standard deviation of the responses, the five factors with the greatest contribution to the generation of waste are: Poor handling, rushed program, damaged materials on-site, odd-sized components and design issues.

Table 2: Acceptance level and ranking of waste generation causes

Statement	ALA	SD	CV	IV	Rank
St. 1: Rushed program leads to increased material waste on-site	4.20	0.757	5.550	9.75	2
St. 2: Design issues are a major contributor to material waste on-site	4.18	1.134	3.686	7.87	5
St. 3: Damaged materials on-site lead to more waste disposed	4.36	0.908	4.799	9.16	3
St. 4: Packaging waste is a major issue within the industry	3.89	1.092	3.563	7.45	6
St. 5: Sub trades on-site are main contributors to waste	2.78	1.491	1.865	4.65	10
St. 6: Poor handling creates more waste on-site	4.02	0.543	7.402	11.42	1
St. 7: Odd sized components increase waste with off cuts etc.	4.24	1.069	3.965	8.21	4
St. 8: Over ordering of materials contributes to on-site waste	3.76	1.417	2.654	6.41	9
St. 9: There is not sufficient time allowed for material waste management on-site	3.84	1.476	2.601	6.44	8
St. 10: Poor scheduling of deliveries leads to increased volumes of waste on site	3.98	1.196	3.327	7.31	7

Section C- Construction waste methods of prevention

In this section the respondents were asked to state their level of agreement / disagreement with the consideration of the following factors as contributing factors to the waste generation minimisation: Site Waste Management Plans, Designing out waste, JIT deliveries, Adequate storage, waste targets for sub-trades, segregated skips, efficient ordering of materials, timescale of project, reuse of materials, tool-box talks.

The views of the respondents in relation to waste prevention methods on site were analysed as detailed in the previous sub-section and are presented in Table 3.

Table 3: Acceptance level and ranking of waste prevention methods

Statement	ALA	SD	CV	IV	Rank
St.1: The use of a Site Waste Management Plan (SWMP) is important	4.42	0.753	5.866	10.29	4
St. 2: Designing out waste reduces material management issues on-site	4.24	1.069	3.965	8.21	8
St. 3: Just In Time (JIT) deliveries ensure less material waste	4.22	0.951	4.438	8.66	5
St. 4: Adequate storage lessens the amount of damaged material on-site	4.29	0.626	6.853	11.14	1
St. 5: Targets set for sub trades in terms of waste ensure less wastage	4.18	0.936	4.464	8.64	6
St.6: Segregated skips on site ensure effective recycling	4.09	0.900	4.544	8.63	7
St. 7: Efficient ordering of materials reduces waste	4.51	0.758	5.954	10.46	3
St. 8: Timescale of project can ensure effective waste reduction on-site	3.80	1.375	2.763	6.56	10
St.9: Maximizing the reuse of materials lessens the impact of waste	4.42	0.723	6.116	10.54	2
St.10: Tool box talks on-site raise awareness	4.02	0.965	4.166	8.19	9

It can be seen that the average level of agreement for the 9 out of 10 factors reviewed is equal or greater than 4, which denotes wide acceptance of the factor as waste prevention method. The last factor, which is the project's timescale can also be considered acceptable as its ALA is 3.8. Taking into account the standard deviation of the responses, the five more widely accepted factors as waste prevention methods are the adequate storage of materials, the reuse of materials, the efficient ordering of materials, the use of SWMP and JIT deliveries of materials.

DISCUSSION

The results of the survey were further analysed in correlation with the job role of the respondents to allow for different perceptions resulting from different professional backgrounds to be revealed. For this purpose the respondents were grouped in three different groups: Group1: designers/architects, Group2: construction /project managers and Group3: site-related post holders (site managers and engineers, quantity surveyors, health and safety officers). As presented in Table 4, all the three groups rank the statements 3,4,5 and 9 referring to the role of damaged materials, packaging, sub trades and time at the same or similar (up to two places higher or lower) position. The ranking for statement 7 referring to the role of odd-sized components is significantly different across the different groups: although odd-sized components are considered the most important factor by the group of Managers, site-related post holders give this factor the fourth place while designers consider it even less important than the majority of the factors reviewed, ranking it at the eighth place. Furthermore, the views of designers (Group1) and site-related post holders (Group3) broadly coincide with regards to the statements 1, 2, 6 and 10 referring to rushed program, design issues, poor handling and poor scheduling of materials for which the group of managers seems to have different views. Especially for the statement referring to the role of poor handling in waste generation (st.6) it is worth noting that both groups 1 and 3 have ranked it first while the group of managers (Group2) has ranked it fifth. Finally, the role of materials' over ordering (st.8) seems to be much more appreciated by designers and managers than by the site-related post holders who rank it at the bottom of the list (group 3).

Table 4: Ranking of waste generation causes per group of professionals

	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10
Group1	3	5	4	7	9	1	8	2	10	6
Group2	6	8	3	7	10	5	1	3	9	2
Group3	2	5	3	7	10	1	4	9	8	6

With regards to the various waste prevention methods, the respective group analysis of the responses (Table 5) reveals that there is significant diversity of views across the different groups.

Table 5: Ranking of waste prevention methods per group of professionals

	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10
Group1	1	9	7	4	6	8	1	10	1	5
Group2	3	1	4	6	5	2	8	10	7	9
Group3	4	6	5	2	9	7	1	8	3	10

The most noteworthy difference concerns the role of efficient ordering of materials which is ranked first by designers and site related job holders while the group of managers only give it the eighth place. On the other hand, managers' list has at the first place the factor of designing out waste, which quite unexpectedly is given the ninth place by the "responsible" group of designers. Finally, it is also apparent that the use of SWMPs is widely acceptable across the different disciplines as all the three groups have ranked it highly.

CONCLUSIONS

The construction sector is the UK largest contributing sector to the generation of waste, with more than 100 million tonnes per year. Therefore, the effective management and reduction of construction's enormous quantity of waste is a goal as well as a major challenge for the industry. This research investigated the perceptions of construction practitioners in Northern Ireland with regards to the causes of construction waste generation and the methods of prevention. Key factors in waste management as identified by the semi-structured interviews are the project's design, the proper materials handling, management and on-site storage, the reuse/ recycle of materials and use of proper skips, the implementation of the SWMP and the adequate time management of construction processes. To supplement the viewpoint of the interviewees, a questionnaire survey was undertaken to capture the views of a greater number of professionals. The 45 survey respondents confirmed that waste generation is attributed to both design inefficiencies like odd-sized components as well as on-site related factors like poor handling and on-site damage of materials. Additionally, it emerged that the reuse of materials is a key factor for the successful waste prevention and this is the case for the SWMPs as well, although their use is currently not compulsory in Northern Ireland. Other factors widely accepted by the respondents as preventing waste generation are the efficient ordering of materials, their delivery JIT and the adequate storage facilities. Furthermore, the results of the survey were analysed in correlation with the job role of the respondents (designers, managers, on-site positions) to allow for different perceptions resulting from different professional backgrounds to be revealed. This analysis highlighted significant differences in the relative importance attached to factors like the poor handling of materials, the over-ordering of materials and design related issues. This research enhances the understanding of construction waste generation and prevention and highlights the practices which can significantly contribute to the target of construction waste minimisation in the immediate future.

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