The Assessment of Construction and Demolition Wastes Arising on Selected Case Study Construction Projects in the Galway Region

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Declaration

31/08/05

I hearby declare that the work presented in this thesis is my own and that it has not been used to obtain a degree in this Institute of Technology or elsewhere.

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Abstract

This study examines the volumes and types of construction and demolition wastes generated on selected case study construction projects in the Galway Region.

Construction and demolition waste is currently one of the most significant problems facing the Irish construction industry. The volume of construction and demolition (C & D) waste generated in Ireland has continually increased since the publication of the first C & D waste estimate by the Environmental Protection Agency (EPA), in 1995. The most recent C & D waste volume published by the EPA in 2001 estimated that 3.6 million tonnes of C & D waste was generated in that year.

There is a lack of Irish sourced C & D waste statistics for the estimation of C & D waste volumes on a national basis, and within construction companies. Construction waste volumes are estimated by the EPA using waste data from Irish waste management facilities, and C & D waste rates from the United States. The EPA has highlighted the need for extensive C & D waste audits to generate C & D waste statistics and waste rates specific to the Irish construction industry.

This is the first long term C & D waste assessment that includes an extensive analysis of the C & D waste management techniques used on selected case study construction projects. This research has provided previously unavailable C & D waste rates and waste data for the building contractors involved. It has also been established that increased segregation of selected high volume C & D wastes such as timber, metals and insulation, can lead to reductions in waste disposal costs.

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List of Acronyms

BRE	Building Research Establishment
C & D	Construction and Demolition
CIF	Construction Industry Federation
CIRIA	Construction Industry Research and Information Association
DoEHLG	Department of the Environment, Heritage and Local Government
DoELG	Department of the Environment and Local Government
EAP	Environmental Action Program
EC	European Commission
ECSC	European Coal and Steel Community
EEA	European Environment Agency
EEC	European Economic Community
EPA	Environmental Protection Agency
EPI	Environmental Performance Indicator
EU	European Union
EWC	European Waste Catalogue
GIS	Geographical Information System
H & S	Health and Safety
HWL	Hazardous Waste List
IPC	Integrated Pollution Control
KPI	Key Performance Indicator
NAHB	National Association of Home Builders
NCDWC	National Construction and Demolition Waste Council
NWPP	National Waste Prevention Program
PRI	Producer Responsibility Initiative
SCWM	Site Construction Waste Manager
US	United States
USEPA	United States Environmental Protection Agency
WCa	Waste Cost alternative
WCs	Waste Cost standard

List of Acronyms

WMH	Waste Management Hierarchy
WMO	Waste Management Operative

Chapter 1
Introduction and Methodology

1.1 Introduction

The main aim of this chapter is to introduce the methodology used to perform the analysis of Construction and Demolition wastes arising on the selected case study construction projects. This chapter also describes the logical progression of the research, from the initial aims and objectives, to the analysis of the collected Construction and Demolition waste data.

1.2 The Scope of this Research

The selected area of research is an examination of the impacts of, and the volumes of, Construction and Demolition (C & D) waste generated on selected case study construction projects in the Galway Region. A detailed and extensive assessment of the areas relevant to, and associated with, the management of C & D waste was also carried out to:

1. Examine the relevant legislation, policy actions, and regulations.

2. Evaluate current best practice recommendations and guidelines for the management of C & D wastes generated on construction sites.

3. Assess existing C & D waste audit methodologies to determine their suitability for conducting a waste audit.

4. Select an appropriate C & D waste audit methodology to perform waste audits on the selected case study construction projects.

The evolution of the previous points stemmed from a logical succession of steps, which were established to carry out the study. These points also assisted in establishing the aims and objectives of the research.

1.3 The Aims and Objectives

The main aim of this project was to carry out an assessment of C & D waste volumes being generated on selected case study construction projects, in the Galway Region, and to analyse the associated impacts of C & D waste generation on site with a view to establishing:

1. The composition and volume of C & D wastes generated, and the resulting C & D waste rates, for the selected case study construction projects.

2. The reasons for C & D waste generation on site, and the identification of potential waste management strategies to prevent, reduce, reuse or recycle C & D wastes generated.

To achieve the aims established above, a number of objectives had to be met:

- Identify the various legislation, regulations and policy actions specifically related to the management of C & D wastes in Ireland.

- Evaluate existing best practice guidelines for the successful management of C & D wastes on construction sites.

- Examine existing C & D waste audit methodologies, and select the most appropriate methodology, to conduct the waste audits on the selected case study construction projects.

- Examine the case study construction project details, and the C & D waste management practices used on site.

- Analyse and quantify the various C & D waste streams, and volumes, generated on site using the selected C & D waste audit methodology.

- Calculate the C & D waste rate for each case study construction project.

- Recommend necessary improvements, and alternative C & D waste management practices, to ensure effective and efficient C & D waste management on site.

1.4 Methodology

The initial idea for this study stemmed from the fact that figures currently published by the Irish Environmental Protection Agency (EPA) for C & D waste volumes generated by the Irish construction industry are partially calculated using American Environment Agency waste rates. The relevance of these waste rates to the Irish construction industry is unknown (*EPA, 2001*).

American Environment Agency C & D waste rates are used because no detailed research into the volumes, types, and reasons for C & D waste generated has been conducted on Irish construction sites. This posed the initial question of how much, and what types of, C & D wastes are actually being generated on typical construction sites in Ireland? The EPA has highlighted the need for detailed C & D waste characterisation studies on Irish construction projects:

"The link between output and waste production is uncertain; the factors used were derived in the USA and their applicability to Ireland would need to be tested through detailed waste characterisation studies at construction sites."
(*EPA, 2001).*

The need for accurate C & D waste statistics, specific to the Irish construction industry, was also emphasized elsewhere. In their first annual report, 2002/2003, the National

Construction and Demolition Waste Council (NCDWC) also highlighted the need, under the recommendations made by Task Force B4, to gather relevant C & D waste statistics and to:

"monitor, report, research, promote and demonstrate best practice."
(*NCDWC, 2003*).

The scope of this study was dictated by the time available and financial constraints. It was decided initially that the proposed research would be restricted to the Galway Region and would pursue the following strategy.

In developing the strategy for this study a number of widely used research methods were considered. After careful consideration it was decided that the most appropriate research methodology was the case study approach, supported by quantitative and qualitative analysis. The basis for this study, and the two main questions being asked were; How much C & D waste is being generated on typical Irish construction projects? and; Why is waste being generated? When the questions `how` or `why` are being asked about a set of contemporary events, over which the investigator has little or no control over, case study research is especially suited (*Yin, 1994*).

Chapters 2, and 3, which are of a qualitative nature, entailed a comprehensive literature review of relevant publications on the subject of C & D waste to examine; the current legal obligations governing the management of C & D wastes; and to establish recommendations for best practice C & D waste management on site.

These initial chapters developed a comprehensive understanding of current C & D waste management legislation in Ireland. They also established that there is significant potential for managing C & D wastes in an effective and efficient manner by implementing a C & D waste management strategy, based on waste prevention, minimisation, reuse, and recycling.

The conclusion of chapter 3, was that there is significant potential to improve C & D waste management on site, increase the reduction and recycling of C & D wastes generated, and to reduce costs, provided the necessary facilities are available, and are not cost prohibitive. The next step was to identify potential methodologies for estimating and auditing C & D wastes on the selected case study construction projects.

Chapter 4, examines existing C & D waste audit methodologies. This chapter addresses the identification and selection of the C & D waste audit methodology utilised on the selected case study construction projects. Existing C & D waste audit methodologies were examined to identify the most appropriate methodology to perform the waste audits. After identifying a number of methodologies it was decided that the most appropriate strategy for selecting the waste audit was to test three methodologies for a short period of time and select the most suitable.

The next logical step was to select appropriate construction projects to use as case studies. Four construction projects, in the Galway Region, were identified and selected as case studies. These case studies formed the 'core' of the research. The selection of these construction projects was based on the size of the development, the type of development, and the construction timeframe. The selected construction projects used as case studies consisted of the following development types:

1. Case Study 1: Residential Development.
2. Case Study 2: Residential Development.
3. Case Study 3: Hotel Development.
4. Case Study 4: Educational Development.

Chapter 5, details the specifics of each case study construction project and the waste management practices used on site. This chapter also presents the results of the C & D waste audits, including the resulting C & D waste rates for each case study. Following this, chapter 6 includes a detailed analysis of the research findings and results, with recommendations being made based on this analysis.

1.5 Summary

The analysis of the C & D waste volumes generated, and the waste management practices used on the case study construction projects, was successful in its attempt to compile C & D waste statistics, and to develop C & D waste rates for each construction project. The collected waste data has provided valuable, previously unavailable, information on the volumes, and reasons for, C & D waste generation on selected case study construction projects in the Galway Region.

The collected C & D waste data has also provided a platform for the implementation and development of a formalised, integrated C & D waste management strategy for the contractors involved. Some waste management practices previously used by the case study contractors have been altered, based on the waste audit results.

Previously, the management of C & D wastes on site consisted of disposing of site wastes with little thought or concern for the overall financial and environmental effects. The management and disposal of site wastes was, to a large extent, dictated by the services offered by waste management contractors in the locality, without the main building contractors developing innovative prevention, minimisation, and recycling strategies for their C & D wastes. Increased segregation and new attitudes to C & D waste management have begun to develop within the case study companies as a result of this research.

It has been confirmed, due to the time constraints on this study, that in order to develop more accurate C & D waste rates, and waste statistics, for construction projects, conducting waste audits from the commencement of construction to its completion is necessary. This study was limited to auditing C & D wastes being removed from site and has confirmed the necessity for further research to quantify wastes being reused, or disposed of, on site. The comparison of waste rates for similar types of Irish construction projects remains unchecked due to the limitations of the number of case studies undertaken in this research, and the fact that a full project duration waste audit was only completed on one case study construction project.

Chapter 2

Construction and Demolition Waste Management Legislation

2.1 Introduction

This chapter examines the legislation which governs the management of C & D waste in Ireland. The Irish waste management framework and C & D waste management legislation, although now advanced and comprehensive, has been implemented much later than that of some of our larger EU neighbours. In recent years Ireland has moved away from total dependence on the method of disposal by landfill. This has been achieved by increasing the number of recycling and recovery facilities in operation, thus making the landfilling of waste a more short term solution. Two waste incineration facilities have been granted planning permission, with other proposed developments seeking the same, but none has yet been licensed. Landfill will continue to be a short term solution, and due to the increases in waste recycling the landfill capacity available in Ireland has been increased from 6 years capacity in 2001, to a capacity of 10 years (*DoEHLG*).

2.2 Sustainability in the Development of Construction and Demolition Waste Management Legislation

The development and progression of C & D waste management legislation in Ireland has been a direct result of increased waste production, and the attempt to ensure increased sustainability in C & D waste management for the construction industry in the future. Sustainability and environmental protection are the key concepts which drive and direct the development of C & D waste management legislation. Sustainable development has been defined as:

"Development which meets the needs of the present without compromising the needs of future generations to meet their own needs."
(*Brundtland Report, 1987*).

Currently there are six accepted principals of sustainability which are:

1. *"Minimise energy consumption.*
2. *Maximise resource use.*
3. *Use renewable or recyclable resources.*
4. *Protect the natural environment.*
5. *Create a healthy, non-toxic environment.*
6. *Pursue quality in creating the built environment."*

(*Kibert, 1994*).

2.3 The Waste Management Hierarchy

The Waste Management Hierarchy (WMH) forms the basic principle upon which waste management policy and legislation is developed within the EU, and Ireland. The Waste Management Hierarchy prioritises the most desirable methods of dealing with waste.

The prevention of C & D waste from being generated is the most desirable option in the WMH. Waste prevention is also the most difficult form of waste management to achieve, as in many cases it would require significant alterations to work practices and technologies used within the construction industry. Minimisation and reuse of waste materials is achievable by efficient management of construction sites and through the use of innovative design and new technologies.

Waste recycling has improved in Ireland in recent years. This has been due to increased numbers of recycling facilities becoming available, and through the introduction of new waste management legislation e.g. the Waste Management (Packaging) Regulations, 2003. Waste management legislation, when being developed, is steered away from unsustainable waste management options such as disposal. Although the incineration of waste for energy recovery may be a more beneficial option for the management of waste than landfilling, Ireland has yet to license a waste incineration facility.

The Waste Management Hierarchy can be seen in Figure 2.1.

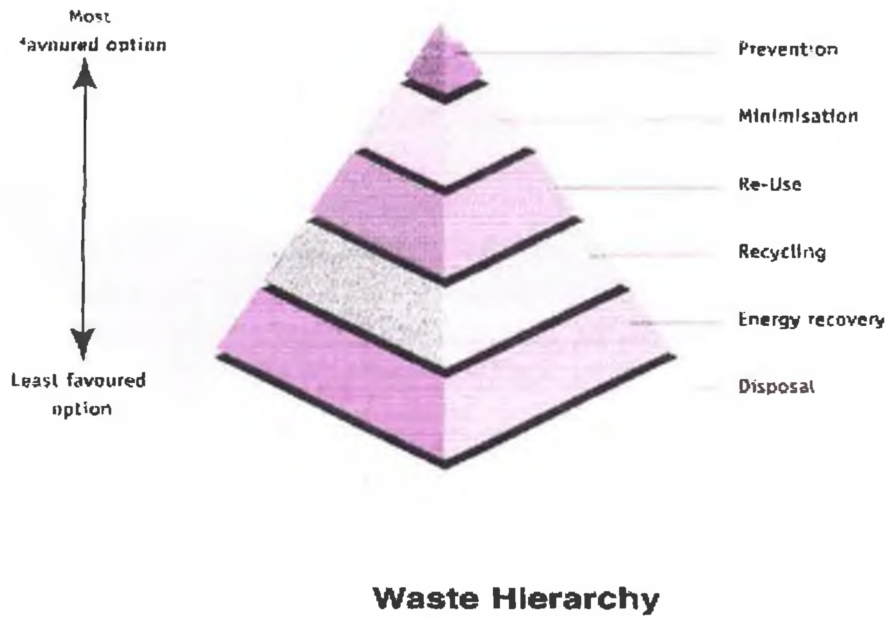


Figure 2.1 The Waste Management Hierarchy

2.4 The European Waste Catalogue and Hazardous Waste List

In Ireland, and within other EU countries, all wastes must be classified using the standard waste classification system currently in operation. This allows waste to be identified and categorised in a standard format by all waste management contractors and operators in Ireland, and across the EU. The European Waste Catalogue (EWC) and Hazardous Waste List (HWL) is a reference system developed for classifying, collecting, collating and reporting waste statistics from various waste producing industries within the EU.

This referencing system was designed to establish a consistent waste classification system throughout the EU and forms the basis for issuing waste licenses. The EWC has been adopted by the EPA for the classification of all wastes associated with activities such as the transport of waste, waste licenses, waste permits, etc.

The European Waste Catalogue and Hazardous Waste List, 2002, includes 44 different types of C & D waste. 16 of these waste types are classified as hazardous. C & D waste is defined as:

"Construction and demolition waste is taken to include all waste that arises from construction, renovation and demolition activities and all wastes mentioned in Chapter 17 of the European Waste Catalogue. This includes surplus and damaged products and materials arising at construction works or used temporarily during on-site activities (Priority Waste Stream Project Group 1995, Report to EU on Waste from Construction and Demolition), and dredge spoil."
(EPA, 2000).

2.4.1 The Development of the European Waste Catalogue

The first European Waste Catalogue and Hazardous Waste List, was published in 1994, as two individual document's. These primary waste classification document's were first used by the EPA in 1995, to compile waste data collected for that year. They were also incorporated into Irish legislation in the Waste Management Act, 1996, in that same year.

In 1996, the EPA published the first document combining the European Waste Catalogue and the Hazardous Waste list. The most recent Waste Catalogue, and Hazardous Waste List, was introduced in 2000. This list came into force on January 1st, 2002, following a number of amendments. All waste reporting subsequent to that date must use the appropriate waste codes provided in the EWC document. (The step by step development of the European Waste Catalogue and Hazardous Waste List can be seen in Appendix A.)

2.5 The Waste Management Framework in Ireland

Irish waste management legislation, policies and practices have undergone significant change and development since the inadequate standards of the early 1990's. Increased disposal costs, due to new legislation, and the lack of new waste disposal facilities (landfills) have increased the volumes of waste diverted to recycling and have also helped promote the minimisation of waste.

Prior to the 1990's, waste management legislation concerning C & D waste was non-existent in Ireland. Waste management framework legislation was introduced between 1990 and 1996. The lack of legislation prior to this resulted from widely available, inexpensive, waste disposal options by landfill. This resulted in waste not being seen as a significant problem. Other European countries were far more advanced in their waste management legislation and practices prior to the formalisation of a waste management framework within Ireland.

"In comparison to some of the larger EU member states, Ireland's enactment of modern waste management controls commenced quite late. Since that time, there has been a significant catch-up process and now an extremely sophisticated system is in place." (*Enterprise Ireland, 2002*).

Although some waste management legislation in Ireland is a direct result of EU Directives, waste management regulations are also implemented by the Irish Government without external influences. An example of an Irish based waste management initiative is the Waste Management (Landfill Levy) Regulations, 2002.

The Department of the Environment, Heritage and Local Government (DoEHLG) has the principle responsibility for waste policy and legislation in Ireland. The DoEHLG implements its legislation through policy statements, national laws, the Departments funding of local authority waste management activities, and through the Environment Fund. The Environment Fund provides funding for waste treatment facilities and waste initiatives within the country. The monies and grants distributed by the Environment Fund result from finances accumulated from landfill levies, plastic bag levies, etc.

The concept of the Waste Management Hierarchy, introduced by the EU, has formed the nucleus for developing Ireland's waste management policies. These waste management policies are contained in the policy document's, "Waste Management, Changing Our Ways", 1998, and, "Preventing and Recycling Waste, Delivering Change", 2002. The intended application for the Waste Management Hierarchy is to promote the prevention, reduction and recycling of wastes, moving away from landfill which is the most undesirable method of waste disposal.

2.6 The Function of Environmental Protection Agency

In 1993, the Environmental Protection Agency (EPA) was formed under the Environmental Protection Agency Act, 1992. The formation of the EPA acted as a catalyst for the development of a formalised waste management framework in Ireland. The EPA has the primary responsibility for pollution control within the state, and was established to perform a number of environmental functions. Some of the main responsibilities of the EPA include:

1. Licensing and regulation of large/complex industrial processes, and other processes with significant polluting potential.
2. Monitoring the quality of our environment.
3. Development and publication of waste databases.
4. Advising public authorities in respect of environmental functions.
5. Promotion of environmentally sound practices.
6. Promotion and coordination of environmental research.
7. Licensing and regulation of all significant waste disposal and recovery activities.
8. Preparation of national hazardous waste management plans.

The Office for Environmental Enforcement is the enforcing arm of the EPA. This office was established as part of the 2002, Programme for Government, and is responsible for the enforcement of waste management legislation within the state.

2.7 The Waste Management Act, 1996

The primary legislative instruments governing waste management in Ireland are the Waste Management Act, 1996, and the Waste Management (Amendment) Act, 2001. These two pieces of legislation are the statutory basis for all C & D waste management legislation in Ireland. Under the Waste Management Act, 1996, waste is defined as:

"any substance which the holder discards, intends to, or is required to discard, and anything which is discarded or otherwise dealt with as if it were waste shall be presumed to be waste until the contrary is proved."
(*Waste Management Act, 1996*).

The Waste Management Act, 1996, has transformed waste management legislation in Ireland and has imposed a number of broad industry implications. The primary function of this piece of legislation is to provide a legal framework to ensure that environmental pollution is prevented. This is achieved by regulating the transportation, storage, recovery and disposal of waste within the country. This was the first piece of waste management legislation which implemented the principle of producer responsibility, and imposed basic obligations to prevent and minimise waste generation.

The various waste types which occur in Ireland are defined by the Act. The concept of the European Waste Catalogue (EWC) was also introduced by this legislation. Measures were included to promote recycling and the reuse of waste materials, and to reduce waste production. The EPA and the various local authorities enforce this legislation, and are also responsible for penalising non-compliance and prosecuting offenders.

2.7.1 The Waste Management (Amendment) Act, 2001

In 2001, the Waste Management (Amendment) Act, 2001, was implemented to update existing legislation. This Act set out provisions to establish landfill levies, plastic bag levies, the establishment of the Environment Fund, and has also provided a process for adopting waste management plans.

The implementation of this piece of legislation has improved Ireland's waste management planning strategies. This legislation has led to the development of a waste licensing and permitting system, and it has also provided for the introduction of secondary legislation in response to EU and national requirements.

Prior to the implementation of the Waste Management (Amendment) Act, 2001, fifteen local authorities, in three regional groups, refused to adopt the proposed regional waste management plans, and others proposed to adopt regional plans subject to conditions. The National Sustainable Development Strategy has aided and underpinned this Act by giving clear policy direction, and the commitment of monies through the National Development Plan, 2000-2006, has provided finances to improve Ireland's infrastructural deficits (*DoELG, 1997*). There are also other provisions for the development of more C & D waste recycling facilities:

"The Regional Waste Management Plans provide for the development of around 18 C & D waste recycling facilities, to be located close to major raw material sources and potential product markets. This network will be supported by the provision of mobile crushing plant to serve population centres in rural areas where stockpiles of C & D waste are accumulated."
(*DoEHLG, 2002*).

2.8 Implementing Construction and Demolition Waste Management Legislation in Ireland

In 1998, the Department of the Environment and Local Government published the policy document entitled, "Waste Management Changing Our Ways". This document took the initial step to establish recycling targets for the Irish construction industry. The proposed recycling targets established for C & D waste can be seen in Table 2.1.

Table 2.1 Recycling Targets Established for the Irish Construction Industry

C & D Waste Recycling Targets	
Year	**Recycling Target**
2003	50%
2013	85%

(*DoELG, 1998*).

The policy document, "Waste Management Changing Our Ways", was published in response to the following two reports:

1. *State of the Environment in Ireland.* (*EPA, 1996*).
2. *Europe's Environment: A Second Assessment.* (*EEA, 1998*).

The publication of this document was also in response to increasing C & D waste generation in Ireland, and decreasing landfill capacity available for the disposal of this waste. This policy document significantly increased awareness of the waste problem within the Irish construction industry. As a result of this policy document, and the Waste Management Act, 1996, a series of C & D waste management regulations were developed and adopted by the Irish Government.

2.8.1 Construction and Demolition Waste Management Legislation in Ireland

The Minister for the Environment, Heritage and Local Government, by implementing the Waste Management Act, 1996, and the Waste Management (Amendment) Act, 2001, has brought into force a number of C & D waste management regulations.

These individual pieces of legislation are specific to certain areas of C & D waste management. They define the roles of the regulatory authority and establish conditions related to particular aspects of C & D waste management covered by the regulation.

The following regulations in Table 2.2 are specifically related to the management of C & D waste and were developed in response to, and under the umbrella of, the Waste Management Act, 1996, and the Waste Management (Amendment) Act, 2001.

Table 2.2 Construction and Demolition Waste Management Legislation in Ireland

	Construction & Demolition Waste Management Legislation
1.	The Waste Management (Permit) Regulations, 1998.
2.	The Waste Management (Hazardous Waste) Regulations, 1998.
3.	The Waste Management (Transfrontier Shipment of Waste) Regulations, 1998.
4.	The Waste Management (Collection Permit) Regulations, 2001.
5.	The Waste Management (Licensing) Regulations, 2000, and Amendments, 2002.
6.	The Waste Management (Landfill Levy) Regulations, 2002.
7.	The Waste Management (Packaging) Regulations, 2003.

2.8.2 The Core Responsibilities for Building Contractors to ensure Compliance with Construction and Demolition Waste Management Legislation

Table 2.3 summarises the core responsibilities that building contractors operating in the Republic of Ireland must adhere to, to comply with C & D waste management legislation currently in force.

Table 2.3 Responsibilities for Work Practice Compliance with Construction and Demolition Waste Management Legislation

1. Waste Management (Permit) Regulations, 1998	
1.	A Waste Permit is required to operate a mobile crusher on site for reprocessing.
2.	A Waste Permit is required for (agricultural) land reclamation as this is a recovery activity.
3.	A Waste Permit allows a contractor to deposit up to 5000 tonnes of non-hazardous excavated material at a site, provided that this is not disposal by landfill.
4.	A contractor cannot recover hazardous waste on site by obtaining a Waste Permit.
5.	A Waste Permit is not required provided there is no disposal or recovery.
6.	A contractor does not require a Waste Permit to dispose of non-hazardous excavated material at a site on which it was generated.
7.	A Certificate of Registration is required from the Local Authority if a contractor intends to store quantities of hazardous material on site.
2. Waste Management (Hazardous Waste) Regulations, 1998	
1.	Hazardous excavated waste materials cannot be reused as fill on site, even if a Waste License has been obtained.
2.	Disposal of hazardous waste must be undertaken at a licensed hazardous waste facility.
3.	Mixed C & D waste on site, containing quantities of hazardous waste material, is classified as hazardous waste.
4.	Transfer of hazardous waste materials off-site requires a waste collection permit and a consignment note (C1 Form) from the Local Authority.
5.	All Hazardous waste recovery activities require a Waste License to be obtained from the EPA.
3. Waste Management (Transfrontier Shipment of Waste) Regulations, 1998	
1.	The waste producer (building contractor) is responsible for the proper disposal of their waste, in compliance with the legislation in force in all relevant countries and local authorities.
2.	All inter-boundary movements of C & D waste must be notified to the competent authority in Ireland (the EPA), and the country receiving the waste.
4. Waste Management (Collection Permit) Regulations, 2001	
1.	A Waste Collection Permit is required for the collection and transfer of non-hazardous waste, inert waste and hazardous waste, and the transportation of surplus rubble, fill, or spoil from a construction site going to disposal or recovery at a licensed facility.
2.	A Waste Collection Permit is not required when transporting C & D waste if the laden axel weight of the vehicle used is less than 1 tonne. (If the laden axel weight is greater than 1 tonne a Waste Collection Permit is required.)
3.	If a building contractor intends to transport C & D waste within a number of areas they should apply to the Lead Local Authority within the area. This will allow the contractor to transport C & D waste within the Local Authorities covered by the Lead Authority.
4.	If a building contractor does not hold a Waste Collection Permit they must employ a licensed waste collector to remove their C & D wastes from site.
5. Waste Management (Licensing) Regulations, 2000, and Amendments, 2002	
1.	A Waste License is required for all waste activities involving large waste volumes which pose significant risk to the environment.
2.	A Waste License is required for disposal facilities where the quantity of material disposed of exceeds 5000 tonnes e.g. landfills and waste transfer stations.
3.	A Waste License is required for hazardous waste incinerators, and for non-hazardous waste incinerators, where the capacity exceeds one tonne per hour.
6. Waste Management (Landfill Levy) Regulations, 2002	
1.	The Landfill Levy does not apply to non-hazardous waste consisting of concrete, bricks, tiles, road planings, etc.
2.	The Landfill Levy does not apply to excavation spoil comprising of clay, sand, gravel or stone.
3.	The Landfill Levy does not apply to dredge spoil from inland waterways and harbours.
7. The Waste Management (Packaging) Regulations, 2003	
1.	If a supplier is not a member of REPAK then all packaging waste supplied to a site must be taken back and recovered.
2.	If a supplier is a member of REPAK then they are not legally obliged to take back their packaging materials.

(*Adapted from: Master Builders & Contractors Association, 2003*).

2.9 The Waste Management (Permit) Regulations, 1998

The Waste Management (Permit) Regulations, 1998, covers waste permits and certificates of registration. There are a number of waste recovery, and disposal, activities set out in this Act, including the operation of mobile crushers, which must be permitted by local authorities. Waste permits are issued by local authorities and are required for activities which, are generally considered to pose a low pollution risk, and deal with small volumes of waste. Under these regulations an application for a waste permit must be made for the following activities:

- Disposal of less than 5000 tonnes of waste material at a site, and to carry out certain waste recovery activities at a site.

- No upper limit for the recovery of waste is set out in the Act, provided 100% recovery is achieved, but in most cases the local authority issuing a waste permit will specify a maximum allowable volume of waste to be recovered.

There are also a number of exemptions provided, where a waste permit is not required:

- The recovery of hazardous waste and the composting of waste, where the quantity of waste and compost on site exceeds $1000m^3$, are exempt from applying for a waste permit, although these activities do require a waste license which can be acquired from the EPA.

- Uncontaminated waste fill can be disposed of on a site without a waste permit, or a waste license, provided that the material has been excavated on that site and is reused on that site.

This regulation also sets out the procedure for a waste permit application which must be submitted to the local authority. This process takes a minimum of three months. The legislation also covers certificates of registration. Contractors are required to apply for a certificate of registration to their local authority if they intend to store hazardous waste materials on site. e.g. A waste permit is required if hazardous waste quantities exceeding 25000 l of liquid waste, or 40 m^3 of non-liquid waste, is to be stored on site.

2.10 The Waste Management (Hazardous Waste) Regulations, 1998

The treatment and disposal of hazardous waste materials are subject to regulatory control under the Waste Management (Hazardous Waste) Regulations, 1998. The Waste Management Act, 1996, defines hazardous waste as waste which:

"appears on the hazardous waste list or is prescribed under section 4(2)(a)(ii) of the Waste Management Act"

and

"displays one or more of the properties indicated in the Second Schedule to the Act" (*Waste Management Act, 1996*).

On May 20th, 1998, the Waste Management (Hazardous Waste) Regulations, 1998, came into force. This legislation implemented provisions relating to hazardous waste, but excluded the collection and transport of hazardous waste which is regulated by the Movement of Hazardous Waste Regulations, 1998. The hazardous waste management regulations obligate local authorities to supervise and control hazardous wastes produced in their functional areas. Procedures are established in this piece of legislation to monitor and track the movement of hazardous waste from its source to its disposal or treatment facility. This ensures that proper and safe hazardous waste disposal takes place on a consistent basis.

The legislation also requires producers of hazardous waste to maintain records of the quantity, nature and origin of the waste they produce. The mixing of different categories of hazardous waste, or the mixing of hazardous waste with non-hazardous waste is prohibited under this legislation. There are many building products and materials which contain hazardous substances. Chapter 17 of the European Waste Catalogue lists 16 C & D waste types which are classified as hazardous. (This list can be seen in Appendix B.) Contaminated waste soils must not be used, or reused, as fill on construction sites. They must be disposed of at a licensed hazardous waste facility.

The recovery of hazardous wastes requires a waste license which must be obtained from the EPA. A waste collection permit and a consignment note (C1 Form), which can be obtained from the local authority, is required to remove and transport hazardous waste. The consignment note details the origin and the destination of hazardous wastes and is issued to all parties involved in the movement of the waste. Hazardous waste, if being disposed of by landfill, must be disposed of in a hazardous waste landfill and any temporary storage requires a certificate of registration from the local authority.

Contractors must ensure that they comply with this and all other C & D waste legislation. The segregation and proper disposal of hazardous construction waste is essential. The responsibility for the proper disposal of hazardous waste lies with the building contractor and they must ensure that their wastes are disposed of correctly after being removed from site.

2.11 The Waste Management (Transfrontier Shipment of Waste) Regulations, 1998

The export of waste from Ireland occurs occasionally and is regulated by the Waste Management (Transfrontier Shipment of Waste) Regulations, 1998. The cross border movement of waste is also regulated by the equivalent, or corresponding, legislation in the destination country.

In the past most wastes exported from Ireland have been hazardous wastes, but in recent years non-hazardous wastes have, and continue to be, exported for disposal and recycling. The export of non-hazardous waste is largely due to the diminishing landfill capacity in Ireland and the lack of sufficient recycling infrastructure. Under these regulations the responsibilities of the waste producer are set out:

- In situations where the export of C & D waste takes place the ultimate responsibility for the proper treatment of this waste, and compliance with the various legislative requirements in the countries involved, lies with the waste producer. In the case of C & D waste the producer is the building contractor.

- The waste producer must notify the competent authority in Ireland (EPA) and also in the destination country. Approval by competent authorities in all areas of transit is required for every container of waste along with the lodging of financial guarantees during transit.

2.12 The Waste Management (Collection Permit) Regulations, 2001

Waste collection activities are controlled by a waste permit system which is regulated by the Waste Management (Collection Permit) Regulations, 2001. All commercial waste management companies operating a waste collection service, transporting hazardous and non-hazardous wastes, are required to obtain a waste collection permit from their local authority to comply with this piece of legislation.

The waste permit system is primarily intended to prevent unauthorised haulage and transportation of waste. The types of waste that haulers are allowed to collect and transport are specified on each waste permit issued. In situations where a waste management contractor intends to collect and transport wastes within a number of different local authority areas in a region, they must make an application for a waste collection permit to the nominated lead local authority in that region. Table 2.4 shows the nominated lead local authorities in each region.

Currently the country has been divided up into 10 regions, with one nominated lead local authority having been appointed in each region. If waste collectors are operating within a number of local authority areas, to avoid applying for a waste collection permit from each local authority, an application can be made to the lead local authority within the region. The lead local authority for the Connaught region is Mayo County Council.

Table 2.4 Lead Local Authorities

Region	Local Authorities	Lead Local Authority
Dublin	Fingal Co. Co Dublin City South Dublin Co. Co. Dun Laoghaire/Rathdown	**Dublin City Council**
Connaught	Galway Co. Co. Galway City Council Mayo Roscommon Sligo Leitrim	**Mayo County Council**
Midlands	Longford Westmeath Offaly Laois Tipperary N.R	**Offaly County Council**
South-East	Carlow Wexford Kilkenny Waterford Co. Co. Waterford City Council Tipperary S.R	**Kilkenny County Council**
North-East	Louth Meath Cavan Monaghan	**Meath County Council**
Mid-West	Clare Limerick Co. Co. Limerick City Council Kerry	**Limerick County Council**
Cork	Cork Co. Co. Cork City Council	**Cork County Council**
Wicklow	Wicklow Co. Co.	**Wicklow County Council**
Donegal	Donegal Co. Co.	**Donegal County Council**
Kildare	Kildare Co. Co.	**Kildare County Council**

(*MBCA, 2003*).

2.12.1 The Impact of the Waste Management (Collection Permit) Regulations for Building Contractors

The Waste Management (Collection Permit) Regulations, 2001, have had a number of impacts for building contractors:

- Waste collection permits are required for the collection of non-hazardous waste, inert waste and hazardous waste. This includes all C & D wastes generated on site. (The disposal of hazardous waste is covered by separate legislation.)

- A single waste collection permit can be used to cover the transportation of waste to a site, from a site, to a waste disposal facility, or to a waste recovery facility. A permit can cover all the previous activities provided all details of the transportation of wastes are included in the waste collection permit application. Waste management contractors, building contractors, sub-contractors, or others transporting C & D wastes must have a waste collection permit.
- The obligation lies with the building contractor to ensure that all their wastes are removed from site by a permitted waste collector, and that the wastes are disposed of at an authorised facility. Contractors must check waste collection permits for those transporting their C & D wastes on a regular basis to ensure compliance.
- In situations where C & D waste is being collected and sorted on a construction site, where the laden axle weight of the transport vehicle is less than 1 tonne, or where the transport of the waste is incidental to the main business activity, a waste collection permit is not required.
- A permitted waste management contractor must be employed to remove C & D waste from site, if the main building contractor does not possess a waste collection permit for transporting their own waste.

The principle function of the Waste Management (Collection Permit) Regulations, 2001, is to regulate the transport of waste, and to eliminate the illegal operation of un-licensed waste carriers. The waste collection permit regulations also cover the application procedure for obtaining a permit. Waste collection permit applications are made to local authorities and take approximately 12 weeks to process. Permits can be refused, or revoked, because of infringements of the Waste Management Act, 1996. Each waste collection permit granted by a local authority is reviewed every two years.

2.13 The Waste Management (Licensing) Regulations, 2000, and Amendments, 2002

Under the Waste Management Act, 1996, provisions were made for granting waste licenses to waste treatment and disposal facilities. The Waste Management (Licensing) Regulations, 2000, and the Amendments, 2002, regulate the licensing system which is operated by the EPA. A waste license defines the nature of environmentally acceptable waste management activities at a waste treatment facility. All waste treatment facilities must obtain a waste license before they can commence activity. When applying for a waste license an application must be made directly to the EPA, including all details for the proposed activities. An application must:

"(e) describe the nature of the facility or premises concerned including, in the case of an application in respect of the landfill of waste, the geological and hydrological nature of the land,"

"(g) specify the quantity and nature of the waste or wastes which will be recovered or disposed of,"
(*Waste Management (Licensing) Regulations, 2000*).

Waste licenses cannot be altered without the prior approval of the EPA. Activities related to large volumes of waste material, which could potentially impose an environmental risk, require a waste license, as do waste facilities where C & D waste is disposed of by landfill. Waste licenses are also required when the volume of waste material disposed of at a facility exceeds 5000 tonnes per annum, and when the following operations occur:

1. Landfilling.
2. Hazardous waste incineration.
3. Non-hazardous waste incineration. (Greater than 1 tonne per hour capacity.)
4. Large composting facilities.
5. Local authority waste disposal facilities.
6. Local authority waste recovery activities.

7. Private sector based disposal facilities. (These include waste transfer stations where the waste intake is greater than 5000 tonnes per annum.)

2.13.1 Applying for a Waste License

The application procedure for a waste license can take up to 12 months. The granting of a license by the EPA depends on the nature of the facility and the volumes of waste to be treated, or disposed of. These regulations also cover reviewing of existing waste licenses, objections by the EPA, and the holding of oral hearings. If a facility wishes to change the details of their waste license they must request a license review by the EPA. Environmental Impact Statements (EIS) are also required for some facilities prior to the commencement of work.

The permitting and licensing of waste treatment and disposal facilities is essential to minimise the environmental pollution risk. This licensing system also ensures that wastes are disposed of in a correct and safe manner and highlights the operation of un-permitted and un-licensed facilities. Building contractors are obliged to ensure that all their C & D wastes are disposed of at licensed waste facilities.

2.14 The Waste Management (Landfill Levy) Regulations, 2002

The Waste Management (Landfill Levy) Regulations, 2002, when implemented on June 1st, 2002, introduced a landfill levy. A levy of €15 per tonne is currently charged for the landfill of waste. This fee is charged by local authorities, in addition to the landfill gate fee, for the disposal of waste. Under this legislation the landfill levy can be increased by a maximum of €5 per annum.

There are a number of reasons for implementing a landfill levy for waste disposal. Some of the main reasons for the application of a landfill levy is to:

"incentivise the diversion of waste from landfill, especially towards options which are higher in the waste hierarchy;"

"generate revenues that can be applied in support of waste minimisation, recycling and other desirable waste management, awareness and enforcement initiatives."
(*DoELG, 2002*).

There are some disposal activities, and wastes, that are exempt from the landfill levy, provided that these wastes are used for landfill engineering, or restoration. The following wastes are exempt from the landfill levy:

1. Non-hazardous C & D wastes. (Consisting of concrete, bricks, tiles, road planings, etc. < 150mm in diameter.)
2. Excavation spoil. (Consisting of clay, sand, stone, gravel, etc.)
3. Dredge spoil from inland waterways and harbours.

2.15 The Waste Management (Packaging) Regulations, 2003

On March 1st, 2003, the Waste Management (Packaging) Regulations, 2003, were brought into force. This piece of legislation was introduced to promote the recycling and recovery of packaging waste. Packaging waste consists of materials that are used in the containment, protection, presentation and delivery of materials. This includes timber pallets, plastic sheeting, paper packaging, cardboard packaging, etc.

These regulations apply to those who are supplying packaging, packaging materials, or packaged goods to the Irish market as retailers, packers or manufacturers. Under this legislation a producer of packaging waste is defined as:

"a person who, for the purpose of trade or otherwise in the course of business, sells or otherwise supplies to other persons packaging material, packaging or packaged products"
(*Waste Management (Packaging) Regulations, 2003*).

Those who are members of an approved body, such as Repak, who operate a packaging waste recovery scheme, are exempt from specific obligations under this legislation:

"A producer whom is granted a certificate by an approved body stating that such producer is participating, in a satisfactory manner, in a scheme for the recovery of packaging and packaging waste, shall be exempt from the requirements of articles 9 to 13 and 22"
(*Waste Management (Packaging) Regulations, 2003*).

2.15.1 Repak

Repak is one such, "approved body". They are a non-profit organisation which was established under a voluntary agreement between the Department of the Environment and Local Government, and the packaging industry. To form an "approved body", an organisation must make a formal written application to the Minister for the Environment. The application must include a detailed proposal for the activities to be carried out by the organisation. The Minister for the Environment may then grant, or refuse, the application, subject to compliance with the packaging waste regulations.

The purpose of establishing Repak was to ensure that the recovery target set down in the EU Directive on packaging and packaging waste (94/62/EC) is reached. This target is a 50% recovery rate by 2005, 25% of which must be recycled.

Any company supplying packaging materials is affected by the Waste Management (Packaging) Regulations, 2003. If a company has a turnover in excess of €1 million, and contributes 25 tonnes of packaging or more to the Irish market, they are considered a "major producer". Major producers must comply with these regulations by joining Repak, or by becoming self compliant.

Becoming a member of Repak requires the payment of an annual fee, based on the quantity and type of packaging waste that a company placed on the market in the previous year. Membership negates the packaging waste producer from taking back their packaging waste, and allows the company to register with their local authority. The collected fees are used to finance recycling initiatives, and to subsidise waste management contractors, and local authorities, for the waste packaging materials they collect for recycling.

The Repak Programme Subsidy Scheme (RPS) funds recycling by subsidising waste management contractors for each tonne of packaging waste that they can prove that they have sent for recovery, or recycling. The subsidies paid for recovered packaging wastes are based on the type of packaging material, the recovery activity for that material, the value of the material and the volume of material that Repak has committed to recovering in a given year. Subsidies are paid on packaging wastes such as plastic, paper, steel, glass, aluminium and wood.

Waste recovery companies registered with Repak are issued a monthly claim form in which they record the volume of packaging waste they recovered within that month. The claim is then invoiced to Repak, including support documentation such as weighbridge dockets, and recycling certificates. The subsidy is then paid by Repak to the waste recovery company.

The packaging waste produced by companies, or suppliers, who are members of Repak displays a green dot, 'The Green Dot', which is a European wide symbol. This symbol means that the supplier has paid a fee towards the sustainable environmental management of their waste packaging.

Self compliance by major producers can also be undertaken. This involves the producer registering with their local authority and taking back all their packaging waste materials. This can be very expensive for the packaging suppliers as they must provide the necessary facilities to allow their customers to return their waste packaging.

2.15.2 The Impact of the Waste Management (Packaging) Regulations, 2003, on Construction Sites

In circumstances where materials are supplied to construction sites, and include associated packaging materials, if the supplier is not a member of Repak then they must take back and recover their packaging waste. Although this is the reality of the situation, the opinion of many suppliers is that if you purchase their product you also purchase any packaging materials included. If the supplier is a member of Repak then they are not legally obliged to take back their packaging waste. Local authorities are responsible for the enforcement of the packaging waste regulations, and building contractors should enforce their rights under these provisions.

2.16 Conclusions

The aim of this chapter was to examine existing C & D waste management legislation being enforced in Ireland. The examination of C & D waste management legislation included an analysis of the legislation directly affecting building contractors. Specific emphasis was placed on examining the obligations placed on those responsible for the day to day management of C & D wastes. From the analysis of the legislative framework, and the C & D waste management legislation currently being enforced, the following can be concluded:

- Since the formation of the EPA, and the introduction and implementation of the Waste Management Act, 1996, significant changes have occurred in C & D waste management legislation in Ireland. The Waste Management Act, 1996, is the foundation of the legal framework for C & D waste management legislation in Ireland, and since 1996, the storage, transportation, recovery and disposal of wastes have been regulated.

- The publication of policy statements by the Department of the Environment, Heritage and Local Government has acted a catalyst to improve and direct waste management legislation in Ireland by setting national recycling targets for C & D wastes.

- Currently there are significant legislative requirements for the management of C & D wastes in Ireland. This regulatory system must be complied with by all building contractors and developers generating C & D wastes. The regulatory control of waste is a necessity and increased regulation will further promote waste prevention and minimisation by building contractors, and other waste producers.

The following chapter will examine best practice recommendations for the management of C & D wastes on construction sites.

Chapter 3
Construction and Demolition Waste Management on Site

3.1 Introduction

The aim of this chapter is to examine best practice recommendations for the management of C & D waste on construction sites. This was necessary to determine the appropriateness, and efficiency, of existing practices on the case study construction projects. Prior to the commencement of the waste audits it was essential to have an extensive knowledge of best practice C & D waste management recommendations as this would allow the identification of potential improvements in waste management practices on site during the waste audits.

The Irish construction industry generated an estimated 3.6 million tonnes of C & D waste in 2001 (*EPA, 2003*). This not only has significant negative economic effects for building contractors, and is detrimental to the sustainability of a healthy environment, it also imposes an unsustainable strain on the available landfill capacity in the Republic of Ireland as only 65.4% was recovered in 2001, with the remaining waste volume being landfilled.

Currently the lack of disposal options, increasing waste management costs, ever increasing volumes of C & D waste generation, the exhausting use of finite resources, and environmental pollution have changed peoples attitudes to waste and have helped develop a mindset where sustainable waste management by preventing, minimising, reusing and recycling waste is the ultimate goal. All persons employed in the construction industry have a responsibility for minimising C & D wastes as all their activities from building design, to construction, can have a direct result on the volume of C & D waste generated.

The core of this chapter is the examination of recommended best practice C & D waste management on site.

3.2 Construction and Demolition Waste Generation in the EU

The EU generates a volume of 1300 million tonnes of waste per annum (*EEA, 2001*). In excess of 50% of this total waste volume is made up of C & D waste. Between 1990, and 1995, the total waste volume generated within the EU increased by almost 10%, as economic growth increased by 6.5% in the same period (*EEA, 1999*).

Unsophisticated waste disposal methods currently used across the EU e.g. landfill, are being replaced continually. This has been achieved through a continued desire to move away from landfill, to follow a waste strategy based on the Waste Management Hierarchy. Landfill is the disposal option currently used for two thirds of municipal waste in the EU, and despite the increase in recycling, and other more sustainable waste management options, the volume of waste generated continues to increase (*EEA, 2002*).

3.3 Waste and its Effects on the Environment

The consequences and effects of waste on the environment are many and wide-ranging, from the depletion of non-renewable natural resources and energy consumption, to the emission of noxious gases, contamination of ecosystems, and leaching of hazardous wastes into groundwater.

Impacts from waste depend on the type, and quantities, of waste being generated. Large volumes of waste, and hazardous waste, pose the most significant problems for the environment. In most situations waste with higher environmental impacts such as hazardous waste is generated in smaller quantities, it is difficult to segregate, and collect. Hazardous wastes include many construction products and materials. The treatment, disposal and transport of waste, has many negative impacts on our environment.

"Transportation of waste has a number of associated environmental impacts, such as emissions to air of dust, SO^2 and NOX; the risk of contamination of water, soil and ecosystems from accidental spills; and the risk to human health from accidental spills of hazardous substances."
(*EFIEA, 2003*).

3.4 Construction and Demolition Waste in Ireland

The volume of C & D waste generated in Ireland has continually increased over the past decade, due to high economic growth and increased construction output. In 1995, the quantity of C & D waste generated was estimated at 1.3 million tonnes (*EPA, 1996*). C & D waste generation has continuously increased in recent years to an estimated volume of 3.6 million tonnes being generated in 2001 (*EPA ,2003*).

Table 3.1 Construction and Demolition Waste Generated : Value of Construction Output

Year	*Value of Output (€ million)	Waste Volume Generated (million tonnes)
1995	7000	1.3
1998	9100	2.7
2001	11200	3.6

(**National Statistics Office.(€ at constant 1995 prices)*).

Comparing the data in Table 3.1 suggests that increased value of construction output by the Irish construction industry results in increased C & D waste generation. Estimated volumes of C & D waste generation have been published by the EPA on a three year cycle. The total volume of C & D waste estimated for 2001, (the most recent national figure published) includes waste quantities from four categories of construction, or construction related activities. Table 3.2 gives a breakdown of C & D waste volumes estimated for 2001.

Table 3.2 Construction and Demolition Waste Breakdown for 2001

Sources of C & D Waste	**Waste Volumes (Tonnes)**
Estimated new construction, repair and maintenance waste.	2,051,950
Excavated Soil.	1,396,516
Estimated Demolition Waste.	202,946
Dredging spoil.	1,257,000
Total C & D waste estimated for 2001 =	**3,651,412**

(*EPA, 2003*).

As seen in Table 3.2 new construction, repair and maintenance accounts for the highest volume of waste generated, followed by excavated soil, dredging spoil and finally demolition waste.

3.5 The Development of a National Strategy for Managing Construction and Demolition Waste in Ireland

In 1998, the Department of the Environment and Local Government published the policy document entitled, "Waste Management - Changing Our Ways". This took the initial step into establishing recycling targets for C & D waste generated in Ireland. This document was published in response to the growing volumes of waste, and the decreasing landfill capacity available for the disposal and recovery of C & D waste. This document also increased awareness of the waste problem and stated that the construction industry:

"clearly has the primary responsibility to ensure the environmentally sound management of C & D waste."
(*DoELG, 1998*).

The following C & D waste recycling targets in Table 3.3 were established in the 1998 document, "Waste Management - Changing Our Ways":

Table 3.3 Recycling Targets Established for Construction and Demolition Waste

Construction and Demolition Waste Recycling Targets	
Year	Recycling Target
2003	50%
2013	85%

(*DoELG, 1998*).

The recycling targets established in the policy document, "Waste Management - Changing Our Ways", had set a target to increase recycling of C & D waste to 50% by the end of 2003, and to 85% by 2013. In 1998, the EPA estimated C & D waste recovery and recycling to be at 43.3%. By 2001, with an estimated 3.6 million tonnes of C & D waste being generated in that year, the EPA established that C & D waste recovery and recycling had reached 65.4%. This figure far exceeded the target of 50% recovery by 2003.

3.5.1 Task Force B4

In response to the recycling targets set out in the policy document, "Waste Management - Changing Our Ways", the Forum for The Construction Industry established, Task Force B4, "Recycling of C & D Waste", in October 1999. Task Force B4 had a wide membership base which included senior representatives from various facets within the construction industry. Membership included persons from:

1. The Construction Industry Federation.
2. The Irish Concrete Federation.
3. The Building Materials Federation.
4. Enterprise Ireland.
5. Public and Private Sector Clients.
6. Professional Bodies.
7. FAS.
8. Local Authority Management.
9. The Department of the Environment and Local Government.
10. Environmental Protection Agency.

The Task Force initiated its work in November 1999, when it held its first meeting. In coordinating its activities three sub-group committees were established to assist the Task Force in understanding the problems posed by C & D waste, and to develop an innovative approach to solving this problem. Relevant areas such as site development, demolition, construction materials, reprocessing, reuse and recycling were examined.

As the sub-group committees completed their work, their findings were discussed and debated by the Task Force and a table of recommendations, issues, measures, responsibilities and target dates were formed. In February 2001, the Task Force published a draft report, "Report on the Development and Implementation of a Voluntary Construction Industry Programme to meet the Governments Objectives for the Recovery of Construction and Demolition Waste". In this report the task force established the following proposals and recommendations:

1. Propose the establishment of a National Waste Authority and a National C & D Waste Council.
2. Cease the use of unauthorised operators.
3. Develop a Code of Best Practice and related training programme.
4. Develop a network of C & D waste recycling facilities.
5. Use established C & D waste recycling facilities where feasible.
6. Introduce a requirement for the preparation of waste management plans by developers.
7. Provide incentives for the use of recycled materials and disincentives for the landfill of readily recyclable C & D waste materials.
8. Provide support for research and development into markets.
9. Seek to optimise the recycling of C & D waste within public contracts.
10. Develop a national awareness programme targeted at the key stakeholders within the C & D waste industry.
11. Alter existing, or introduce new standards / specifications.
12. Develop guidelines to facilitate the adoption of a systematic approach to environmentally sustainable design, optimisation of recycled materials and future deconstruction requirements.
13. Prevent the generation of unnecessary C & D waste by prioritising the waste minimisation issue.
14. Prevent tenders from gaining competitive advantage through unsustainable C & D waste management practices.
15. Specify responsible C & D waste management practices in tender documents and give credit in the evaluation of bids to tenderers with a proven track record.
16. Support legislation and resources to facilitate the closure of unauthorised C & D waste facilities and streamline procedures for regulating C & D waste recycling targets.

3.5.2 The National Construction and Demolition Waste Council

The first recommendation made by the Task Force was to establish a National Construction and Demolition Waste Council (NCDWC). On June 20th, 2002, the NCDWC was launched. The main goals of the NCDWC are to promote awareness of the problems caused by C & D waste, to initiate and carry out the set of recommendations established by the Task Force B4, and to continue development and innovation into the successful management of C & D waste. To date the NCDWC has published two annual reports. In their most recent report the main achievements for, 2003 – 2004, were as follows:

- The need for continued consistent reporting of C & D wastes disposed of at permitted sites was highlighted. This has led to the development of a more comprehensive method to ensure proper records are maintained and submitted.
- The process of developing a C & D waste audit methodology to collect C & D waste data has commenced.
- A specification for the use of recycled concrete materials in road construction has been developed to promote, and allow the reuse, of waste concrete products (*EN 13242*)
- Draft guidelines for the preparation of waste management plans have been submitted to the DoEHLG. The DoEHLG intend to develop guidelines for the preparation of waste management plans.
- The Voluntary Construction Industry Initiative has been launched.
- A C & D waste management training course has been developed in conjunction with FAS.

3.6 The Prioritisation of Construction and Demolition Waste Management on Site

When the word waste is used in connection with the construction industry it is generally considered by those involved that material waste e.g. waste timber, concrete, etc. is the main culprit. The concept of waste in construction is more far reaching than material waste. Waste should be understood as any inefficiency that results in the use of materials, equipment, labour, or capital in larger quantities than those considered necessary for the production of a building (*Koskela L, 1992*).

The quantification, or estimation, of material waste is relatively straight forward, but the measurement and recording of labour and plant waste requires a significant commitment from a building contractor, as constant observation and recording of all site activities is necessary. In a 1999 report, Method for Waste Control in the Building Industry, waste was defined as:

"waste should be defined as any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client."
(*Formoso C.T., et al, 1999*).

In 2002, FAS published a waste management manual, which advises that the following steps, or methods, are adopted to minimise waste on construction sites:

- *"Nominate a manager who will take responsibility for waste management on site.*
- *Develop a waste management plan for each C & D site.*
- *Communicate with site personal.*
- *Improve delivery access and allow "just in time" delivery.*
- *Choose suitable equipment and manage plant adequately.*
- *Store and handle construction materials safely, securely and correctly on site – damaged materials are likely to be wasted.*
- *Keep deliveries packaged until they are ready to be used.*
- *Conduct waste audits.*
- *Demolish for maximum reuse and / or recycling of waste."*

(*FAS, 2002).*

A significant step forward has been made with the publication of the, "Draft Best Practice Guidelines on the Preparation of Waste Management Plans for Construction and Demolition Projects", 2004, by the Department of the Environment, Heritage and Local Government. This document has produced more detailed advice on the management of C & D wastes at the various phases of construction than previous Irish publications, e.g. project conception, asset management, planning, design, pre-construction demolition, and construction.

3.7 Sources of Construction and Demolition Waste

C & D waste can result from a number of construction activities, or project types. Symonds, 1999, established that there are six different site types on which C & D waste can be generated:

1. *"Demolish and clear" sites.*
2. *"Demolish, clear and build" sites.*
3. *"Renovation Sites."*
4. *"Greenfield" building sites.*
5. *"Road build" sites.*
6. *"Road refurbishment" sites.*

(*Symonds, 1999*).

It can be seen from the previous six site types that most construction projects can be categorised under one of the project types. Examining the site types shows that the majority of construction activities produce a volume of C & D waste. It is important that all building contractors are aware of the types of wastes that may occur from the work that they intend to undertake.

3.8 The Environmental Effects of Construction and Demolition Waste

Environmental pressures have increased in recent years to promote the reduction of the harmful effects of C & D waste on our environment. C & D wastes may not be as obvious to most people as wastes from other industries e.g. smoke emissions, but they generate a significant volume of waste annually, with an estimated 3.6 million tonnes of C & D waste being produced by the Irish construction industry in 2001.

50% of the total gas emissions and CFCs contributing to global warming are a direct result of construction related activities (*Edwards. B. et al., 2001*). The landfilling and burning of C & D wastes on construction sites, was common practice in the not too recent past. These are no longer acceptable options for waste treatment as legislation has been implemented to prevent these practices (e.g. Waste Management Act, 1996. Air Pollution Act, 1987. Waste (Permit) Regulations, 1998. Waste (Licensing) Regulations, 2000). Building contractors are obliged to ensure that they prevent, or minimise, their waste production on site to protect the environment, and to minimise their waste disposal costs.

"Environmental and financial criteria now make the issue of limiting waste generation extremely important. The building constructor has a pivotal role to play in ensuring that the construction process at least is as clean and efficient as it possibly can be."
(*McDonald, B. et al., 1998*).

Every opportunity should be taken to divert C & D wastes generated away from disposal. Reuse and recycling options should be identified prior to the commencement of construction. Every effort should be made to prevent wastes occurring, to ensure minimum effects on the environment, and to increase the life capacity of our ever diminishing landfills.

"Environmental aspects are clear: landfill space is becoming more and more limited; faulty landfills pollute air, earth and water; and illegal dumping of C & D Waste is increasing."
(*Laquatra, J., 2004*).

The removal of C & D waste from site can cause other forms of pollution, and increased waste volumes can indirectly affect other public facilities. The transport of C & D waste not only causes pollution by fuel consumption, it also increases traffic on public roads.

Inefficiencies in the disposal of C & D wastes into waste skips, or trucks, can result in unnecessary repeat journeys, to and from site by skip suppliers, further increasing road traffic. In order to minimise this, the most financially and environmentally friendly disposal, or treatment, option available should be chosen. This will depend on the facilities available in the area where the C & D waste is generated.

"The Best Practice Environmental Option (BPEO) for construction and demolition waste will vary according to the facilities available for disposal, reuse or recycling. The haulage distances involved, for example in transporting raw materials to their place of use or in transporting recovered materials to a recycling site, will also determine the environmental impact of the waste management option. Transport is also important financially due to the high density of the materials relative to their value."
(Craighill, A. et al, 1999).

3.9 Compliance with Construction and Demolition Waste Management Legislation

One of the primary aims for any building contractor, when dealing with their C & D waste, should be to comply with all current waste management legislation. Under current C & D waste management regulations the onus is on the producer e.g. the building contractor, to ensure that their wastes are dealt with in an appropriate manner.

The level of legislation governing C & D waste has increased significantly in recent years, and as the generation of C & D waste is increasing annually, further legislation will be necessary to ensure maximum prevention, minimisation, reuse and recycling takes place to develop a more sustainable national C & D waste management strategy.

3.10 The Role of the Waste Management Hierarchy in Construction and Demolition Waste Management on Site

There are many different C & D waste streams generated on construction sites. To successfully manage C & D wastes on site each individual waste stream generated should be assessed using the waste management hierarchy, as shown in Figure 3.1.

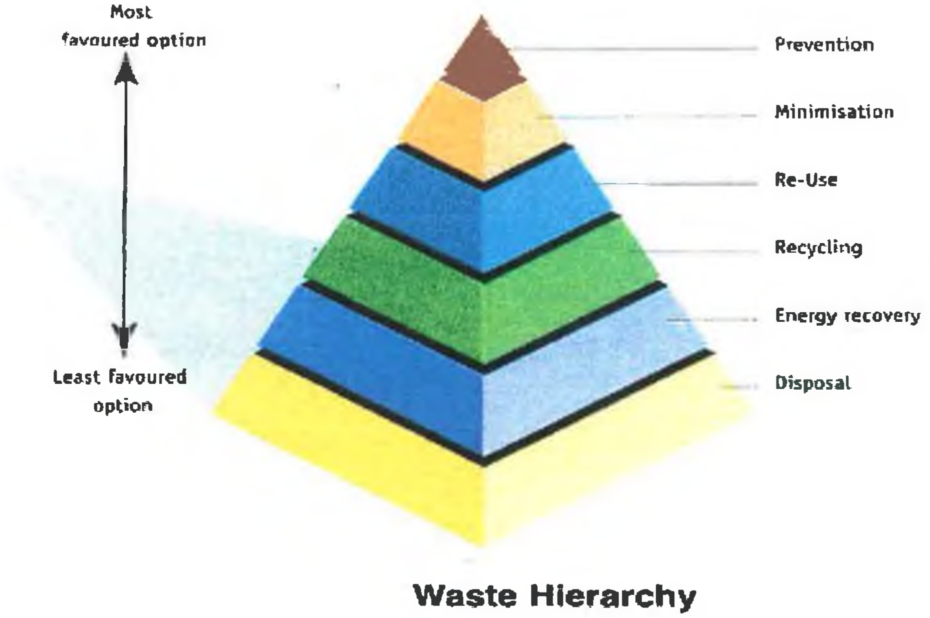


Figure 3.1 The Waste Management Hierarchy

The waste management hierarchy (WMH) not only plays a key role in the formation of waste management legislation, it should also be used as a guide for the management of C & D wastes on site. Each waste material should be examined, starting at the top of the WMH, with prevention being the most desirable option, and working down through the WMH selecting the most appropriate treatment option, highest, on the WMH for each waste material.

3.10.1 Waste Prevention

The primary recommendation of the WMH is to prevent C & D waste from being generated. This can be achieved by using prefabricated structural elements e.g. trussed rafters, or by designing a building to incorporate standard sizes of materials e.g. full plasterboard sheets, preventing waste off-cuts. The building contractor rarely has control over the design of a building, unless it's a company development. This can eliminate the possibility for waste prevention through good design.

3.10.2 Waste Minimisation

The minimisation of C & D wastes can be achieved by proper control of materials on site e.g. ordering, proper storage, handling, movement of materials, etc. Materials management is the prime area of project management where C & D waste can be minimised. Materials on site can be controlled by a building contractor, and all efforts should be made to prevent wastes occurring by effective and efficient management of site materials.

3.10.3 Waste Disposal

On the other end of the WMH is disposal, the option least recommended, and the use of this option is generally a sign of poor waste management. The use of this option highlights the lack of innovative waste management initiatives on site. Conscientious building contractors will not only strive to minimise their waste production, and disposal costs, they will also aim to minimise the negative effects their waste generation has on the environment.

Currently the majority of building contractors manage their waste by complying with existing legislation, and by using available waste treatment options that are most financially beneficial. The WMH is a useful guide for contractors to examine the possibilities and options that may be available for waste treatment. In a situation where a contractor can recycle a waste material, for the same cost as disposing of that waste material, then the contractor should be encouraged to recycle rather than dispose.

3.11 Demolition or Deconstruction?

In recent years with the ever increasing volume of property development and construction taking place in Ireland many new developments are carried out on sites with existing buildings where demolition, or deconstruction, is required. Demolition is the traditional method of disposing of, or removing, unwanted structures on a site which has been built on previously. Demolition by mechanical means is widely used as it generally provides the most economic option available. Most buildings are stripped of any valuable materials prior to demolition, with the resulting demolition wastes being reused, or recycled, if possible. Generally it is easy to quantify the waste materials that will be generated from the demolition of a building as existing buildings can be physically measured on site, or waste quantities can be estimated using existing drawings.

3.11.1 Selective Demolition

Selective demolition is an alternative to the total demolition of an existing structure. Selective demolition is utilised to maximise the recovery of reusable, or recyclable, waste materials. The following selective demolition methodology has been established by FAS, 2002:

1. *"Remove furniture and fittings.*
2. *Remove permanent fixtures (e.g. doors, windows, etc.)*
3. *Remove hazardous materials.*
4. *Selectively demolish structure.*
5. *Segregate demolition materials into individual waste fractions.*
6. *Remove waste materials and prepare site for new construction works."*

(*FAS, 2002*).

Although selective demolition is more similar to deconstruction than total demolition, deconstruction is a less widely used method of removing an existing building from a construction site. This is because deconstruction proves difficult on many existing buildings, as most have not been designed for the process of deconstruction.

"Selective demolition criteria needs to be introduced i.e. waste material ought to be separated into fractions at source. The economics of waste recycling and disposal should be optimised as a result of the Selective Demolition process."
(*NCDWC, 2004*).

3.11.2 Deconstruction

The deconstruction of a building, if possible, is a more desirable option than demolition, as the resulting materials may be reused for their initial intended purpose. Designing buildings for deconstruction has not been a significant design consideration in the past, but in the future this will have many beneficial effects for waste minimisation in the construction industry.

"As its primary purpose, deconstruction seeks to maintain the highest possible value for materials in existing buildings by dismantling buildings in a manner that will allow the reuse or efficient recycling of the materials that comprise that structure. Generally the main problem facing deconstruction today is the fact that architects and builders of the past visualised their creations as being permanent and did not make provisions for their future disassembly."
(*Kibert, C.J., 2000*).

3.12 Waste Minimisation

3.12.1 Efficient Materials Management on Site

The management and control of materials purchasing, scheduling, delivery and handling on site is an important part of waste management, as poor materials control can lead to increased waste generation. Materials management is one of the core activities for waste minimisation on site, in addition to good work practices. On site the responsibility for ordering and delivery of materials usually lies with the project manager, or the site quantity surveyor. Good communication between the person responsible for materials ordering and site staff requiring the materials is essential to prevent over ordering, deliveries arriving too early or too late, incorrect materials being delivered, and other mishaps which can cause material wastage. The use of materials schedules can aid in the control of materials on site, ensuring that the proper materials arrive at the required time and in the correct quantity, thus minimising the potential for wastage.

"Materials schedules have to be synchronised to the sequence of work (or elements of construction) on each phase of a project and also be directly related to the requirements

of the contract programme. The site manager is responsible for 'calling-off' or requesting delivery of materials to the site and for keeping suppliers informed of revised delivery dates where work on site is behind or ahead of schedule."
(*Cooke B. et al., 1998*).

In a survey undertaken in 1998, as part of the research conducted for the publication, "Construction Planning, Programming and Control", 1998, eight residential construction sites were surveyed in Manchester. The following observations were made:

"Although this evidence is anecdotal, and the sample was small, it is probably a fair reflection of the standards of materials management generally. Quite frankly, the standards were shocking. It appears from these observations that little has been learnt from the lessons of the past and that the site managers concerned were unaware of any materials policy within their organisation. Any regard at all for materials waste appeared to be entirely discretionary, and on six of the eight projects materials were appallingly mismanaged. "

"Observations relating to the mismanagement of materials included:

1. *Excessive waste left under scaffolds including bricks, blocks, skirting boards, fascia boards, drainage fittings, etc.*
2. *Expensive facings and engineering bricks being bulldozed into the ground and then covered over with topsoil to provide 'instant brick gardens'.*
3. *Materials being stored on uneven ground, adjacent to unprepared access roads, allowing the materials to become contaminated with mud and water.*
4. *Pallets of bricks and blocks unloaded directly onto unprepared ground, away from the workplace.*
5. *Damage to materials while un-banding the packs.*
6. *Roof trusses being stacked on unprepared areas allowing them to distort and twist.*

7. *Lack of covering and protection to internal timber floor joists, door frames and finishing joinery items. Structural timbers left unprotected in the rain.*
8. *Excessive thickness of ready-mixed concrete to in-situ concrete kerb beds.*
9. *Out of sequence working, resulting in the excessive waste of stone filling materials, bricks and blocks, etc.*
10. *Commencing foundation work with no provision for adequate access to the works. This resulted in chaos with respect to the storage of materials around the work area."*

(*Cooke B. et al., 1998*).

Proper control of materials on site is essential to minimise site wastes and good house keeping is necessary to ensure waste prevention.

Photo 3.1 Poor materials management on site leads to increased waste generation.

Photo 3.2 The build-up of site wastes around scaffolding can be excessive.

Waste due to poor materials control can be avoided by implementing simple but effective materials management techniques. The control of materials on site should follow a logical sequence to minimise C & D wastes.

3.12.2 Basic Materials Management on Site

A materials storage area incorporating storage containers and clean level platforms should be provided for the storage of materials. The storage area should be planned prior to the commencement of construction, and all site staff should be made aware of the materials management system in operation. Ordering and delivery of materials should be delegated to responsible site staff. When materials are delivered to site they should be checked, transported and stored appropriately. The appointment of a store-man responsible for materials control on site can also assist in the prevention of site wastes.

"Waste prevention has two requirements. Firstly, adaptability to the many constraints, reinforced by a realistic materials control communications and recording procedure concerning materials. The site manager is the key to implementing these policies. Secondly, even for the most experienced firm, an on-going reappraisal is necessary for

which a waste committee (or at least an executive who has to keep waste prevention under review) backed by an on-going training (and retraining) policy is desirable." (*Skoyles E.R. et al., 1987*).

It is not only important to implement an effective materials management system on site to minimise C & D waste, it is also important that materials suppliers to the construction industry provide advice and information on recycling, and reusing, their products (*NCDWC, 2004*).

3.12.3 Good House Keeping on Site

Good house keeping is necessary to ensure that a sites productivity is not hindered. Access routes cluttered with C & D wastes, and materials, can result in restricted movement around site which may lead to lower productivity, and increased waste volumes. Materials should be stored in the designated areas provided and not along access routes, on uneven ground, or near public roadways where damage or theft can result. The responsibility for good housekeeping, including materials control and waste management, should be delegated to responsible site personnel. Site wastes should be collected on a regular basis to avoid hazards and to maintain a safe site.

A waste materials collection scheme should form part of a waste management strategy. The waste materials collection scheme should be carried out at least once a week, although this will depend on the size of the development, and the types of materials being used. All waste materials scattered around site which can be reused for their intended purpose e.g. concrete blocks, bricks, lengths of timber, etc. should be collected and reused at the earliest possible time to avoid the possibility of these materials becoming waste again.

The immediate reuse of these waste materials ensures that they are reused and do not become waste for a second time. Double handling of waste materials collected should be avoided at all costs. All wastes collected on site as part of a materials collection scheme should be recorded to calculate and maintain a record of the financial savings achieved.

Table 3.4 shows a sample materials collection record sheet which could be used on site. Ideally a separate record sheet should be maintained for each waste material, as this will aid in calculating materials quantities saved, and cost benefits achieved.

Table 3.4 Record Form for Materials Recovered on Site

Construction and Demolition Waste Materials Recovery Record					
Site Location:			Development Type:		
Waste Manager:					
Date	***Activity**	**Materials Recovered**	**Quantity Vol./Weight**	**Value €**	**Reused for Intended or Alternative Purpose.**
		Totals:			

***Activity: Refers to the activity which the waste material was intended for. e.g. Waste blocks were intended for use in the construction of a boundary wall.**

3.13 Waste Measurement and Assessment

An efficient materials management system will reduce site wastes, but prior to developing and implementing a C & D waste management plan on a construction site, it is first necessary to analyse the types and volumes of C & D wastes being generated. To examine C & D wastes generated it is necessary to audit these wastes to identify high volume, problem wastes. This allows these wastes to be targeted when implementing a C & D waste management plan on site.

The recommended method for waste measurement and assessment is a C & D waste audit. This consists of a formalised methodology for identifying and measuring site wastes. There are various types of C & D waste audit methodologies. The most appropriate waste audit methodology must be chosen for a site audit, based on the requirements set out for the waste audit, and the resources available to perform the audit. The three main C & D waste audit types are:

1. Physical Waste Audits.
2. Visual Waste Audits.
3. Desktop Waste Audits.

The information collected from a C & D waste audit should form the basis for the development and implementation of a C & D waste management plan, or strategy. Waste audits are an important part of the C & D waste management process, and it is essential to identify problem waste materials for prevention, minimisation, reuse or recycling, prior to implementing a waste management plan. Performing a waste audit not only identifies the volumes and types of wastes generated it also identifies problems with existing waste management strategies. (See chapter 4 for detailed explanation about waste audits.)

3.14 Waste Management Personnel in a Construction Company

The appointment of a company waste manager should be the first step in developing and implementing a waste management strategy. The waste manager should occupy a high management position within the company to ensure that C & D waste management starts at the highest level possible, and then filters down through the company management structure to all employees.

"While waste reduction is largely common sense and the adoption of a correct attitude of ALL people in the building firm, it cannot be achieved without constant support from top management."
(Skoyles E.R. et al., 1987).

The role of the company waste manager should include the following duties:

1. *"Identifying and interpreting government requirements and regulations;*
2. *Securing senior management support;*
3. *Conducting and overseeing the waste audit;*
4. *Establishing the waste reduction goals;*
5. *Identifying funding requirements and the costs and benefits of the program;*
6. *Developing a 3Rs programme and implementation schedule;*
7. *Monitoring the waste reduction, reuse and recycling activities;*
8. *Promoting and communicating waste reduction activities."*

(Ministry of Environment and Energy, 1994).

3.14.1 Appointing a Site Construction Waste Manager

To assist in the successful management of C & D wastes on site, a Site Construction Waste Manager (SCWM) should be appointed. This person can be the project manager, site foreman, site engineer, site quantity surveyor, site health and safety officer, or another responsible person working on site. The primary concern when appointing the SCWM should be the time that this person will have available to operate the waste management activities on site on a daily basis.

In many cases the SCWM will have many other responsibilities, which may be essential to the successful progression of the site works e.g. engineering duties, supervision of works, etc. In many cases these duties will take priority over C & D waste management due to their importance. Therefore it is essential that the SCWM is allotted the necessary time to implement and manage the waste management plan on site.

The SCWM should be made responsible for the induction of all site personnel to ensure that they are aware of their waste management responsibilities. The SCWM should coordinate all waste management activities on site, and ensure that all waste records are maintained. The SCWM should also be aware of any new, more economically beneficial waste prevention, reuse, recycling, or treatment options which become available within the locality of the site to maximise any financial benefits available.

3.14.2 Appointing a Waste Management Operative

On larger sites it may be financially worthwhile to appoint a Waste Management Operative (WMO) to ensure that all site wastes are disposed of correctly, and to maintain a tidy site. The appointment of a WMO will depend on the size of the site, and the quantities of waste generated. The WMO should ensure that wastes nominated for segregation, and recycling, are dealt with appropriately and disposed of in the proper skips.

WMO's directly responsible for the handling, moving, or segregation of site wastes can also be used to monitor waste segregation and disposal. The nomination of a WMO can eliminate all other site personal from handling site wastes and disposing of them incorrectly. This improves efficiency and allows the proper control and disposal of C & D wastes on site.

3.15 Waste Management Plans

The preparation of a waste management plan may be driven by economic factors, environmental factors, or by mandatory legislative requirements. The primary aim of most conscientious building contractors when preparing a waste management plan, or when managing their C & D waste, is to maximise the economic savings which can be achieved, and to comply with all legislative requirements.

In some situations a building contractor will have no formal waste management plan for a construction project. In cases like this the waste management techniques used on site are usually dictated by waste management legislation, and the most economical method of waste disposal available in the locality. The Waste Management Hierarchy establishes the waste management options available. Prevention, minimisation, reuse, recycling, energy recovery and disposal are all options to be considered. Naturally prevention is the most desirable, while disposal is the least desirable.

"A properly conceived waste management plan (WMP) allows a contractor to choose economical alternatives in project waste management. These choices are based on pertinent economic factors, such as transportation, labour, and disposal costs.

To provide a cost effective and successful waste management plan, three areas of investigation are required. These are, assessment of project materials; standardising alternative waste disposal methods; and calculation of the economic impact of available disposal methods. In addition two other issues must be addressed to make the WMP successful. First, there must be an effective means to allow comparison of alternative disposal methods and second, environmental conservation of C & D wastes must be addressed without loosing any competitive advantages."

(*Mills, T.et al., n.d.*)

The Task Force B4 recommends that all developments requiring planning permission should be obliged to prepare a C & D waste management plan prior to commencing construction. It was recommended that the waste management plan should include the following:

1. *"Description of project.*
2. *Waste arisings and proposals for minimisation / reuse / recycling.*
3. *Estimated costs of waste management.*
4. *Demolition plan.*
5. *Roles / responsibilities for C & D waste.*
6. *Training system for C & D waste.*
7. *Intelligence system for C & D waste.*
8. *Waste audit."*

(*Forum for the Construction Industry, 2001*).

3.15.1 The Irish Approach to Promoting the use of Waste Management Plans

On September 23rd, 2004, the Minister for the Environment, Heritage and Local Government, launched the new, "Best Practice Guidelines on the preparation of Waste Management Plans for Construction and Demolition Projects", to promote an integrated approach to waste management planning and the use of waste management plans for construction sites in excess of specified levels of construction. This has been one of the first steps taken to implement a voluntary approach for the management of C & D wastes in Ireland. The DoEHLG established the following "thresholds" for which any construction project in excess of these levels should prepare an on-site waste management plan:

1. *"New residential development of 10 houses or more.*
2. *New developments, other than 1. above, with an aggregate floor-area in excess of 1,250m^2;*
3. *Demolition projects generating in excess of 500 tonnes of C & D waste;*

4. *Civil Engineering projects generating in excess of 500m³ of waste (equivalent to 1,000 tonnes), excluding waste materials used for development works on the site."*

(*DoEHLG, 2004*).

These draft guidelines are intended to be used on a voluntary basis as opposed to being a mandatory requirement for building contractors, but it has also been highlighted that local authorities may attach conditions relating to the planning permission for a development with specific requirements for the management of C & D wastes under Section 34 (4) (1) of the Planning and Development Act, 2000. This conditioning by local authorities would be a significant step forward in the management of C & D wastes, and would assist in the compilation of accurate C & D waste statistics within local authority areas across the country.

"Some LAs are currently requesting C & D Waste Plans under Section 34 (4) (l) b of the 2000 Planning and Development Act."

(*NCDWC, 2004*).

3.15.2 Developing a Waste Management Plan

Waste management objectives, and responsibilities, should be established initially in an overall company waste management strategy outlining the company policy on waste, waste reduction, reuse, recycling and disposal. Within the waste management strategy details for conducting waste audits and the preparation of waste management plans should also be included. A waste management plan should be prepared for each individual construction project and should be developed prior to the commencement of construction. The preparation of a waste management plan is necessary to implement the various waste management strategies for the C & D wastes generated on site. The initial step in preparing a waste management plan should be to review existing waste management activities. This will highlight opportunities for improvement, and will assist in establishing realistic, achievable goals for the successful management of site wastes.

The waste management plan should be structured in such a way that the important waste reduction, reuse and recycling tasks to be undertaken are given priority over the disposal of wastes produced on site. The waste management plan should also assign responsibilities to site staff for the management of site wastes, and set out the expected results from the strategy implemented. A basic monthly waste progress report should be prepared by an appointed SCWM. This report should include details of any waste audit being conducted, the costs of C & D waste disposal, etc. and should outline the progress of the waste management plan, and any problems encountered on site.

3.15.3 Implementing a Waste Management Plan during Construction

In many situations it may be necessary to implement a waste management plan during construction. This can be a difficult process if construction is in full flow as site staff may have become accustomed to existing methods of waste handling, and disposal. In a situation like this proper waste management training must be provided to ensure that all new waste management initiatives are properly implemented and complied with. Previous studies have found that the implementation of a waste management plan during construction can be successful.

"The changes made to traditional methods were small scale and involved only slight modifications to the construction process. Nevertheless, the results demonstrate that substantial improvements can be made with minimal disruption to current working practices. Of particular importance, however, are the overall strategy adopted and the degree of cooperation that was achieved with the trades subcontractors. This resulted in the rapid development of a waste minimisation culture that, in turn, led to the generation of considerably less waste than on a site where a waste management plan was not implemented."
(*McDonald, B. et al., 1998*).

3.16 Preparing a Waste Management Plan

When preparing a waste management plan for a new construction project there are a number of steps which should be undertaken. The first requirement is that a waste management plan should be completed by the end of the design stage (*NCDWC, 2004*). Although this recommendation is made by the NCDWC the preparation of a waste management plan by the end of the design stage may not be possible as the building contractor who will have the main responsibility for the management and disposal, or treatment, of site wastes may not have been appointed at this stage.

Although a C & D waste management plan can be prepared at design stage, and may include predictions of the volumes of C & D wastes expected to be generated, this will only assist contractors in the management of C & D wastes on site, it will not necessarily dictate the disposal methods utilised. Building contractors will usually adopt the most financially advantageous method of dealing with site wastes, in compliance with the current waste management legislation.

3.16.1 The Core Construction and Demolition Waste Management Plan

The core C & D waste management plan should be straightforward and include the primary strategy for the management of all site wastes. Details of all waste prevention, reduction, reuse, recycling and disposal strategies should be included. The waste management plan should be clear, concise and include all other relevant waste management data. The waste management plan can be displayed in site offices, and in site canteens, to ensure all personnel are aware of the intended waste management plan for a construction project.

The progress of a waste management plan should be discussed at all site meetings to ensure that proper control of C & D waste is taking place, and to establish the costs of waste management on site. Table 3.5 shows a sample C & D waste management plan prepared for a proposed residential development. The layout of a waste management plan can be formatted in many different ways, depending on the level of detail required, and the information to be displayed. This sample waste management plan includes basic site details, is based on the volumes of waste expected to be generated on site, and the treatment options to be used.

Table 3.5 Sample Waste Management Plan

Waste Management Plan				
Building Contractor:	Residential Construction Ltd. Sandy Road, Galway.			
Project Description:	This development consists of the construction of 125 no. three and four bedroom residential units, including all associated services and site works. This project also includes the demolition of two existing apartment blocks on site.			
Project Location:	Terryland, Galway.		**Phone:** 091-54456	
Project Duration:	**Start Date:**	June 2005.	**Completion Date:**	August 2006
Waste Manager:	Joe Bloggs.			
Waste Manager Responsibilities:	The waste manager on this site is responsible for the management of all C & D wastes generated on site on a daily basis. This includes maintaining all records on site wastes, supervision of all site activities concerning C & D waste, and carrying out C & D waste inductions for all site personal.			
Demolition Contractor:	Oaks Demolition Ltd., Ocean Drive, Salthill, Galway.			Phone: 091-54457
Waste Management Contractor:	Carna Waste Ltd. Carrowbrowne, Headford Road Galway.			Phone: 091-55546

Waste Material	Expected Volume of Waste (m^3)	Company Responsible For Disposal or Treatment	Treatment Option (Landfill. Reuse. Recycling.)	Use of Material After Treatment
Excavated Soils	20,000	Main building contractor	Reuse. (On-site.)	Reused on site for landscaping.
Demolition concrete & rubble.	15,000	Oaks Demolition Ltd.	Recycling. (On-site.)	Reused as fill on a permitted site elsewhere.
Timber.	350	Carna Waste Ltd.	Recycled. (Off-site.)	Reused for particle board manufacture.
Plasterboard.	90	Carna Waste Ltd.	Landfill.	Landfill at licensed site.
Metals.	10	Galway Metal Ltd.	Recycling. (Off-site.)	Recycled for manufacture of new metal materials.
Polystyrene insulation.	50	Aeroboard Ltd. (Take-back agreement arranged with material supplier).	Recycling. (Off-site.)	Recycled for re-manufacture of insulation products.
Timber Pallets from cement deliveries.	200	Irish Cement Ltd. (Take back agreement.)	Reuse. (Off-site.)	Reused for repeat deliveries.
Canteen waste.	25	Carna Waste Ltd.	Landfill.	Landfill at licensed site.
Packaging wastes. (Plastic sheeting, cardboard, paper, etc.)	200	Respective material, or product suppliers.	Recycling or reuse. (Off-site.)	Recycled for manufacturing new packaging products.

All waste materials are to be treated/disposed of in accordance with all current waste management legislation.
All site wastes are to be segregated in designated skips for recycling.

3.17 The Waste Management Manual

A waste management plan can be as complicated, or as simplistic as a contractor requires. A detailed waste management plan can be prepared by the main building contractor detailing all the specifics for the management, control and recording of C & D wastes generated on site for the full project duration. The company waste management strategy should be dictated to all waste management personnel in the form of a company waste management manual.

A waste management manual should be prepared for the company detailing all C & D waste management activities, and the overall company waste management strategy. The waste management manual should be prepared by the company waste manager. It should include details of all waste management activities within the company, with the intention being that site construction waste managers, and other waste management personnel can easily find information on any aspect of the company waste management strategy. A waste management manual should contain the following information:

1. General strategy for the management of C & D wastes within the company.
2. Appointment of waste management personnel.
3. Responsibilities of waste management personnel.
4. Waste management training for company personnel.
5. Waste management legislation.
6. Specifics for the measuring, and recording, of site wastes including methodologies and record forms.
7. Details and recommendations for the preparation of waste management plans.
8. Details on the waste management contractors employed for the removal of site wastes. etc.

The list above is not exhaustive and a waste management manual should be specific to each building company. The waste management manual should act as a detailed guide for all waste management personnel within a company. It should be reviewed on a regular basis to ensure that all waste management activities performed by the company are included.

3.18 Construction and Demolition Waste Management Training

The training of site staff is essential for the success of a waste management plan. All site staff from site management personnel to general operatives should be engaged in a training course, or toolbox talk, at the commencement of their duties on site. This training/induction should be carried out by the site construction waste manager and should form part of the site safety induction, which all site personnel must undergo. Waste induction/training is important to ensure that all site personnel are aware of the objectives set out under a waste management plan.

"If site personnel do not know what measures should be taken on site to minimise waste, they will not be able to participate. People need to know why they are doing something so that they can recognise the value of the measure.

As their awareness is raised, people will realise that there is a point for allocating time and resources to waste reduction, reuse and recycling and will incorporate good practice into their daily regimes. Good waste management is part of good safety on site, and central to economic efficiency on site."
(*CIRIA, 1999*).

Sustainable waste management techniques used on site should be displayed using posters in site offices and canteens to sustain and increase the emphasis placed on the management of C & D wastes. Personnel responsible for the overall management of waste at senior management level, and at site management level, should attend appropriate C & D waste management courses to ensure they are aware of all current waste management legislation, and recommended best practice, for the management of C & D wastes.

Waste management education must start at a high level within a company and then be filtered down to all site staff. Without proper training, and a knowledge of current best practice for the management of all C & D wastes, inefficiencies will be prevalent and money will be wasted.

3.19 Health and Safety in Construction and Demolition Waste Management

Health and Safety (H & S) has become more prominent in all areas of construction in recent years. One of the core considerations in the management of C & D wastes on any construction site is H & S, especially where demolition, or deconstruction, is being conducted and where hazardous wastes are being generated. Any personnel handling C & D waste on construction sites must use personal protective equipment.

Although H & S has come to the forefront of the construction industry in recent years there is a necessity for increased guidance concerning the management of C & D wastes, including hazardous wastes. The NCDWC have identified the need for environmentally responsible C & D waste management practices, and the lack of H & S guidance for demolition. The Health and Safety Authority are currently setting up a registration system for asbestos contractors, and have also started development of guidance documents in relation to demolition on construction sites.

"The NCDWC has reviewed UK Guidance Notes concerning H & S in Demolition. The NCDWC has identified the HSA as the appropriate body to develop H & S guidance in relation to demolition and has been requested to complete this task."
(*NCDWC, 2004*).

3.20 Skip Management on Site

In the current climate the majority of C & D wastes are removed from site by waste skips supplied by waste management contractors. One of the overriding factors dictating the number and size of waste skips used for a construction project is the space available on site for skip storage. Naturally large open sites will allow storage for many skips of varying sizes, while sites with restricted space will accommodate fewer waste skips. Sites with restricted space, and with fewer waste skips, may dictate the management of some site wastes by reducing the quantities of wastes that can be segregated and stored on site, thus dictating the waste management strategy for that particular site. The segregation of site wastes is generally only carried out if there is a financial incentive for the building contractor.

Waste management contractors in the Galway Region supply waste skips to sites in varying sizes. The standard C & D waste skips supplied are 35 cubic yard (cy) skips, 12 cubic yard skips, 8 cubic yard skips, and 1.5 cubic yard skips. The majority of waste skips used for general site wastes are 12 cubic yard skips, with 1.5 cubic yard skips being used only for canteen wastes. Only permitted waste management contractors should be used to dispose of C & D wastes at licensed facilities. The waste management contractors waste collection permit should be checked on site on a regular basis when waste skips are being removed.

3.20.1 Managing Waste Skips on Site

The location of waste skips on site is an important factor in the management of site wastes. Ideally waste skips should be located as close to the point of waste generation as possible. If waste skips are scattered around site then the segregation of C & D wastes can be hindered, unless all site personnel disposing of wastes have been properly trained in the waste management strategy being used on site.

Site personnel, if they have any responsibilities for waste disposal on site, must be aware of the wastes that have been nominated for segregation, and the appropriate skips for the segregation of these wastes. In situations where the location of waste skips on site is not managed properly the segregation of nominated wastes can be difficult, and the use of waste skips for the disposal of wastes from off-site e.g. wastes which originate elsewhere and are brought onto site by staff, can be a problem.

Ideally construction sites should have a waste compound where all the main C & D waste skips are located. On some sites a number of waste compounds may be necessary. Naturally, establishing waste compounds may not be achievable on smaller congested sites. The waste compound should be fenced off, and access should be restricted to waste management personnel only to avoid the disposal of wastes in the wrong skips, and to avoid the use of waste skips by other site personnel for the disposal of off site waste which may be brought onto site for improper disposal.

As wastes are generated on site from different elements of a construction project smaller skips e.g. 3cy skips, 4cy skips, may be utilised and provided to the various trades to dispose of their wastes, and to segregate these wastes as required. These smaller waste skips can then be transported to the waste compound by waste management personnel on site and disposed of in the appropriate skips. In most cases there will be many general wastes such as packaging wastes, pallets, etc. which will be generated on site and these wastes may occur outside subcontractors work. Nominated waste management personnel will need to be appointed to handle and dispose of these wastes. A number of general, guidelines for the management of waste skips on site are as follows:

1. Operatives placing C & D wastes into waste skips should ensure that wastes are placed into skips, rather than thrown in. This will aid in maximising the volumetric capacity of the skip and minimise the amount air space.
2. Easily compactable wastes such as paper bags, cardboard, plastic sheeting, etc, should be segregated into separate skips as they can be easily compacted using the bucket of an excavator. This will again maximise the volume of waste contained in the skip and minimise the volume of air space. Waste skips with removable covers are available and should be used to keep wastes such as cardboard dry, if this waste is to be recycled.
3. It is important to cover waste skips when being removed from site to avoid debris falling out during transport. This is usually standard procedure by waste management contractors when removing waste skips from site. It is also vital to

ensure that only full skips are removed from site to prevent excessive disposal costs and inefficiencies.

4. On a site where waste is being produced continually it is essential to ensure that there are enough skips available for waste disposal to avoid double handling of wastes placed on the ground.
5. Waste skips should not be overloaded as this can also lead to potential hazards during skip transportation.

3.20.2 The Management of Waste Skips by Subcontractors

Subcontractors should be made aware of all waste reduction, minimisation and disposal strategies on site. An alternative to the management of waste skips on site, as previously described, where the main contractor manages all site wastes, is to require all subcontractors to supply their own waste skips on site. Although this might initially sound like a suitable waste management strategy it may lead to problems when there are many subcontractors on site.

In a situation where there are few subcontractors on a smaller site it may be possible to have each subcontractor supply their own waste skips, and to dispose of all their own wastes without any input from the main building contractor. In a situation like this it would be easy for each subcontractor to ensure that only their wastes are disposed of in their waste skips. On larger sites with many subcontractors supplying their own waste skips it would be difficult for each subcontractor to prevent others from using their waste skips. Table 3.6 shows sample wording for a main contractor/subcontractor agreement for establishing subcontractor waste management responsibilities on site.

Subcontractor waste generation may also be controlled by ensuring that the materials supply responsibilities, by the main contractor, or by the subcontractor, are properly managed on site.

"It is recommended either that sub-contractors are responsible for the supply of the materials that they require, or that clauses are introduced into the contract that penalise them for wastage; or both."
(*CIRIA, 2001*).

Table 3.6 Sample Wording for a Contractor / Subcontractor Waste Management Agreement

Construction Waste

Site Address:
To all Subcontractors.
Re: Waste disposal on this site:
Due to ever increasing waste disposal costs (up over 400% in four years) including:

- Extra materials wastage.
- Cost of removing waste from the job site.
- Waste skip charges (running at up to €200 tonne).
- And lost production as a result of untidy working conditions.

We must advise all subcontractors of their obligations to arrange for the proper and legal disposal of their own materials waste from this site.

Each individual subcontractor is no doubt quite aware of the national waste problem besetting construction projects and all are hereby equally asked to cooperate.

We have appointed a waste control manager on this site and would ask for your cooperation with him to minimise waste arising on this site and to arrange to segregate such wastes wherever possible.

Failure to act in a positive manner may result in subcontractors facing Main Contractor contra charges for all associated costs including labour and waste skip collection and weight cost.

Our objective is to keep the site safe, clean and clear from unsightly wasted materials to maximise on safety and ultimately improve production, which is in everybody's interest.

Your co-operation is required to make this success.

Signed: **Date:**

(*Donnelly, J., 2003*).

3.21 Signage for Construction and Demolition Waste Management

To ensure that all C & D waste management initiatives are promoted on site, and to ensure that site personnel are aware of the importance of the management of site wastes, it is necessary to use appropriate waste management signage on site. Waste management signage should be located around site, and in common areas such as the site canteen and site offices, to ensure all site staff are aware of the waste management strategies utilised on site.

All skips being used for C & D waste should have the appropriate signage to ensure that only nominated C & D wastes are disposed of in those skips. The alternative to using signage on waste skips is to use colour coded skips. Although this may initially sound like a good idea it may not be possible to obtain appropriately coloured skips. In most cases waste management contractors use a single colour for their skips. This may necessitate that the main building contractor purchase their own skips, or that the waste management contractor changes the colour of their skips, as required.

3.22 The Cost of Construction and Demolition Waste

C & D waste of any description is contrary to good site management. It reduces profits and requires valuable time and labour for disposal. Building contractors have a tendency to view C & D waste as material waste only, and rarely include the associated time and costs in the collection, disposal, or recovery of these wastes. The implementation of a waste management strategy for a company will increase costs, in the short term, due to increased training, consultation, staffing, etc. (*Shen. L. Y. et al., 2004)*. The successful prevention, minimisation and management of C & D wastes can have many economic benefits for building contractors:

"The construction industry would make significant cost savings by increasing the emphasis on waste reduction, reuse and recycling. For example, when the full cost of waste is considered in a project cost evaluation, it can total more than ten times the disposal cost."

"Waste minimisation will become increasingly important as the costs of waste management and disposal continue to increase. "

"Costs will continue to increase, as landfill space becomes scarcer. Rising disposal costs inevitably will be reflected in the overall cost of construction and demolition projects." (*Coventry, S. et al., 1999*).

Many construction projects are allocated a budget for waste disposal, but this may not include the labour and plant also required for waste management. Generally records of labour and plant used for the management of site wastes are not maintained on site. This makes it difficult to establish an accurate cost estimate for the total expense of waste management for a construction project. Table 3.7 outlines the true cost of construction and demolition wastes on site.

Table 3.7 Calculating the True Cost of Construction and Demolition Waste

The True Cost of Construction and Demolition Waste		
[illegible]	B	C
Purchase price and transportation costs of materials that are being wasted.	The cost of storage, transportation, disposal and handling of waste.	Loss of income from not salvaging waste materials.
A + B + C = The true cost of C & D Waste		

(*Guthrie P.M. et al., 1997*).

As seen in Table 3.7 the true cost of C & D waste exceeds the purchase cost of the waste material and the cost of its disposal. Transportation, storage, handling costs, and the loss of income from not salvaging and reusing the waste materials must also be included to calculate the true cost of site wastes. Although this is what Guthrie, et al., stated, with closer examination it can bee seen that C (Loss of income) can mitigate A + B.

Transportation costs have increased significantly in recent years due to increased operation costs for haulage contractors e.g. increases in road tax, labour, insurance, fuel costs, etc. It is relatively easy to obtain, from site records and suppliers, the purchase price for new materials, the transportation costs, storage costs, disposal costs, and the loss of income from not reusing or salvaging waste materials, all of which are necessary to calculate the true cost of waste.

The calculation of a true cost for C & D waste may be hindered unless comprehensive site records are maintained for waste handling time. Records for waste handling time are not usually maintained on site as the collection and disposal of wastes are intermittent and irregular. (General operatives may spend short periods of time collecting and disposing of site wastes between performing their primary duties, or they may dispose of site wastes as they are generated as part of the work that they are carrying out e.g. a general operative responsible for mixing mortar may dispose of waste cement bags as they are generated. As seen in the previous example, the monitoring and recording of site waste volumes as they are generated makes the estimation and recording of waste handling time difficult.)

On a site where a general operative is appointed solely for the collection and disposal of all site wastes the calculation of waste handling time is simpler as one person is responsible for waste handling. Records for waste handling time can be easily maintained in a situation like this and used to calculate the true cost of C & D wastes generated on site.

3.23 Recording Construction and Demolition Waste Related Data

In order to maintain comprehensive C & D waste data on site, to calculate the full cost implications resulting from site wastes, the following records must be maintained on a daily basis.

- **Skip Removal/Waste Audit Record**

  All waste skips removed from site must be recorded, including wastes removed from site by truck, or by other means. A skip volume analysis form, or waste audit form, must be used to record all skip details. Table 3.8 shows an example of a C & D waste audit form. This record form can also be used to record wastes removed from site by truck.

Table 3.8 Sample Waste Audit Form

<table>
<tr><th colspan="9">Construction and Demolition Waste Audit Form</th></tr>
<tr><td colspan="4">Site Location:</td><td colspan="5">Development Type:</td></tr>
<tr><td colspan="4">Skip Ref. No:</td><td colspan="5">Auditor:</td></tr>
<tr><th>Date</th><th>C/N</th><th>Waste Material</th><th>% Full</th><th>Vol.</th><th>Weight</th><th>Cost €</th><th>Comments</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Totals:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">C: Compacted. N: Non-Compacted.</td><td colspan="5">Skip Ref. No.: Skip No. / Skip Supplier Initials / Skip Size In cy.</td></tr>
</table>

- **Weekly Labour and Plant Record used for Waste Management on Site**
  This information must be recorded for all labour and plant utilised in the management of C & D wastes on a daily basis. Table 3.9 shows a sample labour record form, and Table 3.10 shows a plant record form for site use.

Table 3.9 Sample Labour Record Form for C & D Waste Management

Construction and Demolition Waste, Labour Record					
Site Location:			Development Type:		
Waste Manager:					
Labour Used in the Management of Site Wastes					
Date	**Activity**	**Operative Name**	**Time Hrs.**	**Cost €**	**Comments**
		Totals:			

Table 3.10 Sample Plant Record Form for C & D Waste Management

Construction and Demolition Waste, Plant Record					
Site Location:			Development Type:		
Waste Manager:					
Plant Used in the Management of Site Wastes					
Date	**Activity**	**Plant Used**	**Time**	**Cost €**	**Comments**
		Totals:			

- **Material Recovery/Salvaged Record**
  This record is needed to record all materials collected, or salvaged, on site which are, or were at risk of becoming waste. This record must also record all materials that are recovered for reuse on site e.g. recycled demolition wastes for reuse as site fill. Ideally a separate record sheet should be maintained for each separate waste material recovered on site.

Table 3.11 Sample Waste Materials Recovered Record Form

Construction and Demolition Waste Materials Recovery Record					
Site Location:			Development Type:		
Waste Manager:					
Date	**Activity**	**Materials Recovered**	**Quantity Vol./Weight**	**Value €**	**Comments**
		Totals:			

- **Subcontractor Non-Compliance Record**

  All incidences of non-compliance by subcontractors where their C & D waste responsibilities are established in their waste agreement/contract documents must also be recorded. Table 3.12 shows a sample C & D waste non-compliance record form.

Table 3.12 Sample Record Form for Subcontractor Non-Compliance

Construction and Demolition Waste Subcontractor Non-Compliance Record						
Site Location:			Development Type:			
Waste Manager:						
Date	**Location of Non-Compliance On Site**	**Non-Compliance Details**	**Labour Costs Incurred €**	**Plant Costs Incurred €**	**Penalty Imposed €**	**Total Costs Incurred €**
Total Penalty (€) To be Imposed on Subcontractor for C & D Waste Non-Compliance:						€

- **Monthly Construction and Demolition Waste Expenses Record (Summary)**

  This is a summary page which includes all C & D waste information collected on site over the period of, ideally a month, using information from the data collection sheets e.g. Skip Records, Labour Records, Plant Records, Materials Recovered Records. This form can also be used to summarise all C & D waste data at the end of a construction project. Table 3.13 shows a sample summary sheet.

Table 3.13 Construction and Demolition Waste Summary

Construction and Demolition Waste Summary					
Site Location:			Development Type:		
Waste Manager:			Date From / To:		
Skip Supplier	**Skip Size**	**No. of Skips**	**Skip Costs €**	**Sub Totals €**	**Total Costs €**
Labour	**Activity**		**Labour Costs €**	**Sub Totals €**	
Plant	**Activity**		**Plant Costs €**	**Sub Totals €**	
Materials Recovered	**Materials Quantity**		**Material Cost €**	**Sub Totals €**	
Subcontractor Non-Compliance			**Penalty Cost**	**Sub Totals €**	
Other Construction and Demolition Waste Expenses			**Costs €**	**Sub Totals €**	
Total Construction and Demolition Waste Management Costs:					€

The C & D waste cost data established in the summary above will assist a building contractor in compiling a total cost for the management of C & D wastes for the full duration of a construction project. This will aid in examining the cost improvements that may be made on future construction projects, and will also aid contractors in establishing the true costs of C & D waste management, which will assist in preparing costings for future construction projects.

3.24 The Cost of Waste Skips

The majority of C & D wastes generated on construction sites are disposed of by waste skip. Building contractors generally acquire skips from the waste management contractor offering the most financially beneficial service. Building contractors must ensure that they employ a legitimate waste management contractor who has the necessary waste permits. They must also ensure that all their C & D wastes are disposed of at a licensed, or permitted facility.

There are three main construction waste skip suppliers in the Galway City area. These three waste management contractors supply waste skips based on a flat fee per skip, or a fee per tonne for mixed wastes and segregated wastes e.g. wood. Fees for segregated wastes are generally cheaper than mixed wastes as these wastes have a financial value for the waste management contractor who redirects them for reuse or recycling. Table 3.14 outlines the costs for waste skips from the various waste management contractors supplying skips in Galway City and County.

Table 3.14 Waste Skip Disposal Costs in the Galway City Area

Waste Management Contractor	Address	Skip Sizes Supplied (Cubic Yards)	Waste Types Segregated / Non-Segregated	Cost of Waste Skip Disposal (€)
East Galway Waste.	Killimore, Ballinasloe, Co Galway.	35 cy	Segregated Timber	€500
		12 cy	Mixed Waste	€250
		12 cy	Segregated Metals	€0
		8 cy	Mixed Waste	€175
Barna Waste	Carrowbrowne, Headford Road, Galway.	12 cy	Mixed Waste	€158 per tonne
		12 cy	Segregated Timber	€48 per tonne
		12 cy	Segregated Metals	€0
		8 cy	Mixed Waste	€158 per tonne
Walsh Waste.	Parkmore, Ballybritt, Galway.	35 cy	Segregated Timber	€300
		12 cy	Mixed Waste	€250
		12 cy	Segregated Metal	€0
		8 cy	Mixed Waste	€175

Cost data compiled in August 2004.

Sometimes it can be less expensive to waste materials than to attempt to prevent the wastage of these materials. There comes a point in each waste material that any further attempt to recover this waste will be more expensive than the value of the recovered material. Currently legislation and economics appear to be the driving force behind C & D waste management.

3.25 The Cost Benefits of Advanced Waste Management Planning

Advanced planning for C & D waste management on site can have potential financial benefits. Proper organisation on site, and the segregation of site wastes, can result in reduced disposal costs. Proper storage and use of materials, good work practices, and an efficient labour force can also minimise waste generation and waste management costs. Planning for waste management is critical to minimise wastes, and costs. Table 3.15 shows a cost assessment for recycling of a quantity of sand, as opposed to landfilling.

Table 3.15 Potential Cost Benefits of Recycling Waste Sand

	Cost of Recycling. (€)	**Cost of Landfill. (€)**
Cost of materials wasted (20 tonnes.)	260	260
Cost of recycling (i.e. transportation costs and gate fee @ €7 / tonne)	140	-
Cost of landfill (i.e. transportation costs and gate fee @ €100 / tonne.)	-	2000
Landfill Tax (@ €15 / tonne.)	-	300
Total Costs for 20 tonnes (€)	**400**	**2560**
Total Costs per tonne (€)	**20**	**128**

(*FAS, 2002*).

"Contractors must be educated about possible cost savings from measures which successfully prevent construction waste, as well as the environmental impacts of the waste and its long-term national and global implication."
(*Ekanayake, L.L. et al., 2000*).

When developers and building contractors are in control of project design further reductions in waste generation can be achieved. The use of prefabricated construction elements, and the design for use of standard materials sizes, can also reduce waste in the form of off-cuts. The organisation of take back agreements with packaging waste suppliers can further reduce disposal costs. Advanced planning for C & D waste management on construction projects must be performed prior to the commencement of construction. All cost calculations must be based on the waste treatment facilities available in the locality, and the materials being used in construction.

3.26 Managing and Disposing of Construction and Demolition Wastes Generated on Site

The management of C & D wastes generated on site is dictated by the wastes generated, the resources provided by the building contractor, and the waste management facilities available in the locality. Generally, contractors are motivated to manage their wastes effectively e.g. reuse, recycling, etc., by the economic benefits that can be achieved from this, and by the waste management legislation in force.

Prior to commencing construction on a development, building contractors should investigate all options available for the disposal, and treatment, of site wastes. It is more sustainable for developers, and contractors, to recycle their waste materials rather than dispose of them, if there is no variation in costs. Waste materials nominated for reuse or recycling should be segregated to prevent contamination, which may prevent reuse or recycling.

The composition and volume of C & D wastes generated on construction sites will vary depending on the materials being used, the construction technologies, work practices, and the management of daily activities on site. The auditing of wastes will highlight the high volume wastes, which should be targeted for more efficient management. The composition of the C & D waste stream generated in Ireland was examined in a 1996 survey carried out by the Cork Institute of Technology. This study established that the C & D waste composition was as follows:

Table 3.16 Construction and Demolition Waste Composition in Ireland

Irish Construction and Demolition Waste Composition	
Soil, Stones	45%
Concrete, Bricks, Tiles, Ceramics	31%
Other	10%
Wood	7%
Metals	6%
Asphalt / Tar	1%

(*FAS, 2002*).

The data from this study in Table 3.16 shows that the waste categories are not specific to all individual waste materials which may be generated on site e.g. plasterboard, insulation, etc. This further highlights the need for more extensive studies to be undertaken to develop more detailed C & D waste statistics for Irish construction sites.

3.27 Construction and Demolition Waste Disposal and Treatment Options Available in the Galway Region

Currently the direct landfilling of C & D waste is banned in Galway. The following C & D waste treatment and disposal options are available to contractors in the Galway Region.

3.27.1 Excavated Soils and Stones

The reuse of uncontaminated excavated soils, and rock, has been commonplace in the construction industry for many years. Excavated soils and rock have been continually reused on the site on which they were generated, or on alternative sites. All uncontaminated waste soils can be reused on the site on which they originated, or alternatively they can be disposed of at another permitted site. Soils stored on site can be damaged if they are allowed to be driven over, and damage may also occur to the structure of soils with prolonged storage (*CIRIA, 1997*).

Contaminated soils must be treated to remove contaminants prior to reuse. The owner of a property is responsible for the decontamination of contaminated waste soils, and is liable for the costs of any treatment required.

3.27.2 Crushing Rock on Site

In many cases it may be possible to utilise the natural resources of a construction site to effectively manage waste soils. This can result in significant financial savings and will reduce energy consumption from reduced haulage. In recent years the process of blasting, excavating and crushing rock on construction sites has become commonplace in Galway.

Crushing rock on site for reuse as site fill can result in significant financial savings (depending on the volume of rock being crushed), as it omits the requirement for purchasing new crushed stone for site fill. The resulting void from excavating the rock can be used to dispose of uncontaminated waste subsoil, although this may not be possible if there are structures to be constructed over the area backfilled with waste subsoil.

The disposal of waste subsoil on site will also have financial benefits as transport and disposal costs will be significantly reduced. The financial benefits incurred from this activity will depend on the volume of rock to be crushed, and the volume of waste subsoil to be disposed of. A full financial assessment of the viability of this option must be performed prior to the commencement of construction to ensure it is financially worthwhile.

3.27.3 Concrete, Concrete Blocks, Bricks and Rubble

Inert wastes such as concrete, concrete blocks, bricks and rubble from demolition should not be disposed of by waste skip. Traditionally these materials have been reused on site (if uncontaminated), or on alternative sites, for their intended purpose, or for use as site fill. These materials should be recovered for reuse as site fill, which is achievable in most cases, provided that these wastes are uncontaminated.

Concrete blocks, bricks and rubble from demolition projects can be crushed on site and reused as low grade fill under pathways, back gardens, and in raising green areas to required levels. In situations where these wastes are being crushed on site, and reused, then a waste permit must be obtained from the local authority. The financial implications of crushing concrete wastes on site must be analysed to ensure that it is an economically viable option. (This requires large volumes.)

"Every tonne of concrete waste that is recycled for aggregate in new concrete would save nearly a tonne of primary aggregate being quarried from our countryside or dredged from our seas. Recycling concrete saves money by avoiding waste disposal costs, and has additional environmental benefits."
(Guthrie. P.M., et al., 1997).

Roadstone Dublin Ltd., accept waste concrete products, stone, aggregates, sand, etc. for reprocessing at a rate of €3 per tonne, delivered to their processing plant in Dublin. This is likely to become commonplace at all their plants in the future. In June, 2004, the publication of a new specification by the National Roads Authority allows the use of recycled concrete materials in certain road construction activities. Any recycled materials used must meet Factory Production Control Standards under this new specification. This is a significant step forward into regulating the reuse of recycled inert concrete, stone and brick products, which will increase their reuse in the construction industry and make the use of these recycled materials more widely acceptable.

3.27.4 Waste Polystyrene Insulation

Polystyrene insulation is a product which can be recycled easily, provided it remains unsoiled and uncontaminated. Waste polystyrene off-cuts should be segregated and disposed of in clean plastic bags and stored in a designated storage area on site to prevent soiling and contamination. (Naturally the implementation of this waste management initiative will depend on the volume of waste polystyrene being generated on site, but there can be significant financial benefits).

In most cases insulation manufacturers will agree to take back unsoiled, uncontaminated, polystyrene waste off-cuts free of charge for recycling. Usually polystyrene wastes will be removed from site by the haulage contractor used by the manufacturer to deliver their insulation products to site. On large sites producing significant quantities of waste polystyrene insulation this waste management strategy can have significant economic benefits.

3.27.5 Canteen Waste

Canteen wastes are generated on most construction sites. Canteen waste consists of food waste, and packaging wastes associated with the management of a site canteen e.g. plastic packaging, cardboard packaging, soft drinks cans and bottles, etc. This waste stream should be segregated into smaller waste skips which can be covered to prevent vermin.

The three most prominent waste management contractors supplying waste skips in the Galway area supply 1.5cy covered waste skips specifically for canteen waste.

3.27.6 Waste Plasterboard

Although plasterboard can be recycled there is currently no recycling facility for this waste stream in the west of Ireland. A new recycling plant has been established in Dublin. (Gypsum Recycling Ireland Ltd., 44a Moyle Road, Dublin Industrial Estate, Glasnevin, Dublin 11.) On many construction projects where plasterboard is used in the construction of stud partition walls and ceilings, it can be a high volume waste. This waste stream should be segregated into a separate waste skip to prevent contamination of other C & D wastes with gypsum.

In a situation where there is a treatment facility available for recycling plasterboard waste, then plasterboard off-cuts should be kept unsoiled and uncontaminated, and be segregated into plastic bags to prevent moisture damage. This material should then be stored until sufficient volume has been accumulated for recycling. Eventually with the progressive development of recycling facilities across the country an outlet will be established to recycle plasterboard in the west of Ireland.

3.27.7 Waste Timber

Timber waste can be a high volume, problem waste on many construction sites. Waste timbers, provided they are uncontaminated, and have not been treated with preservatives, can be reused, or recycled. Some waste management contractors provide a reduced rate for segregated timber waste. The segregation of timber waste, including waste pallets, can provide significant cost savings for building contractors.

An alternative to disposing of timber waste by skip is to process it on site by mulching it for reuse as a landscaping material. As this is reprocessing (where a waste material is turned into a new material) a waste permit from the local authority is necessary. Problems can occur with this method of reuse as timbers can contain nails, which may damage processing equipment, unless it is equipped to remove metal contamination.

In many situations timbers may contain preservatives. This means that it cannot be processed, and reused, on site as it may potentially cause contamination. Reuse of recycled timber wastes may also require testing under the conditions of a waste permit to ensure that no contamination will occur. The financial implications of reusing timber wastes in this manner must be examined prior to the commencement of construction to ensure it is a financially viable option.

3.27.8 Timber Pallets

Timber pallets, if they are properly handled and stored on site, can be reused for their initial intended purpose. In many cases pallets will be taken back by the company who supplied the product, or material, to site e.g. cement manufacturers usually take back their pallets. The ideal management option for waste timber pallets would be to arrange take back agreements with all suppliers. Problems can occur with this strategy when products, or materials, are not supplied directly by the manufacturer. Retailers will not accept waste pallets for return to their product, or material, suppliers.

If it is not possible to arrange a take back agreement then the waste management contractor should be contacted as a potential outlet for reusable timber pallets. In Galway some waste management contractors will remove reusable pallets from site for a nominal fee of €1.50 per pallet. Waste pallets are useful for storing materials and moving materials around site. Alternatively waste pallets should be, if possible, crushed on site using a mechanical excavator (to minimise the volume of space that waste pallets will take up in a waste skip) segregated, and disposed of by waste skip for recycling.

3.27.9 Steel and other Metal Wastes

Metal wastes are produced in various quantities on site, depending on the materials being used. These wastes can result from reinforcing steel, metal studs, plumbing pipe off-cuts, steel packaging straps, etc. Metal wastes can be recycled easily, and should be recycled as significant energy requirements are necessary to produce metals which contributes to environmental pollution.

In the Galway Region most waste management contractors will provide a waste skip free of charge for the disposal of metal wastes. In some cases scrap metal companies such as Galway Metal Ltd. will also provide a waste skip for the disposal of metal wastes generated on site.

3.27.10 Waste Cement and Plaster Bags

Cement and plaster bags provide a significant problem for recycling as their packaging invariably contains a mixture of paper and plastic packaging materials. The remaining packaging waste, after these products have been used, are soiled by the material that they contained. This packaging waste material can be incinerated, ideally for energy recovery, but currently no facility exists in Ireland for the incineration of C & D wastes. This waste stream should be segregated as it has a low density which allows it to be compacted easily. If this waste stream is segregated it can be compacted in a waste skip, using the bucket of an excavator, maximising the amount of material contained in the skip.

3.27.11 Packaging Wastes (Paper, Plastic Sheeting, Cardboard)

Packaging waste, which includes cardboard, paper, plastic sheeting, plastic packaging bands, paper bags, etc. can be a high volume waste stream on construction sites as most materials and products have some form of packaging, whether to prevent damage or to display supplier details. If a material, or product, supplier is not a member of Repak then all packaging wastes supplied to site must be taken back and recovered. On the other hand if a supplier is a member of Repak then they are not legally obliged to take back their packaging materials.

Generally the mindset among materials, or product, suppliers is that if you purchase the material, you also purchase the packaging included. Building contractors must enforce their rights under the packaging regulations. Arrangements for the management of packaging wastes should be discussed with materials and product suppliers prior to the commencement of construction. The removal of packaging wastes by suppliers would provide significant savings for building contractors.

Most packaging wastes have a high potential for recycling, provided they are kept unsoiled and uncontaminated. It may be beneficial for a building contractor to contact their suppliers to specify that a minimum amount of packaging is used when materials are delivered to site, but this would need to be tested. Building contractors should ensure that papers and materials with company logos are not disposed of without shredding.

3.27.12 Other Construction and Demolition Wastes

Other C & D wastes, apart from those mentioned previously, can also be generated on site and will depend on the materials being used in construction. Ceramic tile off-cuts, plastic soffit and fascia off-cuts, DPC, roof tiles, roof felt, etc. are some other C & D wastes which can be generated on construction sites. In most situations other wastes like these will be produced in smaller quantities. This limits the financial savings that can be achieved from the segregation of these wastes, although every effort should be made to reduce, reuse and recycle.

3.27.13 Thermal Treatment / Waste – To – Energy

Although most of the previous waste disposal and treatment options include the use of waste management contractors, waste recycling companies, waste transfer stations, etc., there may be alternative treatment options available in the future. The Connaught Waste Management Plan has envisaged that one thermal treatment facility is necessary for the Connaught Region. The prime waste targeted for incineration in the region is municipal waste, and municipal waste types generated in the industrial sector. If this facility was constructed it is likely that some combustible C & D waste streams would be incinerated. e.g. cement and plaster bags, packaging waste, etc.

Although a thermal treatment facility was proposed by the Connaught Waste Management Plan, and was expected to be in operation by the end of 2005, no progress has been made to date. Some progress has been made under other regional waste management plans for the development and operation of thermal treatment facilities.

Dublin City Council acting on behalf of local authorities within the region is currently procuring a Waste – to – Energy plant on a public private partnership. The plant is expected to have a capacity of 500,000 tonnes per annum. The Cork Region has sought and gained permission for a thermal treatment facility in Ringaskiddy, for the incineration of hazardous and non-hazardous wastes. Planning permission was granted by An Bord Pleanala in January, 2004, and a waste license application has been made to the EPA. Planning permission has also been granted for a facility at Carranstown, Co. Meath, and a waste license application has been made to the EPA.

Of the 10 regions covered by different regional waste management plans, 5 regions have made no progress in the development of thermal treatment facilities and their progress will depend on the progress of regions within which actions have been taken to gain permission to operate thermal treatment facilities. The development of a thermal treatment facility in Connaught is currently stagnant.

3.28 Hazardous Construction and Demolition Waste

The segregation of hazardous C & D waste is a necessity on all construction sites. The disposal of hazardous wastes in general waste skips can lead to contamination of all wastes contained in those waste skips. Hazardous wastes must be disposed of appropriately. Contractors must be aware that they are responsible for the proper treatment and disposal of hazardous wastes and all other C & D wastes following their removal from site. Paints, oils, chemicals, aerosols, containers which contain chemicals, etc. are all hazardous wastes which can be generated on site.

"Special or hazardous wastes should be retained in isolation from other wastes to avoid contamination. Certain C & D materials are hazardous, e.g. asbestos, lead, tars, paint and preservative residues, adhesives, sealants and certain plastics. If such materials are mixed with non-hazardous materials e.g. lead-based paint tins thrown onto a pile of bricks and concrete, the whole pile becomes hazardous and must be disposed of as hazardous waste."
(*FAS, 2002*).

The European Waste Catalogue classifies C & D wastes as hazardous if they have any of the following properties:

1. H1: Explosive.
2. H2: Oxidising.
3. H3 A: Highly Flammable.
4. H3 B: Flammable.
5. H4: Irritant.
6. H5: Harmful.
7. H6: Toxic.
8. H7: Carcinogenic.
9. H8: Corrosive.
10. H9: Infectious.
11. H10: Teratogenic.
12. H11: Mutagenic.
13. H12: Substances and preparations which release toxic or very toxic gasses in contact with water, air or an acid.
14. H13: Substances and preparations capable by any means, after disposal, of yielding another substance, e.g. a lechate, which possesses any of the characteristics listed above.
15. H14: Ecotoxic.

Definitions of the 15 properties which render a waste hazardous can be seen in Appendix C.

Expert advice should be sought when dealing with hazardous building wastes. Specialised disposal techniques or waste management contractors may be required e.g. asbestos disposal.

3.29 Conclusions

The aim of this chapter was to examine recommended best practice C & D waste management. This assessment was carried out with a view to establishing the main requirements necessary for a building contractor to implement, and manage, a successful C & D waste management strategy. Having a knowledge of recommended best practice waste management allows a building contractor to determine the efficiency of their existing practices and also highlights the areas which require improvement. The conclusions are as follows:

- The efficiency of a building contractors waste management strategy is essential to preventing, minimising, reusing and recycling C & D wastes. There is no definitive waste management strategy suitable for all construction companies or sites, although the fundamentals will remain the same. Guidance exists for the general management of site wastes, but modifications to existing best practice recommendations may be necessary, depending on the specifics of a site e.g. location, materials being used, availability of disposal, or waste treatment options, etc.

- A basic C & D waste management strategy, or a default waste management strategy (e.g. the management of site wastes without having any formal waste management plan) adopts a method of dealing with site wastes which usually complies with current waste management legislation and utilises the most economic method of waste disposal, or treatment, available in the locality. Little or no thought goes into the management of C & D wastes on most construction sites in Ireland as formalised C & D waste management strategies are uncommon. Other factors such as site management personnel who are not fully aware of the total impact C & D wastes can have on the management and economics of a construction project also contribute to inefficiencies in the management of site wastes.

- The management of site wastes should be initiated by implementing proper materials control methods on site to minimise waste generation. Scheduling, ordering, delivery, site storage, site handling and the correct use of materials on site is essential to prevent and minimise waste. A contractor developing a waste management strategy should do so using the waste management hierarchy as a guide for dealing with site wastes.

- Waste management within a construction company must be initiated and driven from top management level with the appointment of an appropriate member of staff as the company waste manager. The company waste manager must make themselves aware of all new waste management legislation and new opportunities for decreasing C & D waste volumes, and costs. The responsibility for managing C & D waste must be filtered down through the company incorporating every activity. The success of any waste management strategy depends on the acceptance of new initiatives by all company employees who must be trained and inducted accordingly.

- Waste management plans should be prepared for each individual construction project. The main structure of a waste management plan for a construction site will be similar to others, but the specifics may vary from site to site, depending on the facilities available in the locality. The preparation of a waste management manual incorporating details of all waste management activities is important to promote best practice waste management within a company.

- Proper records must be maintained to measure the true costs of C & D wastes to allow improvements into waste management to be made, to allow the comparison of waste management costs for other projects, to aid in the implementation of new waste management initiatives, etc.

The following chapter examines C & D waste audit methodologies which are used to identify and quantify wastes being generated on a construction site.

Chapter 4
Estimating and Auditing Construction and Demolition Waste

4.1 Introduction

In order to examine the various C & D waste streams and waste quantities generated on the selected case study construction projects it was necessary to examine C & D waste audits to select a suitable methodology to perform the waste analysis. Initially this involved an examination of the waste audit methodologies currently used by the EPA to estimate C & D waste volumes for the Irish construction industry on a national basis. This was followed by an examination of existing C & D waste audit methodologies used on construction projects, with a view to selecting the most appropriate methodology for this study.

4.2 The Application of Construction and Demolition Waste Audit Methodologies

The quantification of C & D waste has been the subject of many research studies carried out across the World in recent years. Research projects carried out in the past have focused on areas such as the economic costs of waste (*Skoyles, 1976*), the causes and quantities of wastes generated, the reduction of, and the environmental impacts caused by C & D waste production. Other research projects carried out have focused on the measurement and identification of waste reduction techniques. (*Bossink, B.A.G., et al., 1996*).

In order to manage C & D waste it is first necessary to measure the volumes, and types of wastes that are being generated, so that appropriate measures can be taken to prevent, minimise, reduce, reuse or recycle waste materials generated.

"The first prerequisite of solving a problem is to have a knowledge of it."
(*Skoyles E.R., et al, 1987*).

In order to estimate waste volumes on site it is necessary to use an appropriate, and comprehensive, C & D waste audit methodology. A C & D waste audit methodology is a formal, structured process which is used to quantify the volumes, and record the types of C & D wastes generated on a construction site, by a construction company, or for a construction industry as a whole. C & D waste audits can be defined as:

*"**Waste Audits:** Check of waste to determine amount generated, type, sources, and potential means to avoid or reduce waste production."*
(*DoEHLG, 2004*).

"Waste audits are a tool for measuring the composition of the wastes arising from construction activities and thus a means of estimating the quantities of waste materials.
(*Resource Efficiency Unit, 1999*).

A waste audit conducted on a construction site can identify the types of material that are being wasted, estimate the quantities of waste materials, and analyse the potential for waste reduction. Reducing waste can increase profits and divert waste from landfill.

4.3 Estimating Construction and Demolition Waste Volumes Generated by the Irish Construction Industry

In order to understand and appreciate the problems encountered in estimating accurate C & D waste volumes for the Irish construction industry as a whole, it is necessary to examine the current methodologies used by the EPA to estimate C & D waste volumes on a national basis.

Currently the EPA publish waste data reports on a three year cycle. National waste Database Reports have been published for 1995, 1998 and 2001. The next full report is due to be published in 2005, and will include C & D waste data for the year 2004.

Following 2004, National Waste Databases will be published on a two year cycle to conform with regulation, (EC) No. 2150/2002, of the European Parliament. The EPA also publish full waste datasets for municipal waste management and waste export on an annual basis. These reports do not include information on C & D wastes. C & D waste quantities reported by the EPA are made up of four categories of waste:

1. New construction, repair and maintenance waste.
2. Excavated soil.
3. Demolition waste.
4. Dredging spoil.

Currently C & D waste volumes for the Irish construction industry are estimated by the EPA using two waste audit methodologies:

1. Methodology 1. uses waste factors developed by the United States Environmental Protection Agency.
2. Methodology 2. is based on records of C & D waste accepted for disposal and recovery at EPA licensed and permitted local authority facilities.

4.4 EPA Construction and Demolition Waste Audit Methodology 1

The first waste audit methodology used by the EPA to estimate quantities of C & D waste generated by the Irish construction industry uses waste factors developed by the United States Environmental Protection Agency (USEPA). In 1998, the USEPA published unit waste generation factors for various types of construction project types in the United States (US). The factors developed by the USEPA were adopted by the Irish EPA for the estimation of C & D waste volumes on a national basis.

4.4.1 Utilising EPA Methodology 1

EPA Methodology 1, is used to calculate C & D waste volumes for new construction, including repair and maintenance. For the purpose of estimating C & D wastes the EPA break down activities within the construction industry into four main categories. These categories are then subdivided to include more specific types of construction and development types. The four main categories are:

1. Residential. (New private and public housing.)
2. Private non-residential. (Private and semi-state industry, commercial, agricultural, tourism and worship.)
3. Productive infrastructure. (Water and sanitary services, airports, ports, harbours, energy and telecommunications.)
4. Social infrastructure. (Education, health, public buildings, local authority services and the Gaeltacht.)

C & D waste volumes are calculated by taking figures for the estimated value of output of the Irish construction industry and applying the USEPA unit waste generation factors to the output figures. This allows the calculation of a C & D waste volume for each of the four categories. The value of the output for the Irish construction industry is taken from DoELG publications. Table 4.1 shows calculations for C & D waste generation in 2001.

Table 4.1 EPA Calculations for Construction and Demolition Waste Volumes in 2001

Category	[1] **Value of Construction Output (Million €)**	**Buildings Area (m^2)**	[2] **Unit Waste Arisings** (US Waste Rates) **(kg/m^2)**	**Waste Arisings (tonnes)**
Residential construction.	3,785.8	7,306,418	21.34	155,919
New private non-residential construction.	1,870.8	3,610,557	19.00	68,601
New productive infrastructure.	1,121.2	2,163,864	19.00	41,113
New social infrastructure.	661.3	1,276,278	19.00	24,249
Residential repair and maintenance.	1,792.1	3,458,670	322.00	1,113,692
Private non-residential repair and maintenance.	360.8	696,327	422.00	293,850
Productive infrastructure repair and maintenance.	193.7	373,832	422.00	157,757
Social infrastructure repair and maintenance.	241.6	466,277	422.00	196,769
Total new construction, repair And maintenance waste.	**10,027**	**19,352,222**	-	**2,051,950**

[1] Department of the Environment and Local Government, 2002, Construction Industry Review, Outlook 2002 – 2004.
[2] (US Waste Rates) USEPA, 1998, Characterisation of building-related construction and demolition debris in the United States.
(*EPA, 2001*).

There are a number of omissions in the calculation of C & D waste volumes using EPA Methodology 1. There are no allowances for DIY waste, waste which is reused on construction sites, waste which is illegally buried on site, or waste which is illegally burned on site. The question of the correct categorisation of wastes arising from maintenance and repair is also an issue as it may be more appropriate to classify these wastes as demolition wastes rather than construction wastes.

EPA Methodology 1, makes the assumption that increased levels of construction results in increased C & D waste generation. The unit waste generation factors used in Methodology 1, were derived in the US, and may or may not be accurate for the Irish construction industry.

"This model assumes that increased construction output will result in increased generation of construction waste.
(*EPA, 2001*).

Detailed waste characterisation studies on Irish construction sites are necessary to determine the applicability of the US waste factors to the Irish construction industry. Currently there is no verification that the US waste rates are appropriate for Irish construction sites. Performing waste characterisation studies would not only allow the comparison of Irish and US unit waste generation factors, it would also allow a set of waste factors to be developed specifically for Ireland, which is a necessity for accurate future waste estimates. This research is the first extended study to attempt to compile waste rates, or waste generation factors, for a number of construction sites in Ireland.

4.5 EPA Construction and Demolition Waste Audit Methodology 2

The second waste audit methodology used by the EPA to estimate C & D waste volumes is based on records of C & D wastes accepted for disposal and recovery at EPA licensed and local authority permitted facilities. Waste volumes for excavated soil, demolition waste and dredging spoil are calculated using Methodology 2.

Excavated soil is a by-product of many construction and civil engineering activities such as general construction, land clearing, road building, etc. Soil waste is calculated by the examination of records of soils accepted at local authority permitted sites. Table 4.2 shows estimated general excavation wastes for 2001.

Table 4.2 Estimated General Excavations Waste for 2001

General Excavations Waste for 2001		
Soil accepted at local authority permitted facilities and estimated to have been accepted at unauthorised sites.	**Construction and demolition waste accepted at local authority permitted facilities.**	**Cover material accepted at EPA- licensed landfills.**
1,396,516 Tonnes.	**661,317 Tonnes.**	**459,692 Tonnes.**

(*EPA, 2001*).

The EPA avoid double counting of waste volumes by only counting the known soil quantity. In 2001, this volume was 1,396,516 tonnes. Excavated wastes from construction, repair and maintenance are not included in the general excavations waste as it has already been accounted for.

4.5.1 Estimating Demolition Wastes

Demolition waste quantities reported for 2001, were calculated by examining demolition waste contractors operating in Ireland. Eleven demolition companies were issued with questionnaires prepared by the EPA. Four companies responded to the questionnaire and the resulting figures received from the four companies were used to estimate the total demolition waste volume for 2001.

The figures received from the largest responding company were scaled up and used to estimate waste volumes for the remaining companies based on their relative market share compared to the largest reporting company. An assumption was made that the relative market share correlates with the quantities of demolition wastes generated. Table 4.3 shows demolition waste quantities estimated for 2001. The projected management routes in Table 4.3 are calculated proportionately from the reported quantities.

Table 4.3 Estimated Demolition Wastes for 2001

Demolition Wastes for 2001					
	Demolition waste (tonnes)	**Re-Used on site (tonnes)**	**Recycled Off-site (tonnes)**	**Disposed of To landfill (tonnes)**	**[1] Recovered at landfill (tonnes)**
Reported quantity	77,038	8,264	8,408	13,750	46,616
Projected quantity *	125,908	13,506	13,742	22,472	76,187
Total	**202,946**	**21,770**	**22,150**	**36,222**	**122,803**

[1] Recovered at landfill: this is inert waste, which was reused for landfill engineering e.g. raising land to required levels for redevelopment.

(*EPA, 2001*).

As mentioned previously some wastes included in the estimated waste quantity for repair and maintenance would be more accurately classed as demolition wastes. This makes the estimated figure for demolition waste lower than it should be. The assumption that relative market share correlates with the quantities of demolition wastes generated may or may not be accurate as no research has been conducted to confirm this. The reporting of all wastes generated by demolition waste contractors would increase the accuracy in estimating a total demolition waste quantity.

4.5.2 Estimating Dredging Spoil Wastes

Dredging spoil results from maintenance dredging and capital dredging (*Marine Institute, 1999*). Maintenance dredging is conducted in Irish ports for navigation purposes and produces erodable waste materials such as sands and silt. Capital dredging produces non-erodable waste materials such as gravel and rock. This type of dredging usually takes place in large engineering works where significant quantities of materials have to be removed. The waste quantity for dredging spoil is provided by the Irish Marine Institute. The Marine Institute compiles their waste figures from information submitted by the Irish port authorities. In 2001, it was estimated that 1,257,000 tonnes of dredging spoil was disposed of at sea.

EPA Methodology 2, makes a number of assumptions. Assumption one is that all soils and C & D wastes accepted at local authority permitted sites are recovered. (This assumption is that wastes disposed of at sites where waste permits have been granted, have been reused or recovered for land reclamation, rather than being dumped into a hole in the ground with no benefit being achieved.) Assumption two is that the deposit of an estimated 500,000 tonnes of soil at unauthorised sites in one local authority area is disposal. (The volume of 500,000 tonnes of soil is a figure that was reported by one local authority and is included in the 2001 figures published by the EPA.)

4.5.3 The Problems with the EPA Waste Audit Methodologies

The recycling targets set out in the policy document, 'Waste Management - Changing Our Ways', had set a target to increase recycling of C & D waste to 50% by the end of 2003, and to 85% by 2013. In 1998, the EPA National Waste Database estimated C & D waste recovery and recycling to be 43.3%. By 2001, the EPA National Waste Database 2001, estimated that C & D waste recovery and recycling had reached 65.4%. This figure exceeds the target of 50% recovery by 2003.

Although EPA estimated figures published for recycling C & D waste appear to be on target, there is a question of the accuracy of these figures given the assumptions made in estimating C & D waste volumes using EPA Methodology 1, and Methodology 2. The US waste rates may or may not be accurate for the Irish construction industry.

"The link between output and waste production is uncertain; the factors used were derived in the USA and their applicability to Ireland would need to be tested through detailed waste characterisation studies at construction sites."
(*EPA, 2001*).

4.6 The Classification of Construction and Demolition Wastes

In order to conduct a thorough C & D waste audit an understanding of the various ways in which waste can occur, and the classification of various construction wastes, is necessary. In 1987, E.R. Skyoles published, "Waste Prevention on Site", in which various construction wastes generated on site were examined. Over the course of his research Skoyles established eight different waste types, or categories, which occur on construction sites. In order to understand the variety of ways in which C & D wastes can be generated on site, and to set out the requirements and details of a proposed waste audit, it is necessary to have a knowledge and understanding of the manner in which wastes may occur. The eight waste categories developed by Skoyles are as follows:

1. Natural Waste.
2. Direct Waste.
3. Indirect (Cost) Waste.
4. Substitution Waste.
5. Production Waste.
6. Operational Waste.
7. Negligence Waste.
8. Consequential Waste.

In order to understand the various waste categories it is necessary to examine each individually.

4.6.1 Natural Waste (Skoyles)

Natural waste is waste which is ultimately unavoidable e.g. small timber off-cuts, nails and screws which have fallen on the ground in small quantities, etc. In many situations like this there comes a point when any attempts to reduce this waste volume further is not economical, or realistic, because the cost implications of further reduction exceeds the value of the material saved.

In situations like this, where the waste has reached an acceptable level, or a point where it is not practical or economical to reduce this waste further, it is referred to as natural waste. The levels of natural waste on site can vary and are a direct result of the management of materials. In situations where a site operates a materials management strategy, where all materials used are controlled, the natural waste volume will be small, whereas on a site where materials are poorly controlled it will usually result in a higher volume of natural waste. The production of this waste type centres around the proper control of materials, proper planning, and proper materials storage on site.

4.6.2 Direct Waste (Skoyles)

The second waste type is direct waste which is waste that can be prevented. This waste type results in the loss of, or the required removal and replacement of a material. This waste can result when materials such as e.g. loose concrete blocks, are left around site and not collected for reuse. These blocks lying on the ground become damaged and ultimately become a waste. This waste can also result from delivery of damaged materials to site, or damage to materials during work operations. Another example of this waste type is:

"Losses due to cutting uneconomical shapes, e.g. timber, sheeted goods, etc."
(*Skoyles E.R., et al, 1987*).

Economically this waste poses a significant cost to the contractor. The cost of purchase of the material, purchasing replacement materials, plus the cost of collecting and disposing of these wastes can accumulate quickly. Skoyles breaks down direct waste into subcategories, all of which add to the volumes of direct waste produced on site. These subcategories can be seen in Appendix D.

4.6.3 Indirect Waste (Skoyles)

Indirect (cost) waste is described by Skoyles as:

"Indirect waste for the 'builder', i.e. the purchaser of materials (who could be a subcontractor), is distinguished from direct waste by the fact that usually the materials are not lost physically, but by payment for the whole or part of their value."
(*Skoyles E.R., et al, 1987*).

In other words this waste type only results in a loss of money to the contractor. This waste may occur when a more expensive material is used as a replacement material for a cheaper one and the extra cost is borne by the contractor, or where a more expensive material is used when a cheaper material is specified. Thus the waste is the cost difference between the more expensive material used and the cheaper one specified. This waste can occur due to building errors, delivery of unspecified materials, or the use of an alternative material due to the lack of supply of the specified material.

4.6.4 Substitution Waste (Skoyles)

Substitution waste occurs when the loss of value of a material occurs due to its improper or unintended use. This waste type can occur when e.g. waste concrete blocks scattered around a site are collected and used as site fill rather than for their intended purpose. It can also occur when e.g. expensive bricks are used instead of concrete blocks due to management errors, to prevent work delays on site, over delivery of bricks, etc. This waste category can directly affect the calculation of quantities of direct wastes generated on site as it effects the substituting and substituted materials.

4.6.5 Production Waste (Skoyles)

The fifth waste category is production waste. This waste type occurs when the contractor receives no payment for some materials used because allowances for e.g. the size of an excavator and bucket used for excavation, does not form part of the measurement of building quantities for a construction project. An example of this waste may occur when a large excavation bucket is used to excavate a narrow trench which will result in excess excavated materials being produced (*Skoyles E.R., et al, 1987*).

4.6.6 Operational Waste (Skoyles)

Operational waste occurs when no quantities exist for some materials used in construction operations on site. These materials can be temporary works, or formwork, which may not be removed after completion of the project. A prime example of this can be where timber formwork under a narrow concrete stairs is not removed after the completion of construction.

4.6.7 Negligence Waste (Skoyles)

The seventh waste type is negligence waste which is primarily due to errors on site. This waste can occur when extra materials are used due to e.g. block work constructed that is not up to the required standard and has to be demolished, over excavation of foundation trenches, etc.

4.6.8 Consequential Waste (Skoyles)

The final waste type is consequential waste which occurs as a by product of other wastes. This usually occurs when waste results from the following e.g. work is delayed because of insufficient materials on site due to the wastage of these materials, resulting in lower productivity, extra overheads and costs due to necessary extended work time.

4.7 Alternative Construction and Demolition Waste Classifications

The classification of construction waste is not confined to the system developed by Skoyles. An alternative classification system for various C & D waste types, or occurrences causing waste, has also been developed from a 1999 study by Formoso at the Federal University of Rio Grande do Sol, Brazil. (*Formoso, C.T. et al, 1999*).

Following an analysis of the Formoso classification system it was found that all his waste categories are included in the Skoyles classification system. The majority of the waste classifications in the Formoso system come under the heading, or under a subheading, of direct waste in the Skoyles system. The Skoyles system is specifically orientated to the economics of waste, with a broad emphasis on material wastes. As the majority of the wastes in the Formoso system are covered under direct waste in the Skoyles system, the Skoyles system appears to be a more comprehensive waste classification system.

The complexity in the classification of various C & D wastes has established the necessity for a waste auditor to have a detailed knowledge of waste classification, prior to the commencement of a C & D waste audit. This allows the auditor to identify the waste types to be included, and estimated, in the waste audit, given that the wastes to be audited will depend on the resources provided by the building contractor e.g. labour, plant, finance, etc.

There are a number of different ways to conduct a C & D waste audit to establish waste quantities being generated on a construction project. e.g. visual waste audits, physical waste audits, and desktop waste audits. The C & D waste audit methodology should be selected based on the objectives set out for the waste audit, and the resources available.

4.8 Visual Construction and Demolition Waste Audits

Visual waste audits have been used to perform C & D waste assessments in the past (*BRE, 2000*), and are based on a visual inspection and estimation of a waste quantity, to arrive at a final waste volume, which is recorded in cubic meters, or in some cases cubic yards. This type of waste audit requires a minimum amount of resources and usually serves as a starting point in the exploration of waste generation. The visual waste estimate approach to waste auditing can be described as follows:

"It is based on what is commonly called the "eyeball" method of estimation and uses volume rather than weight as the unit of measurement. In other words, visual approximation of waste volume is used instead of weigh scales. The goal is to produce reasonable estimates of your waste stream and the amount of material available for source reduction, re-use, recycling and composting initiatives."
(*Resource Recovery Fund Board, n.d.*).

A research case study carried out in 2001, on the AMEC Budds Farm, Waste Water Treatment Works Modernisation, in England, established that the visual assessment of waste skips compared favourably with actual skip contents. This waste audit was a visual waste audit carried out using SMARTStart, a C & D waste audit methodology developed by the British Research Establishment.

"On the AMEC Budds Farm site, a comparison was carried out of visual skip audits with actual contents. A close correlation was found, showing that an experienced auditor can make accurate assessments of contents."
(*Stuart Coventry, et al, 2001*).

The use of this methodology for auditing un-segregated waste skips requires the audit to be performed on a regular basis, so that all waste materials can be examined as they are being disposed of in skips. A 1998, C & D waste characterisation survey in Melbourne, Australia, revealed that:

"The key difficulties experienced during the visual assessment were (i) fine material tended to agglomerate at the bottom of the load hence is likely to be underestimated, and (ii) plastic and paper tend to be overestimated due to the visual dominance of these items."
(*Nolan – ITU PTY LTD., 1998*).

It has been found that if a volume of waste e.g. timber, makes up more than 10% of the total volume of a mixed waste quantity, then using the visual waste audit to quantify this waste volume the error will typically be less than 10%. This means that waste volumes resulting from a visual waste audit will typically have an error not exceeding 10%.

"The visual assessment error is typically less than 10 percent for compositional categories where the fraction by volume is greater than 10% of the total load (e.g. concrete, clean soil, soil/rubble, and wood/timber)."
(*Nolan – ITU PTY LTD., 1998*).

4.9 Physical Construction and Demolition Waste Audits

Physical C & D waste audits differ from visual waste audits in that they involve physically sorting and measuring, or weighing, waste materials disposed of in waste skips. Although this is a comprehensive method of waste auditing, it is also a more resource intensive method of waste analysis. (It requires significant labour, time, sorting facilities, plant for moving skips, etc. depending on the volume of waste to be audited.)

In a sorting trial carried out at Pikes Point Refuse Transfer Station, New Zealand, in 1997, 102 waste skips were audited in 18 days with a total labour input of 676 hours (*Resource Efficiency Unit, 1997*). At an estimated labour rate of €20 per hour this waste audit would have cost (676 hrs x €20 = €13,520) €13,520 for labour alone not including the transport and plant utilised for the study.

This is potentially one of the most accurate waste audit methodologies, as all waste streams are identified and measured, or weighed, giving highly accurate waste statistics for each individual waste stream, but the resource investment required for conducting this type of waste audit may be prohibitive for long term waste audits. It is difficult to estimate the cut off point for this type of waste audit (where the benefits of the waste audit will exceed the cost of the audit). Its suitability for auditing C & D waste may be as a tool for auditing a small number of typical waste skips, as opposed to performing long duration waste audits.

4.10 Desktop Construction and Demolition Waste Audits

Desktop C & D waste audits involve an analysis, or review, of inputs and outputs of a construction site by utilising purchasing information, waste disposal invoices and costs records. While visual waste audits, and physical waste audits, are carried out on construction projects as the work is in progress (e.g. from commencement to completion of a project), or for a specific period during a construction project, desktop waste audits are most appropriate for waste auditing on construction projects which have been completed.

For a single construction project the comparison of purchasing information e.g. the quantity of each material brought onto site, against the actual quantity of each material required in the bill of quantities, or used on site, can give waste volumes for certain building materials. In the case of other waste materials such as packaging wastes, pallets, etc. this method cannot be used as packaging wastes are not quantified for the purposes of construction. Records of waste skips can also be used to calculate volumes of waste generated on site, but it may not be possible to quantify individual waste volumes where mixed wastes are disposed of in waste skips.

The difficulty with this methodology is that individual waste streams, and their volumes, cannot be estimated. This means that problem waste materials (e.g. high volume wastes that could be reduced, reused or recycled, at a lower cost) cannot be identified. Unless segregation of all individual waste streams occurs on site and comprehensive site records are maintained the estimation of individual waste quantities cannot be achieved using this methodology.

4.11 Predicting Construction and Demolition Waste Volumes for Construction Projects

The estimation and quantification of C & D wastes on a construction site is feasible using an appropriate C & D waste audit methodology. The calculation of C & D waste volumes for the proposed demolition of an existing building is also a straight forward procedure. Predicting, or estimating, C & D waste volumes for building demolition can be achieved by examining existing drawings, or by performing a pre-demolition site survey.

Waste quantities can be estimated for the demolition of a building by taking off quantities from existing building drawings, from which accurate waste volumes can be calculated. Where no drawings, or no accurate drawings, are available a pre-demolition site survey may be conducted. This involves measuring the building, and recording the various materials in the structure to allow waste volumes to be estimated.

4.11.1 Predicting Construction and Demolition Waste Volumes for New Buildings

Although estimating C & D waste volumes for the demolition of existing buildings can be achieved relatively easily, the prediction, or estimation of waste generation for a new build, prior to the commencement of construction, can be difficult if there is a lack of C & D waste data from similar past projects.

The estimation of an accurate waste quantity for a future construction project requires waste statistics for similar construction projects carried out in the past, where the methods of construction, and the materials used, were similar to the proposed project. Where a comprehensive database of C & D waste information for past construction projects exists, a waste rate can be calculated from this information and applied to new projects. This information allows a more accurate waste volume to be estimated and will also aid in the calculation of associated waste disposal, or treatment, costs.

The lack of C & D waste data for past, similar, projects can prevent an accurate estimation of wastes and any figures estimated will be at best a guess. There is also a question of contractor efficiency when predicting waste generation on a construction site. Waste data from the contractor carrying out the project should be used, if available, as the contractors efficiency during construction will be inherent in the waste data from a similar project constructed in the past.

4.12 Selecting an Appropriate Construction and Demolition Waste Audit Methodology for the Case Study Research

In order to select an appropriate C & D waste audit methodology, to perform the C & D waste audits on the selected case study construction projects, it was decided to examine three existing C & D waste audit methodologies:

1. The Skoyles method of waste auditing.
2. SMARTStart. (BRE developed waste auditing tool.)
3. SMARTAudit. (BRE developed waste auditing tool.)

4.12.1 The Skoyles Construction and Demolition Waste Audit

E.R. Skoyles, and John R. Skoyles, carried out extensive waste audits in England in the 1970's, and 1980's. These studies were initially focused on residential construction projects, and were later expanded to cover other development types, eventually examining a total of 282 varying types and sizes of construction projects.

The first C & D waste audits were carried out to identify problem waste materials, which resulted in consistent losses on similar types of construction sites. Site observers were used to monitor wastes for the full duration of some projects, and at particular times on other sites to monitor specific materials, or operations. Records of materials delivered to site and materials used in the finished project were maintained on site. Bricks, blocks, carcassing timber and plumbing materials were identified as materials which produced the most consistent waste volumes, and financial losses.

Site observers also recorded random incidences of waste around site, noted the causes, while monitoring specific work areas, and recording waste volumes as they occurred. Specific activities identified as wasteful, or waste producing, were analysed as the projects progressed. Records of deliveries were also compared to records of measured finished work which further assisted in more accurate waste estimations. As the waste data was compiled and the collected information increased Skoyles established that:

"Whereas it is relatively easy to measure the overall waste on site and so calculate the total volume of wasted materials and their related costs, it is another matter to calculate what percentage of that figure can be attributed to a particular cause."
(*Skoyles E.R., J.R., 1987*).

4.12.2 The Calculation of Construction and Demolition Waste Volumes

Skoyles recommended that waste calculations should be performed on a monthly basis, or if low waste volumes were generated on a consistent basis, this period could be extended. Waste volumes were calculated using three record forms set up to record the following:

1. The quantity of materials delivered to site.
2. The quantity of material stock on site.
3. Measurement of the completed work on site.

The information required above was gathered for each material to calculate the waste quantities produced. The information required was gathered at the same time to ensure an accurate waste calculation. Materials delivered to site were recorded, all stock materials on site were recorded, and finally the completed work was measured. In doing this it was necessary to ensure that materials recorded as stock were not used in the completed work measured on the day of calculation, as this would lead to these materials being counted twice, leading to an inaccurate waste calculation.

A record form was used to record all materials delivered to site. All delivery details for each material being investigated e.g. size, specification, quantity, return of unspecified or damaged materials, transfers of materials to another site, etc. were recorded. Having dependable accurate site records was essential in carrying out calculations with the main potential source of error coming from not using up to date records.

Quantities of stock materials on site were also recorded. The accuracy in recording this quantity was also essential to calculate accurate waste volumes. The materials should be recorded to within 1% margin of error (Skoyles, E.R. et al, 1987). Skoyles established that the main source of errors in recording materials on site is when materials are missed, which can easily occur on larger sites. He also established that it is necessary to ensure that when accounting for materials on site that some materials will be used in the short term and an allowance should be made for this. All materials being used in the short term (the time it takes to complete the audit) should be included in the measured work record.

The term, 'frozen stock', was also used by Skoyles. This refers to materials that were delivered to site at an early stage, but these materials were not used until well into the contract. All materials recorded as, 'frozen stock', were carried over to each waste calculation until they were used.

The final figure needed to calculate a waste volume is measured work. Quantity surveyors on most projects calculate the completed work at the end of each month to claim monies owed. Skoyles established that the accuracy of this calculation could not always be depended on for waste calculations. The physical measurement of the completed work by the auditor, or works accurately measured by the quantity surveyor, were identified as establishing the most usable and accurate figures for measured work.

It was also recommended that quantity surveyors were the most suitable site staff to perform waste audits as they have access to all the required materials and cost information, and over the course of a contract they are continuously measuring completed work on site which is necessary for waste calculations. Skoyles produced a paper based form for calculating waste (see Appendix E). All figures necessary to calculate waste volumes including materials deliveries, stock materials, measured work, etc. were included to arrive at a final figure allowing the contractor to take appropriate action if necessary.

Overall Skoyles concluded that C & D waste is usually caused by a combination of events, and that there are considerable waste volumes generated on sites which can be avoided by implementing simple prevention procedures. The impacts of improper storage and handling were identified as major causes of waste, and Skoyles also established that the majority of problems caused by C & D waste are a direct consequence of flaws in the site management system.

The Skoyles C & D waste audit methodology is very comprehensive and collects waste data across a wide variety of sources on site. The utilisation of this waste audit would examine most waste producing activities, and would require the waste auditor to be present on site for the full duration of the construction process. As this research project included four case study construction projects it was not possible to be present on site full time on any of the case studies to utilise this waste audit methodology in full. Thus it was decided not to select this waste audit for use on the case study construction projects.

4.12.3 The Building Research Establishment SMARTStart Construction and Demolition Waste Audit Methodology

In recent years the Building Research Establishment (BRE) have conducted C & D waste audits on a number of construction sites in Britain. These waste audits have been carried out using waste auditing tools designed specifically by the BRE for the analysis of C & D waste generation on construction sites.

The development of the SMARTWaste (Site Methodology to Audit, Reduce and Target Waste) auditing tools by the BRE, which consist of a number of individual waste auditing tools, has been the first step into utilising a combination of a computerised internet based system, and a paper based waste audit form specifically for waste auditing in the construction industry.

"In order to achieve better waste management through waste reduction and both re-use or recycling of unavoidable waste, there is an urgent need to quantify waste arisings. SMARTWaste^{TM} (Site Methodology to Audit, Reduce and Target Waste) has been developed by BRE to provide a robust and accurate mechanism by which wastes arising can be benchmarked and categorised by source, type, amount, cause and cost."
(*Hurley James W. et al., n.d.*)

4.12.4 SMARTStart

The SMARTStart C & D waste benchmarking and monitoring tool was developed specifically for entry level waste auditing. This auditing tool was designed with simplicity and ease of use in mind, and is aimed at building contractors who are taking the initial step into sustainable waste management. The tool allows the evaluation of C & D wastes on a single construction site, or across a number of construction sites. The aim of the SMARTWaste tool is to record:

- Waste arisings.
- Approximate composition of waste arisings.
- Level of segregation and recycling on site.
- Continuously update environmental performance indicators for waste generation for the construction project.

SMARTStart is based on records of skips being removed from site and is part paper based, and part internet based. The recorded information for each waste skip is basic and includes the date, reference number, the number of containers, the container size and a brief description of the container contents. A record of the waste generated on site is recorded on the waste audit form and is then logged into the SMARTWaste website where it is processed.

The SMARTStart internet based information processing software generates environmental performance indicators (EPI) and key performance indicators (KPI) for waste on individual construction sites, or across a number of sites. The measurement of EPI for the construction process is, m^3 of waste generated per $100m^2$ of floor area, and the measurement of KPI for the construction process is, m^3 of waste per £100000 worth of project (*BRE, 2003*).

The EPI and KPI can be compared against the BRE national averages. This allows comparison of the company, or site, being audited with the rest of the construction industry. (SMARTStart has not been used previously in Ireland so no statistics for EPI and KPI have been compiled for the Irish construction industry. Only UK, EPI and KPI are available. This is a disadvantage for Irish contractors wanting to use this methodology.)

Prior to being allowed to use the SMARTStart auditing tool the auditor must undergo a training course. The training course consists of an initial introduction into C & D waste management followed by tuition, and testing of the SMARTStart waste auditing tool. SMARTStart is licensed to a company, or organisation, on a yearly basis with a fee per project, or a fee per number of projects.

As this C & D waste audit methodology is part paper based, prior to commencing a waste audit, a waste audit record book incorporating the SMARTStart audit data collection form must be prepared. The paper based audit form can be printed off the SMARTStart web page. This is then used to record all relevant information for each waste skip brought onto a construction site.

4.12.5 Using SMARTStart

The first step in using SMARTStart is to carry out a visual assessment of each waste skip, just prior to it being removed from site. The date and skip size are recorded, as is the degree of compaction of the waste. Each individual skip is given a reference number and any segregation of waste for reuse, or recycling, is recorded. Following the recording of this information the percentage volume of the various wastes contained in the skip are estimated and recorded on the waste audit form. Each waste type is recorded and categorised under one of the 14 waste categories established for the SMARTStart auditing system. Each waste volume is estimated to the nearest 10%. Table 4.4 shows the layout of the paper audit form. See Table 4.5 for a detailed breakdown of each waste category.

Following the collection of the C & D waste data the information is entered into the SMARTStart website. SMARTStart (www.smartwaste.co.uk) is accessed using a password and username supplied by the BRE. After logging onto the website you are directed to your organisations homepage. Projects can be added as desired by clicking on the add icon and entering the project details as directed. The information collected for each waste skip is then entered into the SMARTStart webpage. The information is then processed by the software and monthly waste reports, or a final waste report can be printed as required.

Table 4.4 The SMARTStart Waste Audit Record Form

<table>
<tr><td>Date:</td><td colspan="3">Container size:</td></tr>
<tr><td rowspan="2">Reference No:</td><td colspan="3">Has the waste been compacted? (circle one):</td></tr>
<tr><td>Uncompacted</td><td>Slight Compaction</td><td>Machine Compactor</td></tr>
<tr><td colspan="2">Container segregated for reuse, recycling or recovery (tick here)</td><td></td><td></td></tr>
</table>

Enter percentage composition of wastes below:

Ceramics		Concrete	
Electrical Equipment		Furniture	
Inert		Insulation	
Metals		Miscellaneous	
Packaging		Plaster/Cement	
Plastics		Timber	
Liquids and Oils		Hazardous Materials	

Table 4.5 Waste Categories Included in the SMARTStart Waste Audit

Key Waste Group	Examples of products in the Key waste group
Ceramics	Bricks, ceramic tiles, clay roof tiles, ceramic toilets and sinks.
Electrical Equipment	TVs, fridge, air conditioning units, lamps.
Inert	Soils, clays, sand, gravel, natural stone.
Metals	Radiators, metal formwork, acros, metal sinks, cables and wires, metal bar.
Packaging	Paint pots, pallets, cardboard, bubble wrap, cable drums, wrapping bands.
Plastic	Gutters and down pipes, DPC, upvc windows and doors, socket boxes.
Concrete	Concrete pipes, kerb stones, paving slabs, concrete, rubble, solid blocks.
Furniture	Tables, chairs, desks, sofas, blinds, carpets.
Insulation	Glass fibre, mineral wool, purl board, breather paper.
Miscellaneous	Office and canteen waste, vegetation, ad-hoc materials.
Plaster/Cement	Plasterboard, render, plaster, cement, fibre cement sheets, mortar.
Timber	Plywood, Chipboard, noggins, battens, doors and windows, MDF.
Liquids and Oils	Hydraulic oil, engine oil, transmission oil, liquid fuel, cleaning agents, mould oil.
Hazardous	Creosoted timber, asbestos, radioactive waste, bituminous mixtures with coal tar, tarred products, PCB or mercury coated products.

4.12.6 SMARTAudit

The SMARTAudit waste auditing tool is a more comprehensive tool than SMARTStart. This tool is aimed at companies wanting to perform a more detailed waste audit which records the type, source, cost and cause of wastes on a construction site. The SMARTAudit tool allows more detailed information to be recorded than SMARTStart.

As with SMARTStart, prior to being allowed to use the SMARTAudit C & D waste auditing tool the auditor must undergo a training course. The training course consists of an initial introduction into C & D waste management followed by tuition, and testing of the SMARTAudit waste auditing tool. SMARTAudit is licensed to a company, or organisation, on a yearly basis with a fee per project, or a fee per number of projects. Like SMARTStart the SMARTAudit information processing software generates environmental performance indicators (EPI) and key performance indicators (KPI) for waste on individual construction sites, or across a number of sites

4.12.7 Using SMARTAudit

The auditor using SMARTAudit collects C & D waste data on site by means of a handheld pocket PC. SMARTAudit software is downloaded onto the pocket PC from the SMARTWaste website (www.smartwaste.co.uk). The auditor then records the C & D waste data on site as the waste is generated. The information entered into the pocket PC includes, the section of the works where the waste occurred, the type of waste, the skip code, the volume of waste, the reason for the waste occurring, etc.

Following the collection of the waste data, the pocket PC is connected to a desktop, or laptop, computer which has internet access. SMARTAudit is accessed using a password, and username, supplied by the BRE. After logging onto the website you are directed to your organisations homepage. Projects can be added as desired by clicking on the add icon and entering the project details as directed. The information collected for each waste audit is then entered into the SMARTAudit system. The information is processed by the software and monthly waste reports, or a final waste report, can be printed as required.

4.13 Waste Bulking and Converting Construction and Demolition Wastes from Volume to Weights

C & D waste volumes are recorded and reported in cubic meters, cubic yards, or by weight. C & D waste reporting on a national basis in Ireland utilises the weight of wastes, in tonnes (*EPA, 2001*). The EPA use weight as a reporting quantity, as their waste information gathered from waste treatment facilities is in tonnes, and US waste rates used to estimate C & D waste volumes are also in tonnes. As C & D waste volumes on a national basis are reported in tonnes, to compare any collected C & D waste data with national figures, then the collected waste data must either be recorded in tonnes, or if waste volumes are recorded in m^3, or cy, then these volumes must be converted to weight for comparison.

The conversion of C & D waste volumes to weight can be difficult. This is mainly due to the bulking of wastes. Waste bulking is where variances in the consistencies of a skips total contents occurs:

- Due to the degree of compaction the waste has undergone, if any.
- The irregular shape of some waste skips.
- Poor placement of wastes creating air voids.

- The irregular consistencies of C & D wastes.

"An indication of the effect that the bulking factor has on volume estimates of material in construction bins can be obtained by comparing the density of solid steel – 7800 kg per cubic metre, and the density of metal construction waste – 63 kg per cubic metre. The reason for this difference is due to most steel construction waste being items such as long-run roofing, wrapping straps and reinforcing mesh that have huge amounts of air around them when dumped into a bin, creating a very much larger volume than their weight would suggest."
(*Resource Efficiency Unit, 1999*).

4.13.1 Waste Bulking when Conducting a Construction and Demolition Waste Audit
When conducting a visual waste audit waste bulking should be a primary concern. When estimating a waste volume visually, every effort should be made by the auditor to determine the waste quantity as accurately as possible, keeping in mind that some wastes are easily compacted e.g. cement bags, plaster bags, plastic sheeting, etc.

Where C & D wastes disposed of in skips are mixed e.g. timber, cardboard, insulation, packaging, etc. while waste volumes can be estimated visually, the conversion of the volumes estimated to weights can be difficult if skips are not also being weighed as they are removed from site. In situations where no skip weights are available then conversion factors can be used.

4.13.2 Construction and Demolition Waste Conversion Factors
Attempts have been made at preparing conversion factors, or bulking factors, for C & D wastes (from volume to weight and vice versa). In 1994, waste conversion factors were included in a waste audit guide developed by Ontario's Ministry of Environment, Canada. Although conversion factors were included in this report, details of how the conversion factors were arrived at are not explained, and the conversion factors have a broad range for some materials. The conversion factors developed can be seen in Table 4.6.

Table 4.6 Waste Conversion Factors

Waste Material	Un-compacted (kg/m^3)
Concrete, Brick & Block:	1200 - 2372
Mixed Demolition, non-combustible:	1000 - 1600
Mixed Demolition, combustible:	300 - 400

(*Ministry of Environment and Energy, 1994*).

As seen in the sample conversion factors in Table 4.6 there are large variances in the conversion factors for some materials. This establishes the difficulty in converting volume to weight, and shows the size of the error margin that may occur using these figures. The use of these conversion factors would be dependent on the assumption that Irish C & D wastes are similar to Canadian C & D wastes.

In 1997, the Auckland Regional Council, New Zealand, carried out a trial sorting of construction skip wastes to develop average skip weights for various construction project types. 102 No., 9m^3 waste skips were examined in total, with the project types ranging from residential developments to concrete framed buildings. The conclusion of the report was that the main factor affecting the average weight of the skips was the type of construction project. The following average skip weights were calculated:

Table 4.7 Average Skip Weights

Type of project	Number of skips examined	Average skip weight in Tonnes
Residential	13 No.	1.86
Concrete Frame	14 No.	1.42

(*Resource Efficiency Unit, 1999*).

In some of the skip weight averages calculated for this study, very few skips were analysed, e.g. in non-residential new build only 6 skips were examined. The use of this method for C & D waste conversion can result in a total waste weight for a project, but no weights for individual waste streams can be calculated. This method of waste conversion from volume to weight would also be dependent on the use of 9m^3 skips on the project being audited, and it would not take any account of the various individual waste materials contained in each skip. Again the use of these conversion factors would be dependent on the assumption that Irish waste skips contain similar C & D wastes to those in New Zealand.

In a 1997 study by the National Association of Home Builders, Research (NAHB) Centre, Maryland, a set of waste conversion factors were developed by field measurements conducted in the US construction industry. The development of these conversion factors were specifically aimed at the conversion of volumetric waste estimates in m^3, to weights in kg (*NAHB, 1997*). These conversion factors were based on the densities of waste materials examined in waste skips. The conversion factors were also quoted in the Auckland Regional Councils Guide for Construction Waste Audits, 1999, being described as:

"The figures, derived from field measurements made in North America are very rough and the additional assumption has to be made that the conversion factors are similar for construction wastes in New Zealand."
(*Resource Efficiency Unit, 1999*).

Again, to utilise these figures for Irish C & D wastes, the assumption would have to be made that Irish wastes are the same, or similar, to C & D wastes generated in the US.

In Melbourne in 1998, a C & D waste landfill traffic and compositional survey was undertaken. The purpose of this study was to identify the waste quantities and composition of materials in the C & D waste stream for the Melbourne area. Ten landfill sites were used as survey points with a total of 371 vehicles carrying C & D waste being surveyed. Estimated volumes for 21 waste categories were estimated by visual assessment and manual assortment, with the total quantity of C & D waste being surveyed totalling $3332m^3$, or 2718 tonnes. In this study the waste volumes were converted to tonnes using material densities obtained from weighbridge weights for mono-loads, and from the following sources: (*Tchobanoglous, G, et al., 1993*), (*Wilbertz,* *J., 1985*), (*Steiner, M., 1998*). This study came to the following conclusion concerning C & D waste densities:

"The density based weight estimates are generally within 20% of the weighbridge measurements."
(*Nolan – ITU PTY LTD., 1998*).

4.13.3 Construction and Demolition Waste Conversion Factors in Ireland

Although no specific waste conversion factors have been developed for individual Irish C & D waste streams the Waste Management (Landfill Levy) Regulations, 2002, includes general waste conversion factors. Some factors for C & D waste streams are included but they are intended to be used for estimating the weight of wastes in a container, truck, skip, etc. in the absence of an operational weighbridge at a landfill site. These conversion factors are included in the landfill levy regulations for the purpose of calculating the amount of landfill levy payable. The conversion factors applicable to C & D wastes included in the landfill levy regulations can be seen in Table 4.8.

Table 4.8 Landfill Levy Waste Conversion Factors

Waste Category	Typical Waste Types	Cubic Meters To Tonnes	Cubic Yards To Tonnes
Inactive or Inert Waste.	Largely water insoluble or very slowly biodegradable e.g. sand, subsoil, concrete, bricks, mineral fibres, fibreglass, etc.	1.5	1.15
General industrial waste – non – special not compacted.	Paper and plastics.	0.15	0.11
	Card, pallets, plasterboard, canteen waste, sawdust, textiles, leather.	0.4	0.3
	Timber, building and construction wastes factory waste, and sweepings.	0.6	0.46

(*Waste Management (Landfill Levy) Regulations, 2002*).

To date there has been no significant research carried out in Ireland to develop of a set of bulking factors to convert individual C & D waste volumes to weights. As visual C & D waste audits are the most likely audits to be carried out by building contractors on site, due to their relative low cost when compared to other waste audit methodologies, further research is required to produce accurate waste conversion factors specific to Irish C & D wastes. The development of C & D waste conversion factors would allow the results from visual waste audits carried out by building contractors to be utilised to develop national waste rates for various construction projects.

4.14 Construction and Demolition Waste Reporting

C & D wastes are reported on a national basis by the EPA as a total weight (in tonnes) for the Irish construction industry (*EPA, 2001*). In situations where C & D waste audits are carried out on individual construction projects waste is generally expressed as a volume, or weight, per m^2 of floor area and is usually referred to as a waste rate. The waste rate for a construction project is calculated as follows:

Table 4.9 Waste Rate Calculation

$$\text{Waste Rate. (Cubic meters or Tonnes.)} = \frac{\text{Total Waste. (Volume or Weight.)}}{\text{Total Floor Area. (Meters Squared.)}}$$

C & D waste management costs can also be calculated either for a single construction project, or for a construction company as a whole. The calculation of C & D waste management expenses is expressed as a percentage of the total cost of a construction project, or as a percentage of the turnover for a construction company. This percentage is calculated as follows:

Table 4.10 Percentage Costs for Waste Management Expenses

$$\text{\% Costs For Waste Management Expenses.} = \frac{100}{\text{Total Construction Costs. (Or Total Company Turnover.)}} \times \text{Waste Management Costs.}$$

The reporting of C & D wastes for all EU countries must include the appropriate waste codes in the European Waste Catalogue and Hazardous Waste List. These codes are utilised across the EU by waste management contractors, waste treatment facilities, etc. The relevant C & D waste codes can be seen in Appendix B. The EWC codes can be incorporated into a C & D waste audit methodology, or they can be included in reporting the results of a C & D waste audit.

4.15 Planning a Construction and Demolition Waste Audit

The type of C & D waste audit methodology used to conduct a waste audit depends on the information required from the audit, (e.g. costs of waste, identification of waste streams and quantities, identification of potential reduction, reuse and recycling opportunities, etc.) the scale of the audit, where the waste is and the intended use of the information derived from the audit. The information collected from a C & D waste audit can identify problems with existing waste management practices and assist in the implementation of new measures to make waste management more efficient and cost effective.

"An important factor in planning your waste audit is the level of audit detail you choose to use. The level of detail depends upon the size of the project, complexity of operations, and accuracy you require for your reduction workplan."
(Ministry of Environment and Energy, 1994).

Conducting a C & D waste audit allows the compilation of C & D waste data which assists in proper control and management of C & D waste on a construction site and can result in:

- A more efficient and effective construction site, or company.
- Reduced waste management costs.
- Better use of limited natural resources.

- The establishment of baseline C & D waste data against which the effectiveness of future waste minimisation and management strategies can be measured against.

4.16 Conducting a Construction and Demolition Waste Audit

When conducting a C & D waste audit for a construction company, a single construction site, or for a number of construction sites, management cooperation is essential for the smooth completion of an audit. The auditor must have access to all site records kept on waste and materials. This is necessary to establish an accurate representation of the waste generated on site and the economic effects caused by the waste generated. In performing a site based waste audit the following steps are recommended:

- *"The audit should consist of a systematic study of all waste management practices which have been adopted on-site.*
- *Special attention should be dedicated to obvious opportunities for waste reduction, but all areas and stages within the project should be reviewed.*
- *Details of raw material inputs and the output of waste arising and the quantity, type and composition of all wastes from the site should be identified.*
- *The audit findings should highlight corrective actions that may be taken in relation to management policies on site practices in order to bring about further waste reductions.*
- *A tracking system should be stipulated to determine the success or failure of corrective actions.*
- *Summary audit reports outlining types and quantities of waste arisings should be sent to the competent authority on project completion."*

(*DoEHLG, 2004*).

Although C & D waste audits follow the same general rules different publications make different recommendations for performing a waste audit:

"The key steps in conducting a waste audit are:

- *Identify how and where waste leaves the site – the waste streams.*
- *Estimate the quantity of waste – typically for the audit period or over a year.*
- *Plan the audit in terms of the waste streams to be audited, the information required from the audit and the on-site audit arrangements.*
- *Set up on site and sort, weigh and record the weights of each material.*
- *Analyse the detailed data to give estimates of the waste composition and the overall quantities of particular materials if practical."*

(*Resource Efficiency Unit, 1999*).

Comprehensive planning prior to the commencement of a C & D waste audit is essential to ensure a successful waste analysis and to compile useful waste management data. Following management approval for an audit the following logical steps should be taken.

1. The site being audited should be visited prior to commencement of the audit to establish the waste management practices and site details, e.g. number of skips on site, segregation of wastes, other methods of removing wastes from site, identify any health and safety risks, are waste skips removed from site daily or on a specific day each week, etc. At this stage key management personal on site should be spoken to, to ensure that they are aware of the requirements for the audit. Their knowledge of site operations and management will assist in examining the existing waste management practices on site and highlight any potential problems.

2. The requirements of the waste audit must also be established prior to commencement of waste analysis on site. e.g. identification of various waste streams, potential for waste prevention, minimisation, reuse, recycling, waste classifications to be examined, limitations of the waste audit, etc. In order to select the most appropriate waste audit methodology it is essential that the objectives for the audit are clear and definitive. At this stage it will also be necessary to decide when the audit is to be carried out and to establish the most

appropriate time of day to audit the waste e.g. just prior to the removal of waste skips.

3. The next step is to select the most appropriate waste audit methodology to perform the waste analysis. This will depend on the waste management practices on site and the most appropriate method for waste volume estimation. e.g. visual waste audit, physical waste audit, acquiring waste quantities (by weight in tonnes) from the waste management contractor, etc. An appropriate waste audit methodology must be selected to collect the waste data following the establishment of the end requirements, or objectives, of the waste audit. Waste audits can range from a complex full analysis of all waste quantities generated, labour wastes and plant wastes occurring on a site, and the reasons for the occurrence of these wastes, to a basic waste audit recording the core waste streams generated on site. In some cases commercially available waste audit methodologies, e.g. SMARTStart, or SMARTAudit, may be suitable and can be selected if they meet the audit requirements. If no appropriate methodology exists to meet all the objectives of the waste audit then an audit record form can be drafted to collect the required information to meet the objectives of the audit.

4. In conducting a C & D waste audit on a construction site health and safety is a prime responsibility of any waste auditor. Auditors must possess a FAS Safe Pass card and adhere to all site safety measures set out on site by the main building contractor. In situations where the handling of waste is necessary safety equipment should be utilised to protect against the hazards posed by wastes and tetanus inoculation may also be necessary. Broken glass, nails, metal off-cuts, chemicals, etc. can cause serious injury. Different sites will pose different hazards depending on the materials being used and the waste management practices on site.

"During the course of waste surveys, protective clothing and other safety measures should be used having regard to up to date Health and Safety Legislation and Regulations."
(EPA, 1996).

5. Step five is to estimate C & D waste quantities using the selected waste audit. The audit process usually requires the auditor to walk around site to the various waste containers estimating waste quantities. (The waste quantity data collection method will depend on the audit methodology being used. e.g. visual assessment of waste streams, physical sorting and assessment, etc.) Quantities for the individual waste streams should be estimated and recorded. The management of the collected waste data is important. Clear unambiguous records should be maintained over the duration of the audit. Waste audits carried out over a short period of time, as opposed to an audit carried out from the start of a construction project to the finish, will only give snapshot details of wastes produced on site. Waste quantities may vary on a project from day to day due to changing use of materials, fluctuating production levels, poor weather, holidays, etc. Full project duration waste audits are a more precise method of calculating accurate waste rates for a construction project.

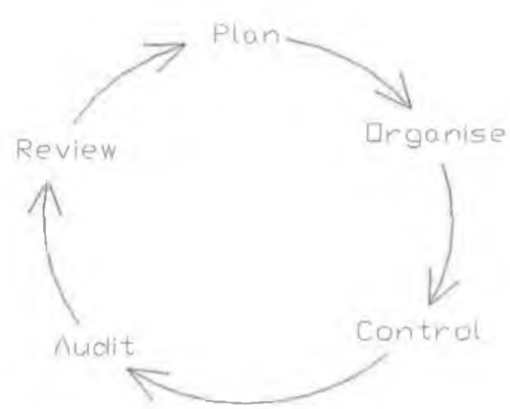
6. As the waste audit is being conducted waste management practices on site should also be observed and any problems identified e.g. poor placement of waste skips on site, overflowing waste skips, poor housekeeping, etc. This is necessary to address the inefficiencies of the existing waste management processes on site and to introduce best practice waste management.

7. The waste audit results should be analysed and processed, ideally on a monthly basis. This involves the compilation of figures estimated for each waste stream on site, and the addition of all waste volumes, or weights, to give an overall waste quantity generated for each month. The individual waste quantities should also be broken down into percentages of the total waste volume generated for each

month, and for the final compilation of the collected waste data. The collected data, including observations on waste management activities, recommendations for waste prevention, reuse and recycling should be compiled into a report and issued to the appropriate personnel within the company. The report format should include a report summary, a report contents page, an introduction, the methodology, the results, the conclusions and recommendations, and appendices if necessary.

The purpose of a C & D waste audit is to allow the measurement, and analysis, of C & D wastes, and waste practices on site. The results of the waste audit allows waste management practices to be improved. The waste audit should be included as part of a continuous improvement loop, which follows five logical steps.

Figure 4.1 Continuous Improvement Loop



Adapted from ISO Quality Management Strategy.

1. Plan: Step one allows a contractor to plan a C & D waste management strategy for a construction project, including performing a waste audit.
2. Organise: Step two involves organisation on site for the implementation of a waste management strategy to follow the plan established in step one.

3. Control: Step three involves controlling the waste management strategy, once implemented and operational.
4. Audit: The fourth step is the waste audit which is carried out on site. This allows the progress of the waste management strategy and any resulting improvements to be assessed, recorded and reported back to the contractor.
5. Review: The final step is to review the C & D waste audit results. The waste audit results will highlight achievements and problem areas on site. This will allow the plan (step one) to be adjusted to continuously improve the management of C & D wastes on site.

4.17 Selecting the Case Study Construction Projects for this Research

In order to establish the objectives for the waste audits it was first necessary to identify the case studies. Four construction projects were identified and used as case studies.

1. Case Study 1, consisted of a residential development located in Galway City. The development consisted of the construction of a total of 225 residential units including semidetached houses, terraced houses, apartments, and also included crèche facilities and a shop.

2. Case Study 2, was also a residential development located on the outskirts of Galway City. This project was similar to case study 1, as the same contractor/developer carried out the work on this project. This development consisted of 148 units including detached houses, bungalows, terraced houses, apartments, a crèche and commercial units.

3. Case Study 3, consisted of the construction of a hotel with a double basement car park, a petrol filling station, retail units, and offices. Again this project was located in Galway City.

4. Case Study 4, consisted of a concrete framed building constructed for educational purposes. This development included an office complex and associated facilities.

4.18 Objectives for the Construction and Demolition Waste Audits on the Selected Case Study Construction Projects

Following the identification of the case study construction projects the objectives for the waste audits were established. The initial step was to get management approval from the building contractors on the projects identified as potential case studies. Following the granting of approval from the building contractors the objectives for the C & D waste audits were established as follows, taking into consideration the time and resources allocated for the study:

1. Determine the composition and quantities of C & D waste being generated and removed from site.

- The composition and volume of the C & D waste stream would be examined. Safety equipment would be utilised for handling any waste if necessary.
- The C & D waste quantities would be estimated (in cubic meters) using a selected visual waste audit methodology. This method would be used as weights for each waste skip, and weights for individual waste streams, would not be available on all four case studies. It was decided following preliminary site visits that wastes would be estimated in multiples of 5%, based on the volumes of the skips on site. As the majority of the waste skips on the selected case studies were (12 cubic yards) $9.2m^3$ skips, 5% would equal $0.46m^3$ ($0.77m \times 0.77m \times 0.77m = 0.46\ m^3$). A conversion table for converting the percentage of C & D waste estimated to a volume of waste in cubic meters was prepared for each different skip size on the selected case study sites. This conversion table can be seen in Appendix F.
- All C & D wastes being removed from site by skip, or by truck, would be recorded.
- Each site would be visited once daily to carry out the waste audit.

2. Observations for wastes being reused on site would be made and recorded. These volumes of wastes reused on site would not form part of the final waste audit statistics.

3. The existing C & D waste management strategy would be observed and examined.

4. Opportunities for improving C & D waste management on site would be identified and reported back to the building contractors.

5. Reports containing the collected C & D waste data and recommendations, would be prepared and issued to the building contractors on a regular basis, or at the end of the construction project, depending on the specifics of the case study. Confidentiality of all information collected would be maintained at all times for each case study.

4.19 Selecting a Suitable Construction and Demolition Waste Audit Methodology for use on the Selected Case Studies

Having examined a number of C & D waste audits it was decided that SMARTStart and SMARTAudit were potentially the most appropriate methodologies for this research. It was decided to test SMARTStart, SMARTAudit, and a waste audit record form specifically drafted to collect the C & D waste data necessary to meet the objectives established for the case studies. It was decided to test the selected methodologies over a short period of time to examine their suitability, and to select the most appropriate methodology.

4.19.1 Designing the Draft Construction and Demolition Waste Audit Methodology for use on the Case Study Construction Projects

The C & D waste audit record form drafted to meet the objectives established for the case studies allowed C & D waste data to be collected for all wastes being removed from site by waste skip, or by truck, and allowed the following information to be recorded.

- The Site Location.
- The Job Number. Each separate site would be given a job number to identify one from the other.
- The Auditors name.
- Job Description.
- The Date. This refers to the date that the waste skip is audited.
- The Skip Reference. Each skip would be given a unique reference number. This consisted of the skip number, e.g. skip 27, followed by the supplier initials, e.g. EGW for East Galway Waste, and finally followed by the skip size, e.g. 12 cubic yards. In this case the skip reference number would be **27EGW12**.
- The Area Code. On larger sites it would be necessary to divide the site into zones to track the waste skips. Each area would be given a separate number e.g. Area 1, Area 2, etc. to maintain a record of the skip location on site. This method of tracking waste skips on site was discarded during the audit. An alternative method of tracking waste skips on site was used. This involved numbering each waste skip using a permanent marker, which proved a more successful method of tracking waste skips.
- Compacted / Non-Compacted. On some sites it was expected that C & D wastes in skips would be compacted. It would be necessary to record this to ensure waste bulking is taken into account, e.g. compacted waste would have a higher density than un-compacted waste.
- Waste Material. Each individual waste stream would be identified and recorded.
- The Waste %. A visual waste estimate based on the volume of the skip being audited would be estimated and recorded for each waste stream.
- Waste Quantity (in cubic meters). Following the estimation of the percentage of a waste material in a skip this percentage would be converted into volume. e.g. If a 12 cubic yard skip is 50% full with timber wastes then the volume of waste in the skip is 6 cubic yards.

- Notes. The notes section allows the reasons for waste generation to be recorded and any other information thought necessary. A copy of this waste audit record form can be seen in Appendix G.

4.20 Examining the Selected Waste Audit Methodologies

4.20.1 SMARTAudit

SMARTAudit was not selected for use on the case studies. In order to carry out a waste audit it was necessary to examine each skip on a daily basis as wastes were disposed of in varying quantities at various times during the day. This resulted in each skip being filled with wastes on a gradual basis. The problems encountered with SMARTAudit during the testing period were as follows:

1. With SMARTAudit all data was recorded using a pocket PC, with each individual waste quantity being recorded separately. As the site on which the waste audit methodologies were tested had up to 14 separate waste skips at any one time it was necessary to record the exact location of each skip, and the waste materials contained in each skip on a particular day. In order to audit the skips accurately it was necessary to know what wastes, if any, were in each skip on the previous day/s to prevent the over estimation of wastes and to establish if any new wastes had been placed in the skips. SMARTAudit does not allow you to see waste entries for the previous day/s, and does not allow you to record the exact location of the skip on site.
2. All waste quantities entered into the SMARTAudit software have to be entered in centimetres. (Length (cm) x Width (cm) x Height (cm) = Waste Volume in cubic centimetres.) As waste estimates were calculated by visually estimating percentages of C & D waste in skips rather than measuring waste volumes in centimetres this made the recording of waste volumes difficult using this system.
3. Over the period of analysing this waste audit methodology other problems were also encountered. In a situation where a waste quantity is entered incorrectly into the pocket PC it cannot be altered resulting in inaccuracies in the waste volumes recorded.

4. The SMARTAudit software will only retain the waste data recorded for the duration of the battery life of the pocket PC. All recorded data must be downloaded onto the website prior to the battery running out, or alternatively, the battery must be kept on charge when the pocket PC is not in use between audits to prevent loss of recorded data.
5. This audit methodology also requires an internet connection to allow the waste data collected to be downloaded onto the website. In many cases this would have required returning to the office to download data before completing the audit, prolonging the time taken to perform the waste audit.
6. As the waste audits would be carried out in all weathers the use of the pocket PC would prove difficult in inclement weather. The pocket PC being used was not waterproof and would be prone to water damage with prolonged use in wet weather.

4.20.2 SMARTStart

SMARTStart was not selected for use on the selected case studies for the following reasons:

1. The SMARTStart C & D waste audit methodology is a very basic waste auditing tool. It was established that this waste audit, which records only 14 C & D waste types (with some subcategories), would not cover all the various wastes being generated on site in the detail required for the waste analysis. In the testing period up to 30 different C & D wastes were identified on site. Many of these wastes would have to be recorded as miscellaneous wastes as the waste categories used by SMARTStart were not comprehensive enough to cover all C & D wastes encountered on site.
2. The SMARTStart audit does not allow the reasons for waste generation to be recorded. This did not meet the objectives set out for the waste audit.
3. As waste skips were filled up gradually on a daily basis the information for each skip needed to be recorded daily. The SMARTStart skip record form allows waste information to be recorded for one date only meaning that all waste data must be

dated when the skip arrives on site, when the skip is removed from site, or a separate record sheet must be kept for each day making the recording and the input of the data onto the website more difficult and time consuming.

4.20.3 The Draft Construction and Demolition Waste Audit

It was eventually decided to use the C & D waste audit record sheet designed to collect the C & D waste data for the selected case studies as it met all the requirements established for the waste audits. The C & D draft waste audit record sheet allowed the recording of the following data:

1. The date for each different C & D waste material and quantity could be recorded. This allowed the volume and type of each specific waste to be recorded for each day.
2. Each skip could be given a unique skip reference number. This allowed each skip to be identified and tracked on site.
3. The waste audit record form could be used to record the exact location of each skip on site, and whether the waste was compacted or not.
4. Any type of C & D waste could be recorded and attributed a percentage volume, estimated based on the skip volume, and this waste percentage could be converted into volume in cubic meters.
5. The notes section in the audit sheet allowed specific information including the reason for waste generation for each waste stream to be recorded.
6. The C & D waste audit record form was flexible enough to allow C & D wastes being removed by truck to be recorded.
7. All C & D waste materials recorded could be added up manually to arrive at a total waste quantity at the end of each month.

4.21 Conclusions

The aim of this chapter was to examine the estimation, or quantification, of C & D wastes, and the associated requirements, with a view to understanding and selecting an appropriate C & D waste audit methodology to utilise for the collection of C & D waste data on the selected case study construction projects. The conclusions are as follows:

- The estimation of C & D waste volumes for the Irish construction industry is not without its problems. The first methodology used by the EPA for C & D waste estimation utilises waste factors from the United States. This methodology excludes a number of C & D waste producing activities which should result in increased waste estimates, if these wastes volumes were included e.g. DIY waste, waste reused on construction sites, waste buried on site, and waste burned on site. This has established the inaccuracies in the estimation of C & D waste with methodology 1. Further research is necessary to develop Irish C & D waste rates specific to the Irish construction industry, to test the assumption that increased construction output results in increased generation of C & D waste, and to develop a methodology for the inclusion of C & D wastes currently excluded in methodology 1.

- Methodology 2 used for C & D waste estimation by the EPA assumes that all wastes accepted at local authority sites are recovered, and includes the estimated deposit of 500,000 tonnes of soil at unauthorised sites in one local authority. Both these assumptions expose the necessity for more detailed reporting of C & D wastes disposed of by landfill. The estimation of 500,000 tonnes of waste soils disposed of at unauthorised sites highlights the need for more stringent enforcement against illegal waste disposal.

- The identification of the various C & D waste audit methodologies established that the type of methodology selected (e.g. visual waste audit, physical waste audit, desktop waste audit,) largely depends on the resources made available to perform the waste audit. The visual waste audit and the desktop waste audit require the least financial investment as the labour, plant and time input is less that that required by physical waste audits.

- Waste bulking is a significant issue when conducting waste audits when individual waste streams are not being segregated and weighed. Waste conversion factors to convert C & D waste volumes to weights do exist for construction industries in other countries. Conversion factors included in the landfill levy regulations are very general and do not include conversion factors for all individual C & D waste streams. This identified the need to develop a set of C & D waste conversion factors specific to the Irish construction industry.

- Waste audits must be carefully planned prior to commencement, and management approval and cooperation is essential for a successful audit.

- The selection of a C & D waste audit methodology is specific to the requirements, or objectives, set out for a waste audit. Many existing waste audit methodologies may not be flexible, or comprehensive, enough for some waste analysis. In this situation a waste audit record form can be designed to record only the information required.

- There has been no extensive research on construction sites in Ireland to develop Irish waste rates. This is the first extended study to attempt to compile accurate waste rates for selected Irish construction project types as part of the waste audits being conducted.

The following chapter details the C & D waste audit results from the four case study construction projects.

Chapter 5

Construction and Demolition Waste Audit Results on the Selected Case Study Construction Projects

5.1 Introduction

The aim of this chapter is to present the findings of the C & D waste audits on the four case study construction projects. In order to examine the volumes and types of C & D wastes generated on the selected case study construction projects, it was purposely decided to select a number of different types and sizes of construction projects to use as case studies. The analysis of C & D wastes arising on the selected case studies, initially involved the selection of an appropriate C & D waste audit methodology as discussed in the previous chapter.

The most appropriate C & D waste audit methodology was selected and used to perform the waste audits on all four case studies. Daily site visits were carried out to conduct the waste audits, and regular contact and communication was maintained with site personnel responsible for waste management.

5.2 The Case Study Selection Criteria

The following criteria was established to select the case study construction projects:

1. Initially it was decided to select case study construction projects which were located in Galway City, or in close proximity to Galway City, to allow the necessary daily site visits to be carried out to conduct the waste audits.
2. The second step in selecting the case studies was to identify potential construction projects, of various types and sizes, which were at an early stage of construction. This would allow the audit to be commenced at the start, or from an early stage in the project. It would also allow the examination of C & D waste quantities, and waste types generated, on various types and sizes of construction projects.

3. The third step was to ensure that the selected case study projects fitted in with the allotted timeframe allocated for conducting the waste audits so that the maximum amount of waste data could be collected. The allotted duration for conducting the C & D waste audits was from September 2003, to March 2005.
4. Step four in selecting the case studies, after identifying potential case study construction projects, was to request permission from the building contractor, or developer, to carry out the waste audit on their site.

Four construction sites were identified and selected as case study construction projects.

5.3 Limitations for the Construction and Demolition Waste Audits

The limitations of the C & D waste audits were as follows:

- Given that there were four case studies, and considering the restrictions of the timeframe, only C & D wastes being removed from site by skip, or by truck, formed part of the waste audit results.
- Bulking of wastes was an issue in conducting the waste audits. Skips invariably contained a certain amount of air between the waste materials, which could not be accurately estimated. Each C & D waste quantity was estimated as accurately as possible during the audit.
- As the waste audit on three of the case studies was initiated following the commencement of construction every effort was made to examine, and estimate, C & D waste volumes removed from site prior to the start of the audits. Records of the number of skips, and in some cases the number of truck loads of wastes, removed from site prior to the commencement of the waste audits were obtained and included in the audit results.
- This study is not a life cycle assessment of the Construction and Demolition wastes generated on the case study construction projects, and does not include an extensive, or detailed, analysis of the end use of waste materials following their removal from site by waste skip, or by truck.

- Each case study could only be visited once daily. The following, necessary, assumption was made:

To carry out the C & D waste audits each site was visited on a daily basis. In many cases skips were not seen as they were being removed from site. This resulted in the auditor not knowing if each skip was 100% full when being taken away. It was assumed that all unseen skips removed from site were 100% full at their time of removal, if they had not been previously audited when 100% full. A quantity of waste classified as Unknown Waste was assumed when this happened. This assumed waste volume was classified as unknown waste as it was not possible to determine the composition of this waste volume having not seen it. The following is an example why this waste quantity had to be assumed and why it occurred:

Day 1: The waste skip arrives on site. The skip is audited and the volume of waste is estimated to be 25%.
Day 2: The skip is audited and the volume of waste for this day is estimated to be 30%. The total volume of waste in the skip on day two is 55%.
Day 3: The skip is audited and the volume of waste for this day is estimated to be 35%. The total volume of waste in the skip on day three is 90%.
Day 4: The skip has been removed from site before the auditor arrives to carry out the daily waste audit.

- **Day 4**: On the previous day (Day 3) the total waste volume in the skip was estimated to be 90%.
- It is assumed that all skips are 100% full when they are being removed from site if they have not been seen as they are being taken away.
- Unknown waste (in this case) = 100% (Assumed volume of waste in the skip when being removed from site.) – 90% (The actual volume of waste estimated and recorded.) = 10% (Unknown Waste.)

This assumed waste category was classified as unknown waste due to the auditor not knowing the composition of this assumed waste volume. In situations where this assumption was necessary with skips containing segregated wastes e.g. timber, the waste volume was recorded and included in the audit results as timber waste, rather than unknown waste, as it would be realistic to assume that the unknown waste quantity in a segregated waste skip would be that material which it already contained e.g. timber.

As the majority of waste skips where this waste volume had to be assumed contained mixed wastes the classification of unknown waste is appropriate. Ultimately this assumed waste volume, and the assumption that each waste skip was 100% full when being removed from site is realistic, as building contractors are unlikely to allow waste skips which are partially full to be removed from site.

5.4 Mixed Waste

Mixed wastes resulted when small quantities of many different C & D wastes were placed in a skip together, or where a significant quantity of waste was placed in a skip over a short period of time resulting in the auditor having difficulty in determining the composition and volumes of the individual waste streams contained. Mixed waste was made up of many C & D wastes generated on site e.g. timber, insulation, plastic sheeting, cardboard, paper, canteen waste, gypsum plasterboard, cement bags, plaster bags, plastic ducting, paint cans, plastic packaging straps, steel packaging straps, etc. Mixed waste volumes were generated on all four case study sites.

5.5 Off-Site Waste

This waste is that which did not originate on site, but was brought onto site and disposed of in waste skips on site. This waste stream occurred on all four case study construction projects and consisted of garden cuttings, televisions, fridges, stereos, clothes, etc, with the majority of it being kitchen, or household waste.

In most cases these wastes were found in skips located in quieter areas on site where fewer people were working, in waste skips located close to public roads and site boundaries, and in skips located near adjacent houses.

5.6 Hazardous Construction and Demolition Waste

There were a number of waste materials and containers disposed of in waste skips, on all four case studies, that could potentially have caused contamination. These wastes were found in very small quantities during the waste audits, but they can cause serious problems for waste disposal. Aerosol spray cans, paint cans, oil drums, silicone tubes, battery's, etc. are all examples of hazardous wastes which were disposed of in general waste skips located on each case study construction site.

These wastes can lead to contamination of all wastes contained in a waste skip, and contractors must be aware that they are solely responsible for the correct disposal of the C & D wastes they generate following their removal from site.

5.7 Case Study 1

The C & D waste audit carried out on case study 1, a residential development, commenced in August 2003, and was completed in March 2005. The site was visited on a daily basis over this period of time to collect waste data.

C & D waste has become a significant management consideration on developments carried out by this contractor in recent years and the company has continually strived to reduce wastes by utilising the natural resources of their sites to lower their excavated soil waste output and their construction costs.

5.7.1 The Construction and Demolition Waste Audit Results on Case Study 1

The following waste data was collected on case study 1, from the commencement of the waste audit in August 2003, to it completion in March 2005. Table 5.1 shows the C & D waste data collected during the waste audit period.

Table 5.1 Case Study 1: Construction and Demolition Waste Audit Results

Site Location:	Galway City.	**Building Contractor:**	** N/D
Project Description:	The development consisted of the construction of a total of 225 units including 4 bed semi-detached houses, 3 and 4 bed terraced houses and 2 bed apartments, and also included crèche facilities and a shop. The main structure of the various houses and apartments consisted of raft foundations, concrete block and brick external and party walls, internal timber stud partition walls, trussed rafters, concrete roof tiles, PVC double glazed windows, hardwood front and rear doors, and all site landscaping and services.		
Total Floor Area:	265,648 Square Feet / 24,679 Square Meters.		
Estimated Floor Area Completed:	(95%) 24060 m^2		
Project Commencement Date:	Jan 03	**Project Completion Date:**	July 05
C & D Waste Audit Commencement Date:	Aug 03	**C & D Waste Audit Completion Date:**	March 05
Waste Management Contractors on site:	1. East Galway Waste. Killimore, Ballinasloe, Co. Galway. 2. Walsh Waste Disposal Ltd. Parkmore, Ballybritt, Galway.		

No.	Waste Material	EWC Code	Treatment Option Used	Waste Quantity Generated (m^3)	Waste Quantity (%)
1	Soil	17 05 04	Reused on and off-site.	1760	-
2	Mixed Waste	17 09 04	Disposal by waste skip.	1050	33.4
3	Timber	17 02 01	Segregation for recycling.	598	19
4	Unknown Waste	17 09 04	Disposal by waste skip.	355	11.3
5	Insulation	17 06 04	Disposal by waste skip.	259	8.2
6	Plasterboard	17 08 02	Disposal by waste skip.	203	6.5
7	Plastic Sheeting	17 02 03	Disposal by waste skip.	155	4.9
8	Cardboard	17 09 04	Disposal by waste skip.	129	4.1
9	Canteen Waste	17 09 04	Disposal by waste skip.	113	3.6
10	Off-Site Waste	17 09 04	Disposal by waste skip.	92	2.9
11	Cement Bags	17 09 04	Disposal by waste skip.	55	1.8
12	K-Rend Bags	17 09 04	Disposal by waste skip.	53	1.8
13	Skimcoat Plaster Bags	17 09 04	Disposal by waste skip.	27	0.9
14	Paper	17 09 04	Disposal by waste skip.	19	0.6
15	Ceramic Tiles	17 01 03	Disposal by waste skip.	14	0.4
16	Steel	17 04 05	Segregated for recycling.	13	0.4
17	Soffit and Fascia	17 02 03	Disposal by waste skip.	5	0.2
	Total Waste Quantity	=		***3140**	**100 %**
1. Volume / percentage of C & D waste reused on, and off-site.				1760 m^3	-
2. Volume / percentage of C & D waste disposed of by waste skip.				2529 m^3	80.6 %
3. Volume / percentage of C & D waste segregated for recycling.				611 m^3	19.4 %

Cost & No. of Waste Skips Removed from Site from Commencement of Waste Audit to Completion

Skip Supplier	Skip Vol. (yards^3)	Skip Vol. (m^3)	No. of skips for Audit period.	Cost Per Skip.	Total Skip Costs.
East Galway Waste	12.0	9.17	250	€250 Mixed Waste	€62500
Walsh Waste	12.0	9.17	28	€250 Mixed Waste	€7000
Walsh Waste	12.0	9.17	3	€0 Steel (S)	€0
Walsh Waste	1.5	1.14	97	€39 Canteen (S)	€3783
Walsh Waste	35	26.76	16	€300 Timber (S)	€4800
			394 Skips		**€78083**

Waste Rates

Waste Rate including Soil Wastes = (25327m^2/ 100 x 95) = 24060 m^2. 4900 m^3 / 24060 m^2 =	**0.20 m^3 of Waste per m^2 of Floor Area**
Waste Rate excluding Soil Wastes = (25327m^2/ 100 x 95) = 24060 m^2. 3140 m3 / 24060 m^2 =	**0.13 m^3 of Waste per m^2 of Floor Area**

* Total waste quantity does not include soil wastes. For Detailed C & D waste breakdown see Appendix H.
** N/D: Not Disclosed. (S): Segregated.

Table 5.2 Waste Management Savings Achieved on Case Study 1

Case Study 1: Cost Savings Achieved Through Segregation of Nominated Construction and Demolition Wastes				
No.	Waste Material	Management Option	Details of Cost Savings Made	Savings Achieved (€)
1.	Timber	Recycle	A total of 598m^3 of timber waste was produced on site during the waste audit. A total of 428m^3 of waste timber was segregated into 35cy waste skips achieving a financial saving of €430 per 35cy waste skip removed from site. The total saving achieved through proper segregation of timber waste was: €430 x 16no. (35cy waste skips) =	€6880
2.	Metal	Recycle	A total of 13m^3 of metal waste was segregated during the waste audit. This achieved a saving of 13m^3/9.17m^3 (size of general waste skip) x €250 (cost of disposal of general waste skip if metal was not segregated) =	€354
			Total savings achieved on site =	€7234

5.7.2 The Management of Waste Topsoil, Subsoil and Rock

On this particular site the utilisation of the sites natural resources was a significant factor in reducing waste soils, subsoil and rock. Over the course of construction little excavated material was removed from site. During the initial phases of site preparation, before construction commenced, all topsoil on site was excavated and stored for reuse. A total of 15000 m^3 of topsoil was excavated and stored in two stockpiles on site. This topsoil was reused in landscaping the communal areas and back gardens on the development.

In the attempt to reduce excavated soil wastes, and the associated costs of disposal, the sites natural resource of bedrock was utilised. Approximately 90000m^3 of rock was blasted, excavated and crushed.

As the site was being prepared for construction subsoil was excavated throughout the site. The excavated subsoil, approximately 90000m^3, was reused to backfill the void remaining from the rock excavation, again significantly reducing the volume of excavated wastes removed from site and the associated costs of removal. The crushed rock was then used to fill the site to required levels. This is a prime example of waste minimisation and reuse and is replicated by this building contractor on all their developments, when feasible.

Photo 5.1 Topsoil Stockpile (15000m^3).

5.7.3 Waste Bricks, Blocks and Other Concrete Products

Over the course of the waste audit little or no bricks, blocks and concrete wastes were disposed of in waste skips. This waste stream did not form part of the waste quantities recorded. An estimate for this waste volume could be calculated by comparing the quantities of the materials delivered to site against the actual quantities used, and against the billed quantities. (This is ideally conducted at the end of a construction project.)

Broken blocks, bricks and concrete wastes were reused as fill on site. As these materials are inert and inorganic they can be reused without creating any future hazards. This is a good example of waste reuse on site. During the waste audit quantities of these wastes lay around the site and could have easily been reused for their intended purpose, had they been collected.

Photo 5.2 Waste Concrete Blocks.

5.7.4 The Management of Other Construction and Demolition Wastes on Site

All other C & D wastes on this site were disposed of in waste skips. Two waste management contractors were employed to supply waste skips to site. On average there were 14 skips located around site at any one time following the commencement of construction. These skips mainly consisted of 12 cubic yard (9.18 m^3) skips, which were used for general wastes. 1.5 cubic yard (1.15m^3) skips for canteen waste, and 35 cubic yard (26.76 m^3) skips for segregated timber waste.

Photo 5.3 Waste Timber Stockpile.

Timber pallets which were brought onto site when deliveries of cement and roof tiles were made were taken back by the suppliers for reuse. Steel wastes were also segregated into a 12 cubic yard skip and removed from site, free of charge, for recycling.

On this particular site there was no formalised C & D waste management strategy at the commencement of the waste audit. As the audit progressed efforts were made by the contractor to implement a waste management strategy based on the auditors recommendations. This included the appointment of a waste manager on site. A waste manager was appointed but implementing the segregation of wastes proved difficult due to the fact that construction was significantly advanced when implementation was attempted.

Apart from the afore mentioned materials which were reused, or segregated for reuse or recycling, all other wastes were disposed of in the general waste skips. Any operative on site could place waste in skips. Occasionally C & D wastes nominated for segregation were mixed in with other wastes as some site personnel were unaware of the correct disposal procedures for nominated segregated wastes such as timber.

The placement of waste in skips was also an issue at an early stage in the audit. The incorrect placement of pallets, and other wastes, in skips allowed large air voids to be created in some waste skips reducing the maximum volume of waste the skip could potentially hold.

5.8 Case Study 2

The C & D waste audit carried out on case study 2, a residential development, commenced in December 2003, when the first waste skips arrived on site, and was completed in March 2005. The site was visited on a daily basis over this period of time to collect waste data.

As case study 2, was carried out by the same contractor/developer as case study 1, the waste management procedures on site were similar. In response to some of the findings on case study 1, the contractor attempted to establish a formal C & D waste management strategy on case study 2. This was an attempt to increase the efficiency of C & D waste management on site and to make a financial saving.

Case study 1, had been audited for four months prior to the commencement of the waste audit on case study 2, and the preliminary findings had been reported to the contractor/developer.

5.8.1 Construction and Demolition Waste Audit Results on Case Study 2

Table 5.3 shows the C & D waste audit data collected during the waste audit period.

Table 5.3 Case Study 2: Construction and Demolition Waste Audit Results

Site Location:	Galway Region	**Building Contractor:**	** N/D
Project Description:	The development consisted of the construction of a total of 148 units including detached houses, terraced houses, apartments, retail units and also included crèche facilities. The main structure of the various houses and apartments consisted of raft foundations, concrete block external and party walls, internal timber stud partitions, trussed rafters including cut timber roofs, natural roof slates, PVC double glazed windows and hardwood front and rear doors. Some steel columns and beams were also used in the construction of the retail units towards the front of the site. The work included all landscaping and services.		
Total Floor Area:	210045 Square Feet / 19518 Square Meters.		
Estimated Floor Area Completed:	(70%) 13663m²		
Project Commencement Date:	Oct 03	**Project Completion Date:**	Oct 05
C & D Waste Audit Commencement Date:	Dec 03	**C & D Waste Audit Completion Date:**	March 05
Waste Management Contractors on site:	1. East Galway Waste. Killimore, Ballinasloe, Co. Galway. 2. Walsh Waste Disposal Ltd. Parkmore, Ballybritt, Galway.		

No.	Waste Material	EWC Code	Treatment Option Used	Waste Quantity Generated (m^3)	Waste Quantity (%)
1	Soil	17 05 04	Reused on and off-site.	6101	-
2	Mixed Waste	17 09 04	Disposal by waste skip.	462	26.8
3	Timber	17 02 01	Segregated for recycling.	423	24.5
4	Unknown Waste	17 09 04	Disposal by waste skip.	220	12.7
5	Insulation	17 06 04	Segregated for return to supplier for recycling.	196	11.3
6	Gypsum Plasterboard	17 08 02	Disposal by waste skip.	100	5.8
7	Cement Bags	17 09 04	Disposal by waste skip.	82	4.7
8	Canteen Waste	17 09 04	Disposal by waste skip.	70	4.1
9	Plastic Sheeting	17 09 04	Disposal by waste skip.	65	3.8
10	Cardboard	17 09 04	Disposal by waste skip.	34	2
11	Steel	17 04 05	Segregated for recycling	21	1.2
12	K-Rend Bags	17 09 04	Disposal by waste skip.	19	1.1
13	Off-Site Waste	17 09 04	Disposal by waste skip.	18	1
14	Skimcoat Plaster Bags	17 09 04	Disposal by waste skip.	12	0.7
15	Ceramic Tiles	17 01 03	Disposal by waste skip.	5	0.3
	Total Waste Quantity	=		***1727**	**100 %**
1. Volume / percentage of C & D waste reused on, and off-site.				6101m³	-
2. Volume / percentage of C & D waste disposed of by waste skip.				1087m³	63 %
3. Volume / percentage of C & D waste segregated for recycling.				640m³	37 %

Cost & No. of Waste Skips Removed from Site from Commencement of Waste Audit to Completion

Skip Supplier	Skip Vol. (yards³)	Skip Vol. (m³)	No. of skips for Audit period.	Cost Per Skip.	Total Skip Costs.
East Galway Waste	12.0	9.17	133	€250 Mixed Waste	€33250
East Galway Waste	12.0	9.17	2	€0 Steel (S)	€0
East Galway Waste	35	26.76	5	€500 Timber (S)	€2500
Walsh Waste	12.0	9.17	2	€250 Mixed Waste	€500
City Bin	1.5	1.14	60	€39 Canteen (S)	€2340
Walsh Waste	35	26.76	9	€300 Timber (S)	€2700
			211 Skips		**€41290**

Waste Rates

Waste Rate including Soil Wastes = (19518m²/ 100 x 70) = 13663m². 6101 + 1727 / 13663 m² =	**<u>0.57</u> m³ of Waste per m² of Floor Area**
Waste Rate excluding Soil Wastes = (19518m²/ 100 x 70) = 13663 m². 1727 m3 / 13663 m² =	**<u>0.13</u> m³ of Waste per m² of Floor Area**

* Total waste quantity does not include soil wastes. For detailed C & D waste breakdown see Appendix I.
** N/D: Not Disclosed. (S): Segregated

Table 5.4 Waste Management Savings Achieved on Case Study 2

Case Study 2: Cost Savings Achieved Through Segregation of Nominated Construction and Demolition Wastes				
No.	**Waste Material**	**Management Option**	**Details of Cost Savings Made**	**Savings Achieved (€)**
1.	Timber	Recycle	A total of 423m^3 of timber waste was produced on site during the waste audit. A total of 375m^3 of waste timber was segregated into 35cy waste skips achieving a financial saving of €430 per 35cy waste skip removed from site. The total saving achieved through proper segregation of timber waste was: €430 x 14no. (35cy waste skips) =	€6020
2.	Insulation	Recycle	196m^3 of waste insulation was generated on site during the waste audit. A total of 171m^3 was re-directed back to the supplier for recycling. The cost saving achieved was: 171m^3/ 9.17m^3 (size of general waste skip) x €250 (cost of disposal of general waste skip if metal was not segregated) =	€4662
3.	Metal	Recycle	A total of 21m^3 of metal waste was segregated during the waste audit. This achieved a saving of 21m^3/9.17m^3 (size of general waste skip) x €250 (cost of disposal of general waste skip if metal was not segregated) =	€573
			Total savings achieved on site =	€11255

5.8.2 Implementing a Construction and Demolition Waste Management Strategy on Case Study 2

The waste management strategy developed by the contractor, and the auditor, included the following:

1. A C & D waste manager was to be appointed on site and given responsibility for the implementation and day to day management of the proposed waste management initiatives.
2. Wastes disposed of by skip were to be segregated into categories agreed with the waste management contractors supplying waste skips to site. The categories were as follows.

- Timber.
- Steel / metal.
- Paper, plastic, polystyrene insulation, fibreglass, small quantities of glass.
- Tiles, ceramics, tarred products, plastering material.
- Bricks, blocks and concrete.

- Canteen waste.
- Cables, electrical off-cuts and copper pipe off-cuts.

3. The management of site wastes was to follow the waste management hierarchy. e.g. prevent, reduce, reuse, recycle, energy recovery, disposal.
4. No burning, or burying, of C & D wastes was to take place on site.
5. Waste materials would not be allowed to accumulate, and should be disposed of on a regular basis.
6. Subcontractors were to be made responsible for the segregation of the wastes they produced.
7. Suppliers would be made responsible for the disposal of waste arising from packaging. If a supplier was not a member of Repak then all packaging waste supplied to site must be taken back by them and recovered.
8. C & D waste management would be discussed in site meetings as a standard point on the agenda.
9. A waste audit would be conducted by a competent waste management consultant and the resulting waste audit reports, including recommendations made, would be reviewed at site meetings.

On Case Study 2, the contractor employed a waste management operative (WMO) who was solely responsible for the collection and segregation of all site wastes. The WMO was given access to a 6 tonne dumper for the transportation of wastes from various locations on site to the appropriate waste skips, or disposal areas. This allowed the calculation of the costs for waste management labour and plant for this project unlike the other three case study construction projects. Table 5.5 details the cost of this.

Table 5.5 Case Study 2: Construction and Demolition Waste Management Labour and Plant Costs Incurred

Case Study 3: C & D Waste Management Labour and Plant Costs		
Plant	1 no. 6 tonne dumper, operational for 9hrs per day @ € 4.75/hour. Audit duration 307 working days. 307 x 9 x €4.75 =	€13124
Labour	1 no. Waste Management Operative, working for 9hrs per day, for 307 working days, @ €15.48/hour. 1 x 9 x 307 x €15.48 =	€42771
	Total labour and plant cost for this construction project =	**€55895**

The calculation of costs for the labour and plant utilised in C & D waste management on the other three case studies was not possible as the building contractors did not maintain records of this work. On the other case studies waste was collected and disposed of in an erratic and irregular manner by many operatives on site making the recording of such activities difficult without continuous observations being carried out on site.

5.8.3 The Management of Waste Topsoil, Subsoil and Rock

On case study 2, the reuse of waste soils, subsoil, and the blasting and crushing of rock on site significantly reduced the volume of excavated waste materials removed from site. Over the course of the audit 6101 m^3 of excavated material was removed from site and reused elsewhere. Approximately $65000m^3$ of rock was blasted, excavated, crushed and reused on site. This is, again as in case study 1, a prime example of waste minimisation and reuse. The optimisation of the sites natural resources provided significant economic benefits for the contractor.

Photo 5.4 Natural Rock Excavation.

Photo 5.5 Backfilling with Waste Soils.

Photo 5.6 Reusing Crushed Rock.

5.8.4 Waste Blocks and Other Concrete Products on Site

As in case study 1, these inert wastes were retained on site for reuse as low grade site fill. These materials are inert, inorganic and non-hazardous. It was observed during the audit that significant quantities of these wastes lay around the site at early stages of the project, some full and half blocks which could have easily been reused for their intended purpose.

5.8.5 The Management of Other Construction and Demolition Wastes on Site

As on case study 1, all other C & D wastes on this site were disposed of by waste skip. These skips consisted mainly of 12 cubic yard (9.18 m^3) skips which were used for general wastes, 1.5 cubic yard (1.15m^3) skips for canteen waste, and 35 cubic yard (26.76 m^3) skips for segregated timber waste.

As the contractor had developed a more formalised C & D waste management strategy on this project a waste compound was set up at the rear of the site. The waste compound contained all waste skips, apart from the canteen waste skips which were located adjacent to the site canteen, and one 12cy skip which was located next to the mortar mixing pit which was used for the disposal of waste cement bags.

When sufficient quantities of timber wastes were collected, and in some cases as the timber wastes were collected around site, they were placed in 35 cubic yard waste skips and removed from site by the appointed waste management contractor. Timber pallets which were brought onto site with deliveries of cement and roof tiles were taken back by the suppliers for reuse. On occasion the use of 12cy general waste skips for the disposal of timber wastes occurred on site. This resulted in unnecessary increased waste disposal costs.

Metal wastes were also segregated into a 12 cubic yard waste skip and removed from site, free of charge, for recycling.

It was also decided to segregate waste polystyrene insulation for recycling on this site. The contractor arranged a take back agreement with their insulation supplier, a recommendation made by the auditor. Although this recommendation was made for case study 2, the segregation of waste polystyrene insulation was slow to be introduced.

The take back scheme was agreed with the supplier, providing the waste insulation remained unsoiled and uncontaminated. This was achieved by placing the insulation off-cuts into plastic bags and storing them in the waste compound. On delivery of new polystyrene insulation the waste off-cuts were removed from site by the haulier and returned to the supplier for recycling.

Photo 5.7 Waste Polystyrene Disposal.

Apart from the afore mentioned materials, concrete blocks, concrete, timber, and polystyrene insulation, which were reused, or segregated for recycling, all other wastes were disposed of in the general waste skips.

On this site the majority of site wastes were handled by the WMO. The segregation of wastes was successful, but on occasion other operatives, or drivers, disposing of C & D wastes in skips resulted in materials nominated for reuse and recycling being mixed with general wastes.

5.9 Case Study 3

The C & D waste audit carried out on case study 3, a hotel and retail development, commenced in December 2003, and was completed in March 2005. The construction work carried out on this site included the demolition / deconstruction of all existing buildings on site. This work took place prior to the commencement of the waste audit, and as no records of the C & D waste materials generated at that stage were kept by site staff any wastes produced on site at that stage were not included in the waste audit results.

Photo 5.8 Hotel: May 2004.

5.9.1 Construction and Demolition Waste Audit Results on Case Study 3

The following C & D waste data was collected on case study 3, from December 2003, to March 2005. Table 5.6 details the C & D waste data collected throughout the waste audit.

Table 5.6 Case Study 3: Construction and Demolition Waste Audit Results

Site Location:	Galway City	**Building Contractor:**	** N/D
Project Description:	This project was constructed on a site previously used as a petrol station and car sales dealership. The development consisted of the demolition / deconstruction of all existing buildings on site, the construction of a double basement car park, a petrol filling station, retail units, offices and a hotel. The main building structure was a combination of cast in-situ concrete and prefabricated steel. The basement construction consisted of a bored pile retaining wall with an internal basement wall. Following the excavation of the soils / subsoil the cast in-situ concrete basement wall, including columns and floor slabs were constructed. The structure above ground level consisted of a steel frame, incorporating cast in-situ concrete floors, external glazing and stone cladding. The installation of all services, mechanical, electrical, etc. were included as part of the construction works.		
Total Floor Area:	258333 Square Feet / 24000 Square Meters.		
Estimated Floor Area Completed:	(90%) 21600 m^2		
Project Commencement Date:	Oct 03	**Project Completion Date:**	July 05
C & D Waste Audit Commencement Date:	Dec 03	**C & D Waste Audit Completion Date:**	March 05
Waste Management Contractors on site:	1. East Galway Waste. Killimore, Ballinasloe, Co. Galway. 2. Walsh Waste Disposal Ltd. Parkmore, Ballybritt, Galway. 3. Galway Metal Co. Ltd. Oranmore, Co. Galway.		

No.	Waste Material	EWC Code	Treatment Option Used	Waste Quantity Generated (m^3)	Waste Quantity (%)
1	Soil	17 05 04	Reused off-site.	23450	-
2	Rock	17 05 04	Reused off-site.	2500	-
3	Mixed Waste	17 09 04	Disposal by waste skip.	515	37
4	Timber	17 02 01	Segregated for recycling.	396	29
5	Plasterboard	17 08 02	Disposal by waste skip.	130	10
6	Unknown Waste	17 09 04	Disposal by waste skip.	119	8
7	Steel	17 04 05	Segregated for recycling.	114	8
8	Canteen Waste	17 09 04	Disposal by waste skip.	40	3
9	Insulation	17 06 04	Disposal by waste skip.	34	3
10	Cardboard	17 09 04	Disposal by waste skip.	14	1
11	Plastic Sheeting	17 02 03	Disposal by waste skip.	7	0.5
12	Off-Site Waste	17 09 04	Disposal by waste skip.	3	0.2
13	Rubble	17 01 07	Disposal by waste skip.	2	0.2
14	Paper	17 09 04	Disposal by waste skip.	1	0.1
	Total Waste Quantity	=		***1375 m^3**	**100 %**

1. Volume / percentage of C & D waste reused off-site.	25950m^3	-
2. Volume / percentage of C & D waste disposed of by waste skip.	865m^3	63%
3. Volume / percentage of C & D waste segregated for recycling.	510m^3	37%

Cost & No. of Waste Skips Removed from Site from Commencement of Waste Audit to Completion

Skip Supplier	Skip Vol. (yards^3)	Skip Vol. (m^3)	No. of skips for Audit period.	Cost Per Skip.	Total Skip Costs.
East Galway Waste	12.0	9.17	119	€250 Mixed Waste	€29750
Galway Metal	20.0	15.29	13	€0 Steel (S)	€0
Walsh Waste	35.0	26.76	5	€300 Timber (S)	€1500
			137 Skips		**€31250**

Waste Rates

Waste Rate including Soil Wastes = (24000m^2/100 x 90) = 21600m^2. (1375 + 23450 + 2500 m^3) / 21600 m^2 =	**1.27m^3 of waste per m^2 of Floor Area**
Waste Rate excluding Soil Wastes = (24000m^2/ 100 x 90) = 21600m^2. 1375 m^3 / 21600m^2 =	**0.06m^{3}of waste per m^2 of Floor Area**

* Total waste quantity does not include soil wastes. For detailed C & D waste breakdown see Appendix J.
** N/D: Not Disclosed. (S): Segregated

Table 5.7 Waste Management Savings Achieved on Case Study 3

Case Study 3: Cost Savings Achieved Through Segregation of Nominated Construction and Demolition Wastes				
No.	**Waste Material**	**Management Option**	**Details of Cost Savings Made**	**Savings Achieved (€)**
1.	Timber	Recycle	A total of 396m^3 of timber waste was produced on site during the waste audit. A total of 134m^3 of waste timber was segregated into 35cy waste skips achieving a financial saving of €430 per 35cy waste skip removed from site. The total saving achieved through proper segregation of timber waste was: €430 x 5no. (35cy waste skips) =	€2150
2.	Metal	Recycle	A total of 114m^3 of metal waste was segregated during the waste audit. This achieved a saving of 114m^3/9.17m^3 (size of general waste skip) x €250 (cost of disposal of general waste skip if metal was not segregated) =	€3107
			Total savings achieved on site =	€5257

5.9.2 The Construction and Demolition Waste Management Procedures on Site

On case study 3, the contractor had no formal waste management strategy employed on site for the control and management of C & D wastes generated. The waste management practices used by the contractor on this site included complying with all waste management regulations and disposing of all site wastes by the most economical options available.

5.9.3 The Management of Waste Subsoil and Rock

All excavated soils and rock were removed from site and reused as site fill on permitted sites. (e.g. Sites having a waste permit granted by Galway County Council.)

Although this development was located on a site previously used as a petrol filling station, no contamination of soil was found during excavation. Excavated soils were tested extensively for contamination during construction.

Photo 5.9 Rock and Subsoil Excavation.

5.9.4 The Management of Other Construction and Demolition Wastes on Site

Before the redevelopment of this site commenced it was used by a car sales dealership, and a petrol filling station also operated on site. Demolition of existing buildings took place before the C & D waste audit was initiated on site. Records of the quantities of demolition wastes arising from the demolition/deconstruction of these buildings were not recorded by site personnel.

All other C & D wastes generated on site were disposed of in waste skips supplied by the appointed waste management contractors. The skips used on site mainly consisted of 12 cubic yard (9.18 m^3) waste skips which were used for general wastes, and 20 cubic yard (15.29 m^3) skips for segregated steel wastes.

Wastes were collected on site using a 2cy waste skip, the contents of which would then be disposed of into the 12cy waste skips. The skips for segregated waste metals were supplied by Galway Metal and were removed from site free of charge for recycling. As storage space on site was at a premium the maximum number of skips on site at any one time did not exceed 5.

On this site the concrete and formwork subcontractor supplied their own 12cy skips for the wastes resulting from their element of the works. Initially the segregation of timber wastes into 12cy waste skips was not done for economic benefit, or recycling, but as this subcontractor supplied their own waste skips, and their main waste stream was timber, the segregation of waste timber was by default rather than by design.

During the course of the project the main contractor was made aware, by the auditor, of the economic benefits of segregating waste timber into 35cy waste skips, as apposed to a 12cy skip. (A possible saving of €430 could be made per 35cy skip used.) The use of 35cy waste skips on site for segregated timber wastes was commenced shortly afterwards.

5.10 Case Study 4

The C & D waste audit carried out on case study 4, commenced in December 2003, and was completed in July 2004. The waste audit covered the full duration of the construction process. This case study was located in Galway City.

5.10.1 The Construction and Demolition Waste Audit Results on Case Study 4

Table 5.8 details the waste audit data collected on case study 4.

Table 5.8 Case Study 4: Construction and Demolition Waste Audit Results

Site Location:	Galway City	**Building Contractor:**	** N/D
Project Description:	This educational development consisted of an office building including all associated facilities, e.g. canteen, reception area, toilets, etc. The main structure of the building was cast in-situ concrete with concrete block internal and external walls. The exterior of the building was rendered and has a painted finish. The construction also included all services installations, ground works and landscaping.		
Total Floor Area:	$1125m^2$		
Estimated Floor Area Completed:	(100%) 12107sq/ft / $1125m^2$		
Project Commencement Date:	Sept 03	**Project Completion Date:**	July 04
C & D Waste Audit Commencement Date:	Dec 03	**C & D Waste Audit Completion Date:**	July 04
Waste Management Contractors on site:	1. Barna Waste, Headford Road, Galway.		

No.	Waste Material	EWC Code	Treatment Option Used	Waste Quantity Generated (m^3)	Waste Quantity (%)
1	Soil	17 05 04	Reused off-site.	694	-
2	Mixed Waste	17 09 04	Disposal by waste skip.	191	47.5
3	Timber	17 02 01	Segregated for recycling.	100	25
4	Unknown Waste	17 09 04	Disposal by waste skip.	49	12.3
5	Cardboard	17 09 04	Disposal by waste skip.	12	3
6	Steel / Metal	17 04 07	Segregated for recycling.	11	2.8
7	Canteen Waste	17 09 04	Disposal by waste skip.	9	2.3
8	Plastic Sheeting	17 02 03	Disposal by waste skip.	9	2.3
9	Insulation	17 06 04	Disposal by waste skip.	8	2
10	Plasterboard	17 08 02	Disposal by waste skip.	6	1.5
11	Off Site Waste	17 09 04	Disposal by waste skip.	5	1.3
	Total Waste Quantity	=		***$400m^3$**	**100%**
1. Volume / percentage of C & D waste reused off-site.				$694m^3$	-
2. Volume / percentage of C & D waste disposed of by waste skip.				289m3	72.2 %
3. Volume / percentage of C & D waste segregated for recycling.				$111m^3$	27.8 %

Cost & No. of Waste Skips Removed from Site from Commencement of Waste Audit to Completion

Skip Supplier	Skip Vol. ($yards^3$)	Skip Vol. (m^3)	No. of skips for Audit period.	Cost Per Skip.	Total Skip Costs.
Barna Waste	12.0	9.17	39	€158 / Tonne Mixed Waste	€10069
Barna Waste	8.0	6.12	7	€158 / Tonne Mixed Waste	€1204
			46 Skips		**€11273**

Waste Rates

Waste Rate including Soil Wastes = $(694m^3 + 400m^3) / 1125m^2$ =	**$0.97m^3$ of Waste per m^2 of Floor Area**
Waste Rate excluding Soil Wastes = $400m^3 / 1125\ m^2$ =	**0.36 m^3 of Waste per m^2 of Floor Area**

* Total waste quantity does not include soil wastes. For detailed C & D waste breakdown see Appendix K.
** N/D: Not Disclosed.

Table 5.9 Waste Management Savings Achieved on Case Study 4

Case Study 4: Cost Savings Achieved Through Segregation of Nominated Construction and Demolition Wastes				
No.	**Waste Material**	**Management Option**	**Details of Cost Savings Made**	**Savings Achieved (€)**
1.	Timber	Recycle	A total of $100m^3$ of timber waste was produced on site during the waste audit. Although much of this waste was segregated the contractor was charged the mixed waste rate of €158 per tonne as opposed to €48 for segregated timber, thus no saving was achieved.	€0
2.	Metal	Recycle	A total of $11m^3$ of metal waste was segregated during the waste audit. This achieved a saving of €250.	€250
			Total savings achieved on site =	€250

5.10.2 Construction and Demolition Waste Management Procedures on Site

On case study 4, no formal C & D waste management strategy was employed on site for the control and management of C & D wastes generated. As on case study 3, the waste management technique used by the building contractor on this site was to comply with all waste management legislation, and to dispose of all site wastes by the most economical methods available.

Photo 5.10 Construction in Progress.

Unlike the other three case studies, on this site the building contractor was charged for waste disposal by the weight of C & D wastes removed from site. (On the other case studies a fee per skip was paid for C & D waste disposal.)

5.10.3 The Management of Construction and Demolition Wastes

All excavated soils and rock were removed from site and reused elsewhere as site fill.

Waste timber generated on site, for the most part, was segregated into specific skips. The segregation of this waste stream into 12cy waste skips was done for economic benefit as the disposal cost per tonne of segregated waste timber was less than the disposal cost per tonne of mixed C & D wastes.

Photo 5.11 Excavated Soil Stockpile.

Although the segregation of waste timber could have potentially provided a financial saving, the contractor was charged the standard rate for mixed waste skips for all skips removed from site. On this site pallets used for the delivery of cement were taken back by the supplier.

Waste steel / metal for the C & D waste audit period was disposed of by waste skips supplied by the waste management contractor and removed from site.

5.11 Conclusions

The presentation of the information collected on the four case study construction projects provides a unique window into the C & D waste management practices currently used by building contractors in the Galway Area. The C & D waste data collected during the waste audits has established a sample of the various types and volumes of C & D wastes generated on typical construction sites, and the resulting waste rates. The main conclusions are as follows:

- The presentation of the C & D waste quantities, and management details analysed, on each of the case studies has identified a number of waste management activities that are common to all four construction projects.

1. Each building contractor complies with waste management legislation for the disposal of C & D wastes generated.

2. Each building contractor utilises the services of one or more waste management contractor on site.

3. Each waste material was disposed of, within the legislative framework, by the most economical option available, or the most financially beneficial disposal option that the building contractor was aware of. (This is why a number of waste management contractors were used to supply waste skips to the case study construction projects, due to the economic benefits offered by different contractors for different waste streams.)

4. All uncontaminated waste soils were reused on site, or on alternative sites.

5. No formal C & D waste management strategy, or waste management plan, was in operation on any case study site at the commencement of the C & D waste audit. This establishes that the use and implementation of formal C & D waste management strategies are in their infancy in the Galway area.

The following chapter will examine the results of the case studies in detail, and analyse the potential for improved C & D waste management initiatives for use on future construction projects.

Chapter 6

The Assessment of Construction and Demolition Waste Audit Data Collected on the Case Study Construction Projects

6.1 Introduction

Following the waste audits and the detailing of the C & D waste management practices on the case study construction projects, it was then necessary to examine the impacts of C & D waste, and the C & D waste management practices, on the four case study construction projects.

While it is almost certain that a volume of C & D waste will be generated on most different types of construction projects, the prediction and estimation of the volumes of wastes produced, prior to the commencement of construction, can be difficult.

"C & D Waste can be classified according to its three sources: new construction, renovation or remodelling, and razing or demolition. While the types of wastes generated from these three areas are similar, the amounts each produces are different."
(*Laquatra, J., 2004*).

The C & D waste quantities collected for this research project were based on a skip analysis on each of the four construction projects. This included recording all C & D wastes removed from site for the duration of the waste audits.

6.2 Calculating Valid Construction and Demolition Waste Rates

To establish a valid and accurate C & D waste rate for each case study construction project examined as part of this research the completion of a waste audit from the commencement of construction on site to its completion has proved to be necessary. In order to understand the importance of C & D waste rates on a national basis, and in regards to allowing a building contractor to estimate C & D waste quantities for a future project, it is first necessary to understand the following:

1. A full project duration C & D waste rate can be described as a quantity of waste in m^3 per m^2 of floor area, or in kg per m^2 of floor area, which does not vary from the waste rate calculated at the end of a construction project. A full project duration C & D waste rate is calculated when the total volume of waste generated on a construction project, in m^3, or in kg, is divided by the total floor area of the completed project.

2. A snapshot C & D waste rate is where a waste rate is calculated using information on C & D waste volumes generated on a construction project, which were collected over a short (snapshot), or specified period of time during construction. This calculation does not include information on all C & D wastes generated for the full duration of the construction process, and thus it may or may not result in a waste rate equal to the full project duration C & D waste rate.

In the research findings set out in Table 6.1 it has been established that C & D waste generation is highly variable from month to month on case study 1, and case study 4, as it is on the other two case study construction projects. (A full breakdown of the waste generation for each case study on a monthly basis can be seen in Appendix L.)

Table 6.1 Waste Arisings on Case Study 1, and 4

Monthly Construction and Demolition Wastes Arising on Case Study Construction Projects 1 & 4													
Total Monthly Waste Arisings. (Cubic Meters.)	Oct 03 (m^3)	Nov 03 (m^3)	Dec 04 (m^3)	Jan 04 (m^3)	Feb 04 (m^3)	Mar 04 (m^3)	Apr 04 (m^3)	May 04 (m^3)	Jun 04 (m^3)	Jul 04 (m^3)	Total (m^3)	Floor Area Complete.	Waste Rate. (m^3 per m^2)
Case Study 1	159	116	93	141	142	222	140	148	262	122	1545	12664	0.12
Case Study 4	11	17	32	44	52	54	29	57	63	41	400	1125	*0.36
Case Study 1:	Residential. C & D waste rate shown above has been calculated using 'snapshot' waste data.												
Case Study 4:	Educational. C & D waste rate calculated using data collected for full duration of construction. This is a valid waste rate for this construction project. * This is a valid waste rate calculated using C & D waste data for the full duration of construction.												

The data shown in Table 6.1 establishes the difficulty in calculating accurate, valid waste rates for construction projects, when only, 'snapshot', C & D waste audit data is available and utilised to calculate a waste rate.

6.2.1 The Importance of Full Project Duration Waste Rates

On case study 4, where C & D waste data was collected for the full duration of the construction project a C & D waste rate was calculated at $0.36m^3/m^2$. Waste rates have also been calculated for case study 4, using, 'snapshot', waste data for the first five months of construction, and for the last five months of construction. This allows comparison of the actual C & D waste rate for the full duration of the construction project with waste rates calculated using, 'snapshot', C & D waste data for the same project. Table 6.2 shows the calculated waste rates.

Table 6.2 Waste Rates Calculated for Case Study 4

Waste Rates for Case Study 4	
Actual, Valid, C & D Waste Rate for the full duration of construction on case study 4. $400m^3 / 1125m^2 =$	Waste Rate 1 **$0.36m^3/m^2$**
Waste Rate calculated using, 'snapshot', C & D waste data for the first 5 months of construction. $156m^3 / 563m^2 =$	Waste Rate 2 **$0.28m^3/m^2$**
Waste Rate calculated using, 'snapshot', C & D waste data for the last 5 months construction. $244m^3 / 563m^2 =$	Waste Rate 3 **$0.43m^3/m^2$**

In Table 6.2, waste rate 1, which is the full project duration C & D waste rate, has been calculated at 0.36 m^3/m^2.

- Waste rate 2, calculated using, 'snapshot', C & D waste data for the first five months of construction has been calculated at $0.28m^3/m^2$. Waste rate 2, is 22.2% less than the actual valid C & D waste rate. The extrapolation of waste rate 2, to calculate C & D wastes generated for this type of construction project would lead to an estimated C & D waste volume which would potentially be 22.2% less than the actual C & D waste quantity generated for this type and size of construction project, given the data collected.

- Waste rate 3, again was calculated using, 'snapshot', C & D waste data for the last five months of construction and has been calculated at $0.43m^3/m^2$. This waste rate is 19.4% greater than the actual C & D waste rate calculated for the full duration of this construction project. Any extrapolation using this C & D waste rate for the estimation of C & D waste quantities for this project type would potentially lead to an overestimation of C & D waste quantities by 19.4%.

The C & D waste quantities estimated for case study 4, and the three other case studies included as part of the overall research project, have been consistent in their inconsistent volumes of C & D waste generation on a monthly basis (See Appendix L). As explained previously, calculating C & D waste rates for construction projects using, 'snapshot', waste data and extrapolating these waste rates for similar construction projects can potentially result in inaccurate C & D waste volumes being estimated.

Although it would be more desirable to extrapolate, 'snapshot', C & D waste audit data collected on Irish construction projects to calculate C & D waste volumes on a national basis, or for individual construction projects, rather than using waste rates from the US, it has been established that C & D waste rates calculated using, 'snapshot', waste data can vary significantly from the actual, full project duration waste rate. This analysis has shown that in order to calculate valid waste rates, C & D waste audit data must be collected for construction projects from the commencement of construction to the completion of construction.

"In order to improve confidence in construction and demolition waste generation, recovery and disposal data, improved information on construction and demolition waste disposal and recovery is required."
(*EPA, 2001*).

The current lack of Irish sourced C & D waste data prevents the calculation of C & D waste volumes generated on a national basis using waste data specific to Irish construction sites. Extensive C & D waste audits must be conducted to fill the current void in C & D waste statistics available to the EPA, and to allow valid waste rates to be calculated for various types of construction projects.

6.3 Waste Rates Calculated for the Case Study Construction Projects

This is the first extended study to attempt to develop waste rates for a number of Irish construction projects. Waste rates for a construction project can be calculated as follows:

$$\frac{\text{Total volume of waste produced in m}^3\text{.}}{\text{Total Floor Area in m}^2\text{.}} \quad \textbf{or} \quad \frac{\text{Total weight of waste produced in kg.}}{\text{Total Floor Area in m}^2\text{.}}$$

As the C & D waste audit used to collect waste data on the case study construction projects was based on a visual waste estimate (in m^3), the waste rate was calculated by dividing the total volume of waste audited by the total floor area completed (data on the weight of wastes was only available for case study 4). The following waste rates were calculated for the four case study projects using the C & D waste data collected.

Table 6.3 Waste Rates for the Case Study Construction Projects

Construction and Demolition Waste Rates Calculated Using Collected Construction and Demolition Waste Audit Data			
Case Study.	Development Type.	C & D Waste Rate Including Soil Wastes. (m^3 per m^2 of Floor Area.)	C & D Waste Rate Excluding Soils Wastes. (m^3 per m^2 of Floor Area.)
Case Study 1	Residential	0.20	0.13
Case Study 2	Residential	0.57	0.13
Case Study 3	Hotel	1.27	0.06
Case Study 4	Educational	0.97	0.36

The comparison of these waste rates with others calculated for similar Irish construction projects is currently not possible due to the lack of data on waste generation on Irish construction projects. It is also difficult to accurately compare waste rates calculated for the two residential case studies (case study 1, and 2) as construction on both was not fully completed during the period of research.

Until completion of work on site and the calculation of waste rates, for case study 1, and 2, using the total volume of waste generated on site, definitive waste rates cannot be accurately calculated. Although this is the case it is expected that case study 2, may have a higher waste rate than case study 1, as the waste rate for case study 2, is $0.13m^3/m^2$, the same as case study 1. Case study 2, was 70% complete at the end of the audit, and with 30% remaining to be completed the waste rate is likely to increase beyond that of case study 1, which was 95% complete at the end of the waste audit.

This has established that the waste rate for case study 1, and case study 2, both residential projects carried out by the same contractor, will most likely be different at the end of construction. The majority of the labour force on case study 2, had previously worked on case study 1, and the work methods and work efficiency appeared similar.

In previous case studies conducted elsewhere it has also been found that similar types of construction projects using similar materials in similar locations have produced varying volumes of C & D wastes per metre squared of floor area. The following case study data in Table 6.4 is an example of two similar projects where C & D waste audits were carried out resulting in different waste rates being calculated:

Table 6.4 Waste Audit Results

	Dandenong Police and Court Complex.	Frankston Police and Court Complex.
Construction Cost.	A$ 14.5 m	A$ 13 M
Gross Floor Area.	10600 m2	8271 m2
Project Duration.	16 Months.	13 Months.
Site Waste Costs. (Actual.)	A$ 9266	A$ 14670
Waste Costs per m2 of Gross Floor Area.	A$ 0.87	A$ 1.77
Additional Office and Amenity Savings.	A$ 27500	-
Additional Excavation and Demolition Savings.	A$ 10000	-
Actual Volume of Waste.	887 m3	798 m3
Volume of Waste Sent to Landfill.	575 m3	786 m3
Percentage of Waste Recycled.	35%	1.5%
Waste Generated per m2 of Gross Floor Area.	0.084 m3	0.096 m3

(*McDonald, B. et al., 1998*).

The Assessment of Construction and Demolition Waste Audit Data Collected on the Case Study Construction Projects

The previous case study establishes that similar types and sizes of construction projects may not produce similar volumes of C & D wastes. This highlights the necessity for waste audits to be carried out across many similar types of construction projects to develop average C & D waste rates for all types of construction projects.

The waste rates for case studies 3, and 4, are difficult to compare as both developments are completely different and used different construction materials and work methods. Case study 3, included a double basement car park under the hotel and retail development. This area included no internal finishes and structures apart from cast in-situ floors, columns and retaining walls to support the building. This resulted in less waste being produced for the basement area, which led to a much lower waste rate for the project as the basement floor area is included as part of the total building floor area.

Waste generation, and waste rates, appear to be a function of many factors on site e.g. development type, project design, contractor efficiency, materials controls, work methods, site location, etc. Waste generation throughout construction also fluctuates from month to month. There are many factors which may influence this e.g. labour force, materials use, weather, etc. A construction site is subject to many variations, and fluctuations in waste generation cannot be confined, or attributed, to a single factor during a period of construction. Ultimately waste generation is a result of many inefficiencies in the site management structure (*Skoyles, 1987*). Increased studies across many similar construction project types, including civil engineering projects, are necessary to develop average national C & D waste rates. It cannot be assumed that similar projects will produce similar waste rates.

The waste rates calculated for the case studies in this research are the first from extended waste audits on Irish construction sites, and although valuable, are limited due to the fact that construction on three of the case studies was not completed during the course of the research.

6.4 Comparing Construction and Demolition Waste Rates calculated from this Research Project with Waste Rates currently used by the Environmental Protection Agency

In our current climate one of the most challenging areas within the Irish construction industry is the management of C & D wastes. The most recent figure available for C & D waste volumes generated by the Irish construction industry is for the year 2001.

"The best estimate for construction and demolition waste generation in 2001 is 3,651,412 tonnes."
(*EPA, 2001*).

The figure of 3.6 million tonnes of C & D waste is referred to as the, "*best estimate for construction and demolition waste*", due to the inadequacies of the two methodologies currently used by the EPA to estimate C & D waste volumes for the Irish construction industry. The non-existence of C & D waste statistics specific to wastes generated by the various types of construction projects in Ireland has lead to the use of C & D waste rates derived from the United States.

6.4.1 Comparison of USEPA Waste Rates with Waste Rates Calculated from this Research

Although the waste rates established by the USEPA are utilised by the EPA in Ireland the comparison of these waste rates with those which have been derived from this research project is difficult.

The data collected from this research study is based on a visual assessment. This results in an estimated volume of C & D waste in m^3. All unit waste rates established by the USEPA are in Lb/sq ft. The conversion of a waste rate in Lb/sq ft, to, Kg/m^2 is quite straightforward, but the conversion of a volume of waste recorded in m^3, to an equivalent quantity of waste in kg, is much more difficult due to the bulk densities of wastes disposed of in waste skips, and the inconsistencies in the degree of compaction that waste undergoes after being placed in a waste skip.

To date there has been no research into the densities of wastes contained in C & D waste skips for the Irish construction industry, and thus there are no reliable conversion factors to convert C & D waste volumes to weights. Although no conversion factors specific to C & D wastes have been developed, the landfill levy regulations do provide a set of inadequate conversion factors for some C & D wastes which can be seen in Table 6.5.

Table 6.5 Landfill Levy Waste Conversion Fators

Waste Category.	Typical Waste Types.	Cubic Meters To Tonnes.	Cubic Yards To Tonnes.
Inactive or Inert Waste.	Largely water insoluble or very slowly biodegradable e.g. sand, subsoil, concrete, bricks, mineral fibres, fibreglass, etc.	1.5	1.15
General industrial waste – non – special not compacted.	Paper and plastics.	0.15	0.11
	Card, pallets, plasterboard, canteen waste, sawdust, textiles, leather.	0.4	0.3
	Timber, building and construction wastes factory waste, and sweepings.	0.6	0.46

(*Waste Management (Landfill Levy) Regulations, 2002*).

The weights of waste skips were only available for one case study construction project in this study. In order to establish the inadequacies, and inaccuracies, of the landfill levy regulation waste conversion factors, the volumes of wastes recorded on case study 4, using the visual waste audit method were converted to weights using the landfill levy regulations conversion factors. These figures were then compared with the actual total weight of C & D wastes recorded at the waste transfer station utilised by the waste management contractor when removing waste skips from case study 4. Table 6.6 shows the figures calculated.

Table 6.6 Comparison of Actual Weight of Waste on Case Study 4, with Calculated Waste Weight

Weight of C & D Wastes Calculated Using The Landfill Levy Regulation Conversion Factors.	Actual Weight of C & D Wastes Weighed Following Removal from Site.
233.6 tonnes	71.4 tonnes

It can be seen in Table 6.6 that the actual weight of C & D wastes removed from site is 71.4 tonnes. The weight of C & D wastes calculated using the landfill levy regulations, 233.6 tonnes, is more than three times the actual weight of C & D waste generated.

The comparison of the USEPA waste rates with the waste rates derived from this study is difficult due to the lack of essential conversion factors. To develop a set of waste conversion factors for the Irish construction industry it would be necessary to examine a large cross section of construction sites carrying out a visual C & D waste audit, and then also weighing all waste skips removed from site.

The visual waste audit is the most practical and least resource intensive method of auditing C & D wastes generated on construction sites, thus it is the most likely method of waste measurement to be utilised by building contractors. In order to facilitate the use of this waste audit type, and to accurately compare USEPA waste rates with Irish C & D waste rates, it is essential that a reliable set of waste conversion factors (m^3 to kg) are developed.

6.5 The Bulking of Construction and Demolition Wastes on Site

Bulking of C & D wastes was also an issue in conducting the C & D waste audits. Skips invariably contained a certain amount of air between the waste materials which could not be easily estimated. Each C & D waste volume was estimated as accurately as possible during the audit.

While it would have been more accurate to segregate all C & D wastes generated on site into separate waste skips, and then weigh each skip to quantify the waste volumes, this was not practical, or feasible, on any of the case study construction sites.

6.6 Inadequacies of the European Waste Catalogue Codes

The EWC codes used across the EU for waste reporting were insufficient (not specific enough) to catalogue all C & D wastes generated on the selected case study construction projects. The codes were used for reporting the waste audit results. Although the codes cover most C & D wastes they are very general and are not specific to all individual waste types encountered on the case studies. Table 6.7 is a list of the C & D wastes that were encountered on site where there was no appropriate EWC code, or where the waste codes were not specific enough to categorise the waste.

Table 6.7 Wastes Not Included in The European Waste Catalogue

Wastes Not Included in the European Waste Catalogue		
Plaster Bags	Cement Bags	Timber Pallets
Plastic Sheeting	Plastic Packaging Bands	Steel Packaging Bands
Paper	Cardboard	Tile Adhesive Bags
Plastic DPC	Dust, Sawdust, (Sweepings)	Canteen Waste
Radon Barrier	Hydrodare Pipe	Office Waste
Carpet	Electrical Conduit	Flue Liners
Carpet Underlay	Plastic Ducting and Drainage Pipe	Cement
Linoleum	Mortar	Plaster
Plywood	Concrete Blocks	Tile Adhesive
Medium Density Fibreboard	Render	Electronic, Electrical Equipment
Hardboard	Aggregates	Vegetation (Grass, Tree Cuttings)
Chipboard	Roof Slates	Off-Site Waste
Kitchen Work-top	Stone	Component Wastes (Hinges, doors
Furniture	Sand	Windows, etc.

Please note that this list is not exhaustive and includes only the wastes observed on the case study construction projects.

The EWC codes should be more specific to individual C & D wastes generated on construction sites to allow proper reporting of these waste volumes. A revision of these codes may be necessary.

6.7 Analysis of the Construction and Demolition Waste Composition

6.7.1 Soil and Rock Wastes

Waste soils and rock were generated on all four case study construction projects and produced the largest waste volumes on each. On case studies 1, and 2, some waste topsoil was stored on site and reused for landscaping. Rock was excavated on these two sites and crushed for reuse as site fill, with the remaining void from the rock excavation being backfilled with waste subsoil.

This reduced the disposal costs for waste soils and also provided other financial benefits for the contractor. The other financial benefits resulted from reducing the quantity of new crushed stone required to fill the sites to the required formation levels. Some surplus quantities of waste soils and rock were removed from these two sites by licensed waste carriers and disposed of at permitted local sites.

On case studies 3, and 4, waste soils and rock were also removed from site and disposed of at permitted sites. The disposal of waste soils on case study 3, posed a potential problem prior to excavation as the site was formerly used as a petrol station which can potentially cause soil contamination. Following extensive testing of excavated soils throughout the excavation process, no contamination was found, allowing all excavated waste soils to be disposed of at local permitted sites. The potential contamination of soils on site should be a primary concern for building contractors and soil testing should be carried out if is there is any suspicions that contamination may have occurred in the past.

There are obvious advantages in excavating and crushing rock on suitable sites, for reuse as site fill. The utilization of this process is dependent on large volumes of suitable rock being available for excavation. Prospective development sites must be examined prior to the commencement of construction to establish whether crushing rock for reuse on site is feasible. This process also allows uncontaminated waste subsoil to be disposed of on site (waste soils can be backfilled into voids resulting from excavating rock) reducing waste soil disposal costs.

6.7.2 Contractor Compliance with Construction and Demolition Waste Management Legislation for the Disposal of Excavated Waste Soils

The disposal of excavated waste soils on all four case study construction projects complied with current legislation. These regulations can be summarized as follows:

Waste is any substance which the holder discards, intends to discard, or is required to discard regardless of whether it is contaminated or not. This includes waste soils. **Uncontaminated** topsoil, subsoil and rock can be disposed of in the following manner:

- Uncontaminated soil can be reused on the same site that it has been excavated on without the need for a waste license, or a waste permit.
- A waste collection permit is required by any person/company who is responsible for transferring waste soils/material from one site to another if the laden axel weight of the vehicle being used is greater than 1 tonne.
- Waste soils disposed of off-site must be disposed of at a site where a waste permit has been obtained from the local authority.

The four case study building contractors complied with current C & D waste management legislation for the disposal of waste soils. Although this was the case, none of these contractors were required to report to the local authorities the exact locations where their waste soils were being disposed of.

Soil wastes are one of the few wastes which can be measured with reasonable accuracy prior to the commencement of a construction project, potentially allowing the local authorities to require waste soil disposal details and quantities to be submitted to them prior to the commencement of construction. Without being required to report to the local authorities the exact locations being used for the disposal of waste soils, then disposal at locations that are not permitted may occur.

6.7.3 Excluding Excavated Soil Waste Volumes when Calculating Construction and Demolition Waste Rates

Although waste soils were the largest waste volumes produced on the four case study construction projects this waste stream is not included in the calculation of the C & D waste rates. (An additional waste rate including soil wastes has been included.)

Waste soils are generally not included in C & D waste rates because the generation of soil waste on site is not a C & D waste which results directly from the construction of a building. Waste soil volumes generated are dictated by geological conditions which can vary widely from site to site. (e.g. Two similar buildings are constructed on two separate sites, one site has level ground with good bearing capacity. The second site has uneven sloping ground requiring significant excavation to reach formation level. Although both buildings are similar the second site requires more excavation leading to a higher volume of waste soil, even though the buildings being constructed are the same and would be expected to generate similar levels of C & D waste as a direct result of the construction process.) The inclusion of soil wastes would distort the calculated waste rates and make the comparison of C & D waste rates for the construction of similar buildings more difficult.

6.8 Mixed Waste

Following waste soils, mixed waste was the next largest waste volume generated on the four case study construction projects. As the C & D waste audits on case studies 1, 3, and 4, were initiated after construction began every effort was made to estimate the waste types and volumes removed from site prior to the commencement of the waste audits. Records of the number of waste skips, and in some cases the number of truck loads of waste, removed from site were obtained from the building contractors, and the waste volumes were included in the audit results. Where wastes removed from site were not segregated these wastes were classified as mixed wastes and are included in the mixed waste volumes. Table 6.8 details the quantities of mixed wastes generated on each case study, the percentage of mixed waste making up the total volume of C & D waste produced, and the disposal costs for this waste volume.

Table 6.8 Mixed Wastes Generated

Case Study No.	Total Quantity of Mixed Waste Estimated (m^3)	Percentage of Mixed Waste Making up Total Waste Volume Estimated (%)	Cost of Mixed Waste Disposal (€)
Case Study 1	1050	33.4	28610
Case Study 2	462	26.8	12589
Case Study 3	515	37.0	14033
Case Study 4	191	47.5	5355

Mixed waste volumes occurred when the auditor was unable to determine the exact composition of a volume of waste. This usually happened when smaller volumes of several different wastes were disposed of together, or when a waste skip was filled from empty, or near empty, to full in a short period of time when the waste skip was not being observed by the auditor. This prevented the auditor from observing the types, and estimating the quantities, of individual wastes contained in the skip.

Mixed wastes on all four case studies contained similar waste materials and consisted of a mixture of individually unquantifiable wastes such as plastic sheeting, canteen waste, plywood, cable off-cuts, cardboard, wavin pipe off-cuts, timber, broken pallets, hydrodare off-cuts, steel and metal wastes, paper towels, paint cans, canteen waste, etc.

The volume of mixed waste was high on the case studies due to a number of factors. The prime factor was that in most cases wastes were disposed of by personnel who were not aware of the materials that should have been segregated on site, and many wastes were generated in small quantities. The volume of mixed waste was reduced from 33.4 % on case study 1, to 26.8 % on case study 2, both residential developments. This was due to the appointment of a waste management operative, and the increased segregation of nominated wastes on site. Mixed waste volumes were also high on the case studies due to the fact that financial benefits for segregation can only be achieved for certain wastes e.g. timber, metal, polystyrene insulation, and soils, there was no advantage in segregating wastes such as plastic sheeting, cement bags, plaster bags, plasterboard, etc. Case study 4, had the highest mixed waste quantity as this project produced many wastes in small quantities, and the cost of segregating would outweigh the benefits achieved.

Photo 6.1 Mixed Waste Disposal on Site

Due to the lack of stringent segregation of nominated site wastes on all four case study construction projects the generation of mixed waste volumes was unavoidable. Although mixed waste volumes could not be broken down into their component parts they included quantities of all waste streams generated on each of the four case studies. The estimated quantities of all individual waste streams would increase accordingly if the mixed waste volume could be broken down into individual waste volumes for each waste stream making up the total volume of mixed waste. Without stringent control and segregation of waste disposal on construction sites volumes of mixed wastes will always occur.

6.9 Waste Timber

Timber waste was the largest C & D waste volume on all four case studies, following soils and mixed waste. The volumes of timber waste, the percentage of timber waste making up the total volume of C & D waste generated, and the cost of disposal of timber waste on each case study is outlined in Table 6.9.

Table 6.9 Timber Wastes Generated

Case Study No.	Total Quantity of Timber Waste Estimated (m^3)	Percentage of Timber Waste Making up Total Waste Volume Estimated (%)	Cost of Timber Waste Disposal (€)
Case Study 1	598	19.0	16294
Case Study 2	423	24.5	11525
Case Study 3	396	29.0	10790
Case Study 4	100	25.0	2814

The volumes of timber wastes in Table 6.9 includes waste timber pallets, which may be more accurately classified as a packaging waste.

Timber wastes on case studies 1, and 2, were largely made up of off-cuts from timbers used in the construction of houses and apartments, and from timber pallets. At the commencement of the waste audit on case study 1, timber wastes were stockpiled at the rear of the site for disposal at a later date. Although this proved to be successful in the long run, problems were encountered early in the project when on two occasions timber stockpiles were ignited and burned by trespassers on site.

Large quantities of waste timber lengths and timber off-cuts, which could have been reused for their intended purpose, were generated on case study 1. On this case study all timber trusses, joists, skirting, etc. were supplied by the main building contractor. As a result of this it appeared that subcontractors responsible for the use of these timbers had little regard for the levels of waste that resulted. This was mainly due to the lack of financial penalties, or negative effects, high levels of timber wastes had on their monetary claims for the work they completed. This has led to the conclusion that an alternative method of managing timbers on site should be implemented. Subcontractors should be required to supply their own timbers. This would ensure that waste levels would be kept to a minimum. Subcontractors would become more efficient and have their use of timber under control which should result in the reduction, and minimisation, of timber wastes on future projects.

Photo 6.2 Waste Timber Stockpile

Timber wastes produced on case studies 3, and 4, were made up of timber pallets, timber off-cuts and formwork timbers. As on case study 1, differentiating and estimating a waste volume for each individual type of waste timber was impossible. The mixture of timber off-cuts with waste timber pallets proved to be problematic on all four case studies as the estimation of a separate volume for timber off-cuts and for timber pallets was hindered by the mixture of these wastes. Every effort was made to estimate and record separate waste volumes for timber off-cuts and pallets, but in many cases this was not possible due to the mixture of these wastes.

Timber wastes on case studies 1, 2, and 4, were segregated due to reduced disposal costs for segregated waste timber. Initially on case study 3, timber wastes were also segregated, but this was by default rather than design as timber wastes from formwork were the primary wastes being generated on site. As a result of the research findings from this study the contractor on case study 3, was informed that their waste timber could be disposed of using a large volume waste skip at a lower cost than their disposal was costing at the time. This alternative disposal method was quickly implemented. Table 6.10 outlines the cost benefits of this strategy for the building contractor.

Table 6.10 Financial Benefits of Waste Timber Segregation

Skip Supplier.	Skip Size. (Cubic Yards.)	Contents.	Cost of Skip Disposal	Financial Benefits to the Contractor
Walsh Waste	35 cy	Timber	€300	Disposal of 2.9 times as much timber waste as using a 12 cy skip, for an extra cost of €50. A saving of €425 for disposal of each 35 cy waste skip as opposed to using 12 cy waste skips.
East Galway Waste	12 cy	Timber	€250	None

In order to ensure the financial savings from using a 35cy waste skip it was essential that only timber wastes were disposed of in these skips. On one occasion on case study 1, and case study 2, other wastes were disposed of in these skips. This led to the contractor being charged the mixed waste rate of €2000 for these waste skips, as opposed to the rate charged for segregated timber. This highlighted the necessity for proper waste management training and supervision of the management of all wastes on site.

6.10 Waste Timber Pallets

Waste timber pallets were generated on all four case study construction projects. This waste volume is included as part of the total volume of waste timber which occurred on each case study. The inclusion of waste timber pallets generated, with the timber waste volume, is due to the difficulties encountered when estimating an individual volume for waste timber pallets.

Although it was not possible to estimate a separate waste volume for all waste timber pallets, observations were made on each site over the course of the waste audits and where possible a volume for waste pallets was recorded. Where a volume of waste timber contained waste pallets, which could not be easily quantified, this was also recorded and an estimate of the percentage of timber pallets contained in the waste volume was made. Photo 6.3 shows a skip full of waste timber pallets. In a situation like this the volume of waste was recorded as a volume of waste pallets.

Photo 6.3 Waste Timber Pallets

The estimated percentage volume of waste pallets making up the total volume of waste timber for each case study is shown in Table 6.11.

Table 6.11 Timber Wastes and Pallets Generated

Case Study No.	Total Quantity of Timber Waste Estimated for Each Case Study, Including Waste Pallets (m^3)	Percentage of Timber Waste Making up the Total Waste Volume Estimated for Each Case Study Construction Project (%)	Quantity of Waste Timber Pallets Estimated. This Waste Volume is Included in the Total quantities of Waste Timber for Each Case Study (m^3)	Percentage of Waste Pallets Making up Total Timber Waste Volume (%)
Case Study 1	598	19.0	299	50
Case Study 2	423	24.5	212	50
Case Study 3	396	29.0	119	30
Case Study 4	100	25.0	30	30

6.10.1 Managing Waste Timber Pallets on Site

On all four case studies some waste pallets were reused for storage of site materials and for transporting materials around site. Cement suppliers took back all their own timber pallets, and pallets that were not returned were charged for accordingly by the supplier.

The return of cement pallets occurred on all four case studies. On case study 1, all pallets used to deliver concrete roof tiles were also returned.

This type of take back scheme was not organised by the contractors undertaking the work on site. It was arranged, or undertaken, by the materials manufacturers/suppliers. When making a delivery of new materials to site the supplier would take back all their pallets from their previous delivery. The management of waste timber pallets in this way, pallets which would otherwise have become a waste for the contractor to dispose of, is an effective waste management strategy which has cost benefits for the suppliers and the building contractor. Ideally this strategy should be applied to all timber pallets used for all materials delivered.

6.10.2 Implementing a Take Back Scheme for Waste Timber Pallets

The difficulty in implementing a take back scheme for all waste timber pallets is that in most situations materials are purchased from builders suppliers, or intermediates like this, and not directly from the manufacturer of the materials or products. In order for the contractors to arrange for their builders suppliers to take back their waste pallets, the builders suppliers would also have to have an arranged take back scheme with their manufacturers/suppliers. This is an extra task for the material suppliers to perform, one which they may not wish to undertake due to the extra cost and hassle.

There are also other difficulties in the implementation of this strategy. In many cases on smaller projects there would not be repeat deliveries of materials to site. Unless the supplier was in the area it is unlikely that they would return to site to collect a small number of timber pallets. Many timber pallets used to deliver construction materials to site are flimsy and easily damaged. This would deter materials suppliers from taking back any damaged pallets for their materials manufacturers/suppliers which could lead to financial penalties for them.

Timber pallets can also be classified as a packaging waste. Contractors should employ and enforce their rights under the packaging waste regulations. The packaging waste regulations state that suppliers who are not a member of REPAK must take back all their packaging wastes. If suppliers would take back their waste pallets this would vastly reduce the timber waste volume and disposal costs for future construction projects, especially residential construction projects similar to case study 1, and 2, where there was a high volume of waste pallets generated on site.

6.11 Unknown Waste

Shortly after the commencement of the waste audits it was found that it would not be possible for the auditor to be on site at the time of removal of all waste skips. In order to complete the waste audit an assumed waste volume, Unknown Waste, was used. (Refer to point 5.3 for further explanation.)

The volume of unknown waste was an assumed, but necessary, waste volume. The assumption that all waste skips were filled to their maximum volume is a realistic assumption as the contractors on case studies 1, 2, and 3, were paying for the disposal of their waste skips on a fee per skip basis. Like most building contractors, those on these three case studies were motivated by the production of a quality product for the maximum profit, so the maximisation of the volumetric capacity of waste skips on site is a primary aim for them, disposing of the maximum waste volume in each skip.

On case study 4, wastes were being disposed of on a fee per tonne of waste contained in each skip. This varies from the other three case studies and resulted in the contractor being under less pressure to maximise the volume of waste contained in each waste skip on site as this contractor was only charged for the waste contained. Table 6.12 shows the volumes of unknown waste produced on the case study sites.

Table 6.12 Unknown Waste Volumes

Case Study No.	Total Quantity of Unknown Waste Estimated (m^3)	Percentage of Unknown Waste Making up Total Waste Volume Estimated (%)	Cost of Unknown Waste Disposal (€)
Case Study 1	355	11.3	9673
Case Study 2	220	12.7	5995
Case Study 3	119	8.0	3243
Case Study 4	49	12.3	1543

Future studies, where a C & D waste auditor is present on site at all times, for the full duration of the construction process, would allow a full analysis of the efficiency of, and the maximisation of volumetric capacity of waste skips on site.

6.12 Waste Insulation

Insulation was a high volume waste material on case studies 1, and 2, with smaller quantities being generated on case studies 3, and 4. This waste stream on case studies 1, and 2, primarily consisted of polystyrene insulation, with small quantities of foil-backed polyurethane insulation also being generated. On case studies 1, 3, and 4, all insulation wastes were disposed of by waste skip and removed from site. It can be seen in Table 6.13 that high levels of waste insulation were generated on the two residential construction projects (case study 1, and 2.).

Table 6.13 Waste Insulation Generated

Case Study No.	Total Quantity of Waste Insulation Estimated (m^3)	Percentage of Waste Insulation Making up Total Waste Volume Estimated (%)	Cost of Waste Insulation Disposal (€)
Case Study 1	259	8.2	7057
Case Study 2	196	11.3	5341
Case Study 3	34	3.0	926
Case Study 4	8	2.0	158

The high levels of waste insulation on case studies 1, and 2, was primarily due to the technology used for the construction of the residential dwellings on site. Although some large waste insulation off-cuts were generated the majority consisted of small off-cuts which were not suitable for reuse. These waste insulation off-cuts were generated from cavity wall insulation.

As a result of the research conducted and the recommendations made on case study 1, the contractor undertaking work on case study 2, (case study 1, and 2, had the same contractor) was advised to initiate a take back agreement with their insulation supplier. The contractor was successful in arranging this, and as an alternative to disposing of their waste insulation by waste skip, at a cost of €250 per 12cy skip, the contractor initiated the segregation of unsoiled and uncontaminated insulation wastes on site. These wastes were placed in plastic bags by the general operatives assisting the block layers and stored in a fenced enclosure at the rear of the site.

This waste was removed by the insulation supplier at regular intervals when making deliveries to site. As the supplier does not charge for this service and recycles this waste it is a successful and cost effective waste management initiative. Had this scheme been implemented at the commencement of case study 1, the contractor could have made a saving of €7057. The building contractor has already successfully implemented this waste management strategy on case study 2.

6.12.1 Implementing a Waste Insulation Take back Scheme

The primary requirement for the implementation of this strategy is the generation of sufficient quantities of waste insulation to ensure that it is worthwhile, although every effort should be made to avoid the generation of waste insulation on site. On case study 4, only $8m^3$ of waste insulation was generated. On a small project like this unless the insulation supplier was in the area, or making a repeat delivery to site, it is unlikely that they would return to site specifically to collect a small volume of recyclable waste insulation.

Although this waste management strategy was recommended for case study 2, at an early stage in construction, the contractor was slow to commence this initiative. As a direct result of this delay the contractor suffered needless expense in disposing of waste insulation at the commencement of construction on case study 2.

Following the implementation of the waste insulation take back scheme the majority of this waste volume was returned to the material supplier. Small quantities of insulation wastes were still being disposed of in general waste skips on site after the commencement of this strategy. This further demonstrates the difficulty in the total segregation of a waste stream on site. This take back scheme has proved to be an effective and worthwhile waste initiative on case study 2.

6.13 Waste Plasterboard

Plasterboard wastes were generated on all four case study construction projects. On case studies 1, and 2, this waste volume was more significant as all internal partition walls in each residential unit were constructed using timber stud partitions. Case study 3, also had a significant quantity of waste plasterboard as internal metal stud partition walls were constructed using plasterboard.

Largely this waste volume consisted of small plasterboard off-cuts with little potential for reuse for their intended purpose on site, although there was in some infrequent cases larger off-cuts which could potentially have been reused. This is a difficult waste to deal with on site as it is prone to moisture damage, and if exposed to the elements it disintegrates, eliminating any possibility for recycling. Table 6.14 shows the volumes of plasterboard wastes produced on the case studies.

Table 6.14 Waste Plasterboard Generated

Case Study No.	Total Quantity of Waste Plasterboard Estimated (m^3)	Percentage of Waste Plasterboard Making up Total Waste Volume Estimated (%)	Cost of Waste Plasterboard Disposal (€)
Case Study 1	203	6.5	5531
Case Study 2	100	5.8	2725
Case Study 3	130	10.0	3542
Case Study 4	6	1.5	150

Currently this waste volume is difficult deal with. Plasterboard recycling is prominent in other European countries with companies like British Gypsum recycling plasterboard in England. A new plasterboard recycling facility has commenced operation in Ireland (Gypsum Recycling Ireland Ltd.) and it has been suggested to the case study contractors to contact this company directly to establish the possibilities of segregating their plasterboard wastes, (which would require bagging to prevent moisture damage) having sufficient quantities of waste, and disposing of this waste directly to this recycling plant. This waste disposal strategy would be subject to it being financially viable for the contractor.

6.14 Metal Wastes

Metal wastes were only significant in volume on case study 3. On the other three case studies metal wastes consisted mainly of off-cuts from waste reinforcing bars. On case study 4, waste metals were also generated from metal ducting off-cuts.

Case study 3, produced the largest volume of waste metal, some from reinforcing steel and metal ducting, with the majority coming from metal stud off-cuts from internal partitions and from proprietary steel flooring units. Metal packaging straps, although not a significant waste on any of the case studies, should have been disposed of in the segregated metal waste skips on site to ensure maximum recycling of metal wastes, but this did not appear to happen as metal packaging straps were found in many waste skips on each site.

Photo 6.4 Metal Waste Disposal

On all four case studies metal wastes were disposed of in segregated waste skips, although small quantities of metal wastes were also found in many mixed waste skips on all four sites. On case studies 1, 2, and 4, waste skips were supplied by waste management contractors, whereas on case study 3, the skip used to dispose of metal wastes was supplied by the local scrap metal merchant (Galway Metal.) Table 6.15 shows the volumes of waste metals produced on the case study construction projects.

Table 6.15 Waste Metals Generated

Case Study No.	Total Quantity of Metal Waste Estimated (m^3)	Percentage of Metal Waste Making up Total Waste Volume Estimated (%)	Cost of Metal Waste Disposal (€)
Case Study 1	13	0.4	0
Case Study 2	21	1.2	0
Case Study 3	114	8.0	0
Case Study 4	11	2.8	0

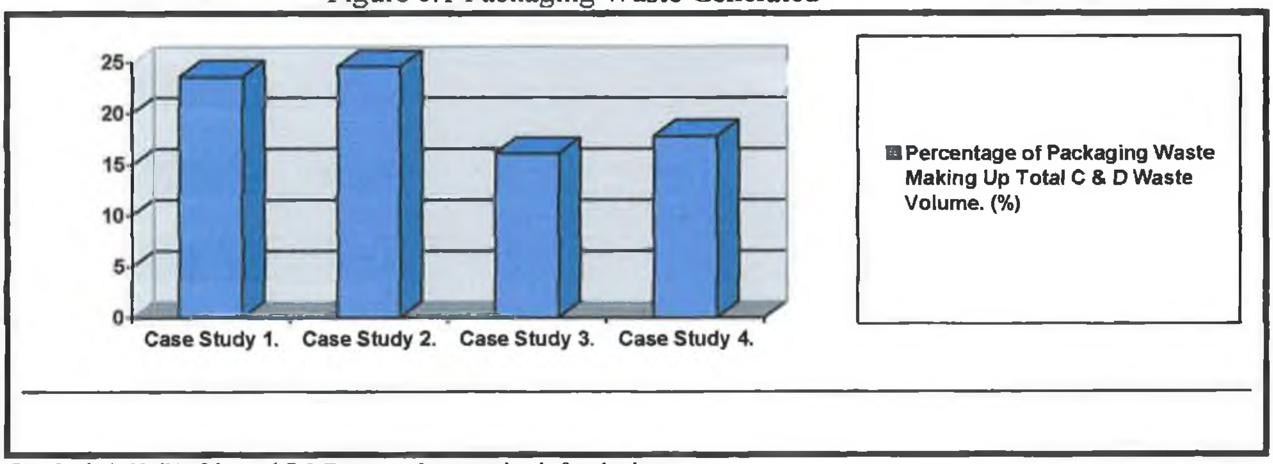
Although waste generation of any kind is contrary to efficient site management metal wastes proved to have little financial impacts on the waste disposal costs on site. All segregated metal wastes were removed from site free of charge. This is due to the high value this waste has, both financially as a material and for its ease of recycling. Although this waste was removed from each site free of charge it should not deflect contractors from ensuring that their metal wastes are minimised.

6.15 Packaging Waste

The generation of packaging wastes, as with all other wastes on the case study construction projects, has proved to be highly variable from month to month. The full implications and effects of packaging wastes on the case study construction projects have been extensive.

Packaging wastes on the four case studies are similar in the types of wastes that were produced but vary in volume. Figure 6.1 shows the percentage of packaging waste produced on each case study in relation to the total volume of C & D waste generated.

Figure 6.1 Packaging Waste Generated



Case Study 1: 23.6% of the total C & D waste volume consisted of packaging wastes.
Case Study 2: 24.6% of the total C & D waste volume consisted of packaging wastes.
Case Study 3: 16.1% of the total C & D waste volume consisted of packaging wastes.
Case Study 4: 17.8% of the total C & D waste volume consisted of packaging wastes.
*The total waste volumes above do not include excavated soil wastes.

Packaging waste has proved to be a significant contributor to the overall volume of C & D waste produced on the case study construction projects. 24.6% of the total volume of C

& D waste generated on case study 2, alone consisted of packaging wastes. These wastes included, cement bags, plaster bags, plastic sheeting, cardboard, paper, timber pallets, etc. Timber pallets were one of the largest contributors to the packaging waste volume making up an estimated 50% of the total volume of timber waste produced on case study 1.

6.15.1 The Effects of Packaging Waste

One of the main findings of this research project has been the lack of enforcement of the packaging waste regulations on the four case study construction projects. Enforcement of the packaging waste regulations is the responsibility of local authorities. There was no enforcement of these regulations on any of the four case study construction projects examined.

"Each local authority shall be responsible for the enforcement of these Regulations within their functional areas and shall take such steps as are necessary for this purpose." (*Waste Management (Packaging) Regulations, 2003*).

Under the packaging waste regulations, packaging waste must be taken back by suppliers/producers if they are not members of REPAK. The general attitude taken by materials/product suppliers (packaging suppliers/producers) is that if you purchase their product you also purchase the associated packaging. Packaging producers are defined under the packaging waste regulations as:

"a person who, for the purpose of trade or otherwise in the course of business, sells or otherwise supplies to other persons packaging material, packaging or packaged products,"
(*Waste Management (Packaging) Regulations, 2003*).

Waste pallets were taken back by cement suppliers on the four case studies, but this was because these pallets had a value for the supplier, not because the suppliers were made to comply with the packaging waste regulations by the building contractor.

Although the lack of enforcement of the packaging waste regulations appears to be the industry standard, contractors need to initiate the enforcement of these regulations on their construction sites. This may be a struggle initially, but given the estimated volumes of waste that packaging generated over the course of a residential construction project (case study 1, 23.6%, case study 2, 24.6%, of the total waste volume estimated consisted of packaging wastes) there are significant savings to be made.

The initiation of take back schemes for packaging wastes would encourage all materials and products suppliers to limit their materials/product packaging to the minimum necessary, further reducing the volume of packaging wastes generated on site. Apart from enforcing the packaging waste regulations there is little else that contractors can do to reduce their packaging wastes on site, apart from using alternative materials and products, or by specifying that the minimum amount of packaging is used for their materials. The contractor on case study 2, is currently attempting to implement a packaging waste take back scheme on their Dublin sites. Table 6.16 shows the volumes of packaging wastes generated on the case study construction projects.

Table 6.16 Packaging Waste Generated

Case Study No.	Total Quantity of Packaging Wastes Estimated (m^3)	Percentage of Packaging Wastes Estimated and Percentage Savings Which Could Have Been Achieved Had All Packaging Wastes Been Taken Back By Suppliers. (%)	Cost of Packaging Waste Disposal (€)
Case Study 1	741	23.6	20191
Case Study 2	425	24.6	11580
Case Study 3	221	16.1	6022
Case Study 4	71.2	17.8	2007

6.16 Canteen Waste

Canteen waste was generated on all four case study construction projects. On case studies 1, and 2, canteen wastes were segregated into 1.5cy, covered waste skips. On case studies

3, and 4, canteen wastes were disposed of in general waste skips. Table 6.17 details the volumes of canteen wastes generated on the four case study construction projects.

Table 6.17 Canteen Waste Generated

Case Study No.	Total Quantity of Canteen Waste Estimated (m^3)	Percentage of Canteen Waste Making up Total Waste Volume Estimated (%)	Cost of Canteen Waste Disposal (€)
Case Study 1	113	3.6	3079
Case Study 2	70	4.1	1907
Case Study 3	40	3.0	1090
Case Study 4	9	2.3	237

Although the impacts of canteen waste is minimal in terms of the overall waste volume generated, and the potential for the reduction of this waste volume is limited, it is important to employ proper disposal methods to avoid attracting vermin on site. All canteen wastes, especially food waste, should be disposed of in small volume covered waste skips which should be emptied on a regular basis. This limits the attraction of vermin and helps prevent foul odours from food wastes.

On the case study construction sites it was impossible to distinguish the individual waste components included in canteen waste volumes. It was observed that many plastic drinks bottles and drinks cans were disposed of in general waste skips on site. Locating a bottle bank, or a drinks can bank, on site for recycling would promote good waste management within a company and improve the company image.

6.17 Off-Site Waste

Off-site waste, for the purpose of this study, is defined as a waste which does not originate on site, but is brought onto site and disposed of in waste skips on site. This waste volume mainly included domestic/kitchen waste, electrical equipment, furniture, etc. which was disposed of in waste skips on site by site workers and by others living close to, or in the case of case study 1, living on part of the completed site.

Off-site waste volumes varied widely on the four case study construction projects. Case study 1, had the largest volume of off-site waste, $92m^3$, at a disposal cost of €2507 to the building contractor. The disposal of this waste on site was an abuse of site facilities and in the long run it could be extremely expensive for a contractor if not eliminated. Table 6.18 shows the volumes of off-site waste estimated on the case study construction sites.

Table 6.18 Off-Site Waste Generated

Case Study No.	Total Quantity of Off-Site Waste Estimated (m^3)	Percentage of Off-Site Waste Making up Total Waste Volume Estimated (%)	Cost of Off-Site Waste Disposal (€)
Case Study 1	92	2.9	2507
Case Study 2	18	1.0	490
Case Study 3	3	0.2	82
Case Study 4	5	1.3	132

6.17.1 Eliminating Off-Site Waste

In most cases off-site wastes were found in waste skips located in quieter areas on site, where fewer people were working and where skips were located near boundary walls or near public roads.

This waste stream can be eliminated if skips are located where they can be easily observed by site staff. Waste skips should not be located in close proximity to any parking areas or public roads. Ideally skips should be located within a waste compound where only authorised personnel are permitted to enter.

On case study 2, the contractor was more aware of the problem with off-site waste from the waste audit results on case study 1. As a direct result of this all waste skips were located in one area on site. The volume of off-site waste was significantly reduced on case study 2. This was a direct result of forming a waste skip compound, and from making the contractor more aware of this problem.

6.18 Construction and Demolition Waste Causing Contamination

There are a number of waste materials that were generated on the case study sites and disposed of in waste skips that could have potentially caused contamination. Hazardous wastes such as, silicone tubes, paint cans, aerosol spray cans, etc. were found in some waste skips on site. These wastes can potentially cause contamination of all C & D wastes contained in a skip.

These wastes were found in very small quantities during the waste audit period. As contractors are responsible for the correct disposal of all their C & D wastes following their removal from site they are obliged to ensure that all hazardous wastes are segregated into a separate waste skip and disposed of appropriately.

6.18.1 Disposing of Hazardous Construction and Demolition Waste Materials

Hazardous wastes must be disposed of in a proper manner. Clearly labelled skips for segregated hazardous wastes, such as those wastes produced on the case study construction projects, are essential to prevent cross contamination. Hazardous wastes should be stored in a separate container/skip and disposed of appropriately by a waste management contractor. The building contractors were made aware of this and it was recommended that they take appropriate measures.

6.19 The Expansion of Waste Segregation In Future

The scope and potential for expanding the types of wastes which are amenable to being segregated is dependent on a number of factors. The contractor must achieve benefits for segregation, either financial or otherwise. This is largely dependent on the facilities available for recycling, the arrangement of take back agreements (for packaging wastes) etc. Until these facilities and arrangements are made it is currently difficult to increase the number of waste materials that it is worthwhile segregating.

6.20 The Total Cost of Construction and Demolition Waste Disposal on the Case Study Construction Projects

On case studies 1, 2, and 3, the contractors disposed of their waste skips on a fee per skip basis, whereas on case study 4, the contractor was charged a fee per tonne of waste contained in each waste skip removed from site. The cost of disposal of C & D waste on site was calculated using the number of waste skips removed from site and applying the disposal cost for each skip. Table 6.19 shows the calculated waste disposal costs for each case study.

Table 6.19 Waste Disposal Costs

Case Study No.	Number of Waste Skips Removed From Site	Total Cost of Waste Disposal (For The Waste Audit Period.) (€)
Case Study 1	394	78083
Case Study 2	211	41290
Case Study 3	137	31250
Case Study 4	46	11273

Apart from case study 4, the waste disposal costs calculated covers the waste audit period only. The total waste disposal cost can only be calculated at the end of a construction project. Case studies 1, 2, and 3, were still ongoing at the time of completing this research project. The total cost of waste disposal for case study 4, represents the total cost of waste disposal for the construction project, as construction, and the waste audit on this case study was completed and all results are included.

While it is easy to calculate the costs of disposing of C & D wastes generated on site it is more difficult to calculate the total cost of waste management, including all the associated costs for handling of site wastes and the costs of plant for moving waste on site. On case studies 1, 3, and 4, wastes were disposed of in waste skips by many operatives working on site. No records of the time spent handling wastes, and the plant involved in this were maintained on site.

As the waste handling on these three sites was intermittent and irregular it would be impossible to arrive at an accurate estimate for the cost of waste handling and plant used under these conditions. To estimate an accurate cost for the handling of waste on site a more structured approach to waste handling, and maintaining waste management records is necessary.

On case study 2, following the recommendations made by the auditor on case study 1, the building contractor appointed a waste management operative on site. His duties included the handling, gathering and disposal of all site wastes. A 6 tonne dumper was used for transporting waste from site to the waste compound for disposal. This more structured approach to waste management on site allowed the calculation a cost estimate for the handling of site wastes. Table 6.20 shows the calculated costs for waste handling and plant used.

Table 6.20 Case Study 2: Construction and Demolition Waste Management Labour and Plant Costs Incurred

Case Study 3: C & D Waste Management Labour and Plant Costs		
Plant	1 no. 6 tonne dumper, operational for 9hrs per day @ € 4.75/hour. Audit duration 307 working days. 307 x 9 x €4.75 =	€13124
Labour	1 no. Waste Management Operative, working for 9hrs per day, for 307 working days, @ €15.48/hour. 1 x 9 x 307 x €15.48 =	€42771
	Total labour and plant cost for this construction project =	**€55895**

Further investigation is also required to calculate the purchase costs of the materials wasted, to arrive at a total cost for the financial impacts of C & D wastes on site. The total costs of waste management on site can only be calculated at the end of a construction project with proper waste records having been maintained throughout the construction process. It will be possible for the building contractor to calculate the total cost of C & D waste management on case study 2, at the end of construction.

6.21 Construction and Demolition Waste Management on the Case Study Construction Projects

One of the core findings of this research was the lack of use of a formalised C & D waste management strategy, or waste management plan, within any of the construction companies, or construction projects being used as case studies. At the commencement of the C & D waste audits the use and implementation of a formalised C & D waste management strategy was nonexistent on the case study construction projects examined. This was due to a number of reasons.

1. There was a lack of prioritisation of C & D waste management on site and within the companies as other company work and the day to day operations on site were considered more important.
2. There was no responsibility being taken for the efficient management of C & D wastes at senior management level within the companies examined.
3. The companies had no hard data on the economic and environmental effects that their C & D waste generation had on their companies. The volumes of wastes generated and the associated costs were unknown to the contractors.
4. There was a lack of concern on some of the sites examined of the negative effects that C & D waste can have on the economics of a construction project and other negative effects such as hazards to health and safety.

The main motivation for the building contractors involved in this study to manage their C & D wastes was:

1. To comply with the current C & D waste management legislation. This obliged them to comply with a number of mandatory requirements to manage their C & D wastes on site. (For the most part the contractors complied with the current C & D waste management legislation).
2. The second motivation for the contractors to manage their C & D wastes on site was to dispose of their wastes by the most economically beneficial options available, while complying with the current C & D waste management legislation.

6.22 The Construction and Demolition Waste Management Strategy on Case Study 1

Two of the case studies examined were residential developments with both projects being carried out by the same contractor. The first residential construction project examined as part of this research did not operate a formal waste management strategy on site for the majority of the project.

This allowed baseline C & D waste data to be compiled for this development. In other words the C & D waste data was collected on this site without the contractor implementing any significant changes to their waste management operations on site. The waste data collected will allow the effectiveness of C & D waste management initiatives implemented on other similar sites in future to be compared to case study 1, highlighting any positive or negative effects.

6.22.1 The Day To Day Management of Site Wastes on Case Study 1

On case study 1, the management of C & D wastes remained largely unchanged from the commencement of the waste audit to its completion. As the C & D waste audit on case study 1, was initiated following the start of construction the contractor found it difficult to implement the changes recommended by the waste auditor. Based on the recommendations made by the auditor the contractor attempted to implement a more formal C & D waste management strategy on this site.

The few changes made, resulted in placing the waste skips in one location on site. This did not include forming a fenced waste compound, allowing all personnel on site to have access to the waste skips, which made policing the disposal of site wastes more difficult. While placing the waste skips in one area made more efficient use of the skips the waste largely remained mixed, with only timber wastes being segregated in large quantities.

6.22.2 The Appointment of a Waste Manager on Site

The contractor also appointed a waste manager on site, but this had little effect on the overall efficiency and management of site wastes. As the waste manager appointed was employed as a company health and safety officer and office clerk on site, they had other essential duties to perform on a daily basis. The management of C & D waste was deemed less important than their other duties resulting in little or no beneficial alterations to the management of site wastes.

Although the lack of change in the management of C & D wastes on case study 1, may seem like a failure by the building contractor, on case study 2, there was a significant change in the attitude adopted by the contractor to their C & D waste management. A more formal C & D waste management strategy was implemented with more success. The C & D waste volumes audited on case study 1, will act as a benchmark for the contractor against which the implementation of future waste management initiatives on other similar sites can be measured against. This will allow the contractor to analyse the effectiveness of any alterations to their C & D waste management strategy.

6.23 The Construction and Demolition Waste Management Strategy on Case Study 2

As there was a more formal C & D waste management strategy in operation on case study 2, a full analysis of the effects of a more efficient waste management strategy could be examined (this construction project is still ongoing) by the contractor at the end of construction, and compared with case study 1. This would allow the contractor to determine the benefits achieved and would highlight any areas where improvements may be necessary.

It has already been seen on case study 2, from the waste data collected and observations made, that the new waste management strategy has had beneficial effects on the efficiency of waste management on site, and on reducing waste disposal costs. (e.g. Waste polystyrene insulation was being returned free of charge to the supplier for recycling, waste timber was being segregated which results in a reduced rate for disposal.)

6.23.1 The Company, and Site, Construction and Demolition Waste Management Strategy on Case Study 2

At the commencement of construction on case study 2, the contractor had appointed a company director as the company waste manager who was made responsible for C & D waste management on all their construction sites. A site waste manager was appointed on each site to manage C & D wastes on a day to day basis. On case study 2, a waste management operative was also appointed for the collection and disposal of all site wastes. One of the most noticeable effects this had on case study 2, was the improvements noticed with the housekeeping on site. The improvements on case study 2, were significant. Unlike case study 1, the site remained tidy and C & D wastes were better managed with less wastes scattered around site.

Waste skips were located at the rear of the site in a designated area for the majority of the time. The waste management operative disposed of all site wastes by dumper, with small quantities of wastes being disposed of by 4cy waste skip and telescopic forklift. The positioning of waste skips on site made the disposal of site wastes more efficient and the segregation of nominated wastes easier as all C & D wastes were disposed of in one place on site, by one person. Although the segregation of wastes was easier small quantities of wastes nominated for segregation were still found in mixed waste skips.

The appointment of one person, the waste management operative, on site to collect and dispose of site wastes had a significant effect on the efficiency of the sites operation. There was no piecemeal, intermittent waste collection on site. Wastes were being collected on a constant basis which kept the site clean and tidy improving access to, and movement of plant and labour around the site. Overall the waste management strategy increased segregation, reduced disposal costs and increased waste management efficiency.

6.23.2 The Problems Encountered in Implementing the Construction and Demolition Waste Management Strategy

There were a number of teething problems on site initially. One of the main problems at the start of construction was the lack of sufficient numbers of waste skips on site. This led to volumes of wastes building up near full waste skips on site, and resulted in double handling of these wastes which led to increased labour costs. Recommendations were made to increase the number of waste skips on site to avoid this problem. The contractor complied with most recommendations made by the auditor with various degrees of urgency.

Photo 6.5 Build Up of Site Wastes

The contractor also learned an important lesson in the segregation of nominated wastes which could be disposed of at a reduced disposal cost. On one occasion on this site a 35cy waste skip being used for segregated waste timbers, contained some other site wastes such as plastics and insulation. On that occasion the contractor was charged the mixed waste fee for the disposal of the waste skip which resulted in the contractor paying a fee of €2000, as opposed to a fee of €300 for segregated timber waste. Needless to say this did not happen again.

Based on the appointment of a waste management operative the estimation of the total labour and plant costs for the management of C & D wastes on case study 2, will be easier for the contractor to calculate at the end of the project. The total costs of labour and plant used for waste management on site should be calculated at the end of the project to compile an accurate cost estimate for the total management of C & D wastes on site. The contractor on case study 2, currently has no hard data on the total costs of waste management on any of their construction sites. The compilation of labour and plant cost information will prove valuable when estimating costs for future projects and for examining the benefits of new waste management strategies implemented.

6.23.3 The Development of the Construction and Demolition Waste Management Strategy within the Company

In implementing a more formal C & D waste management strategy on case study 2, and across all their sites, the contractor adopted many of the recommendations made from this study. This included adopting altered versions of the waste record documents recommended as part of this research. This has resulted in a more formalised waste recording and management system being established within the company. The adoption and development of the C & D waste management strategy within the company will be ongoing and changing as new waste disposal options and strategies are developed.

This contractor has embraced the concept of sustainable C & D waste management and will strive to manage their wastes as efficiently as possible in the future, implementing new waste management initiatives as the development of their waste management strategy moves forward.

The continued monitoring of the development of this company's progress in implementing their waste management strategy would highlight the benefits and pitfalls of managing C & D wastes in our current climate. This could also potentially lead to the formation of a detailed best practice C & D waste management guide for other building contractors when implementing a C & D waste management strategy.

6.24 The Construction and Demolition Waste Management Strategy on Case Study 3

As on case study 1, there was no formal C & D waste management strategy in operation on case study 3. Although the contractor on this case study was conscious of the negative impacts of C & D waste on construction sites, their strategy was based on disposing of all site wastes at the minimum cost, while complying with all current waste management legislation.

6.24.1 Waste Disposal on Site

Timber wastes generated on site were being segregated at the commencement of the waste audit. This was by default rather than design and was a result of their being only one subcontractor on site whose waste largely consisted of formwork timbers. At that stage in the project there was only one subcontractor on site who supplied their own 12cy waste skips. Despite the segregation of their timber wastes they were charged the full disposal rate of €250 per skip by their waste management contractor when removing waste skips from site.

As the project progressed the auditor recommended the use of a 35cy waste skip from an alternative waste management contractor operating in the area. This waste skip, filled with segregated waste timber, could be disposed of for a fee of €300 making a significant financial saving for the subcontractor as it contained 2.9 times more waste than a 12cy skip for an extra cost of €50. In this situation where this subcontractor (the only subcontractor on site at the time) supplied their own waste skips it proved a successful strategy, but a similar strategy on a large site with many subcontractors could prove more difficult to manage.

Metal wastes were also segregated into a waste skip, supplied by Galway Metal, and removed from site free of charge. The contractor was also informed of the take back scheme which could be arranged with their insulation suppliers. While waste insulation volumes were small on this site the contractor intends to establish a take back scheme for insulation wastes on future projects when significant volumes of waste insulation are expected to be generated. It was also recommended that canteen wastes, which were disposed of in the mixed waste skips, be segregated into smaller covered skips to avoid vermin and foul odours on site.

6.24.2 Implementing a Formalised Construction and Demolition Waste Management Strategy

Overall this site remained tidy and well maintained with the majority of the skips being removed from site containing mixed C & D wastes. As the site was congested and had little storage space for waste skips the good housekeeping on site was as much a result of this as it was of disposing of site wastes quickly to maximise the available space on site.

As this contractor carries out many different types of construction projects a more formalised waste management strategy, with increased segregation and the appointment of waste management staff within the company, may prove more useful on larger construction projects with more scope for waste segregation and storage. A more formalised C & D management strategy was recommended and may be adopted by the contractor on future projects.

6.25 The Construction and Demolition Waste Management Strategy on Case Study 4

Again, on case study 4, there was no formal C & D waste management strategy employed on site. Waste disposal on this site was driven by the disposal services provided by the waste management contractor, rather than a strategy proposed and dictated by the building contractor. The disposal of C & D wastes in this manner could be described as a default C & D waste management strategy. That is the management of C & D wastes which is not based on any specified disposal requirements by the building contractor, but results in waste disposal based on the services offered by the waste management contractor.

6.25.1 Waste Disposal on Site

Wastes were disposed of by waste skip, with timber and metal wastes being segregated for reduced disposal costs. The majority of the waste skips contained mixed wastes, and all skips were disposed of at a rate of €158 per tonne of waste. With the average skip weight being 1.53 tonnes, the average cost of a skips disposal was €245 which compares favourably with the fee per skip of €250 being paid by the contractors on the other three case study construction projects.

Although this compared favourably in terms of disposal costs there was a reduced pressure on the contractor to maximise the volumetric capacity of each waste skip as the contractor only paid for the weight of the waste that each skip contained. The lack of pressure on the contractor to maximise the volume of waste disposed of in each skip could be a potential problem leading to other forms of waste such as unnecessary or increased repeat skip collections and disposals for partially full waste skips. This would result in inefficiencies off site.

When auditing each waste skip on site every effort was made to accurately estimate the total volume of waste contained, but as the auditor was not present at the time of removal of each skip further research is necessary to examine the total volumes of C & D waste contained in each skip at the time of removal from site.

6.25.2 Problems with Construction and Demolition Waste Management on this Project

Although waste timber was segregated on this site the waste management contractor continued to charge the building contractor the mixed waste rate per tonne for these skips. (The waste management contractor supplying waste skips to this site offers a reduced rate for segregated waste timber.) The reason for the building contractor being charged the full mixed waste rate on case study 4, is unknown as it was noted on site that the segregation of timber and metals, for the most part, was successful with no other wastes being disposed of in these segregated waste skips.

As this construction project was brief in duration when compared to the other three case studies it was only at the completion of construction that a reasonable picture of the waste management practices and waste volumes generated was established. This did not allow the auditor to make appropriate recommendations to the contractor, or for the contractor to implement any changes to their waste management strategy on site during construction.

The main recommendations made to the contractor were similar to those made on the other three case studies. They included appointing waste management staff, implementing a formal waste management strategy, organisation of take back schemes for insulation and packaging waste and using alternative waste management contractors to obtain the best deal for the disposal of segregated timbers and other wastes.

6.26 Waste Segregation on the Case Study Construction Projects

The segregation of C & D wastes generated on the case study construction projects was confined to specific construction wastes, which the contractors were motivated to segregate by reduced disposal rates. The wastes segregated and the reasons for segregation are detailed in Table 6.21.

Table 6.21 Waste Segregation On Site

Case Study No.	Wastes Segregated on Site	Reasons for Segregation and Resulting Benefits
Case Study 1	Soils	Soils segregated for reuse on site and off-site.
	Timber	Timber segregated into 35cy waste skip due to reduced disposal costs. 35cy skip disposed of at €300 per skip as opposed to 12cy skip disposed of at €250.
	Metals	Metals segregated for removal free of charge by the waste management contractor supplying waste skips to site.
Case Study 2	Soils	Soils segregated for reuse on site and off-site.
	Timber	Timber segregated into 35cy waste skip due to reduced disposal costs. 35cy skip disposed of at €300 per skip as opposed to 12cy skip disposed of at €250.
	Metals	Metals segregated for removal free of charge by the waste management contractor supplying waste skips to site.
	Insulation	Insulation segregated on recommendation based on the results of this study. Polystyrene insulation was segregated in the waste compound and removed from site for recycling by the supplier.
Case Study 3	Soils	Soils segregated for reuse off-site.
	Timber	Timber segregated into 35cy waste skip due to reduced disposal costs. 35cy skip disposed of at €300 per skip as opposed to 12cy skip disposed of at €250. (This procedure for disposal was recommended as a result of this research.)
	Metals	Metals segregated for removal free of charge by the local scrap metal merchant.
Case Study 4	Soils	Soils segregated for reuse off-site.
	Timber	Timber segregated into 12cy waste skip for disposal.
	Metals	Metals segregated for removal free of charge by the waste management contractor supplying waste skips to site.

Table 6.22 details the waste volumes, and the percentage of the total waste volume, segregated for recycling on each case study.

Table 6.22 Waste Segregation On Site

Case Study No.	Volume of Waste Disposed of by Waste Skip (m^3)	Percentage of Total Waste Volume Disposed of by Waste Skip	Volume of Waste Segregated for Recycling (m^3)	Percentage of Total Waste Volume Segregated for Recycling
Case Study 1	2529 m^3	80.6 %	611 m^3	19.4 %
Case Study 2	1087m^3	63 %	640m^3	37 %
Case Study 3	865m^3	63%	510m^3	37%
Case Study 4	289m3	72.2 %	111m^3	27.8 %

The most noticeable difference in Table 6.22 is between case study 1, and 2, (both residential) where the segregation of waste increased from 19.4% on case study 1, to 37% on case study 2, where a waste management strategy was implemented. Case study 3, also had a high percentage of waste segregation. This was mainly due to the large volumes of timber and metal wastes generated, both of which were segregated for financial benefit.

6.26.1 Savings Achieved Through Waste Segregation

Table 6.23 shows the savings achieved through reduced waste disposal rates for waste skips containing nominated segregated wastes.

Table 6.23 Financial Savings Achieved Through Segregation

Case Study No.	Cost Savings Achieved Through Segregation of Nominated C & D Wastes (€)
Case Study 1	€7234
Case Study 2	€11255
Case Study 3	€5257
Case Study 4	€250

Table 6.23 establishes that case study 2, achieved a higher financial saving, than case study 1, by having a waste management strategy in place which increased segregation. Although segregation was also high on case study 4, the contractor was charged the mixed waste rate per tonne for all waste skips removed from site, so the full potential savings which could have been achieved were not realised. The reason for the building contractor being charged the full mixed waste rate on case study 4, is unknown as it was

noted on site that the segregation of timber and metals, for the most part, was successful with no other wastes being disposed of in these segregated waste skips.

There was no significant extra costs in segregating nominated wastes, as these wastes were generated in large quantities and concentrated in certain areas on each site. This resulted in these wastes being naturally segregated by means of the way in which they were generated e.g. timber waste off-cuts were concentrated in certain areas on site where roof timbers were being cut, or where formwork was being constructed, etc. This resulted in nominated wastes, for the majority of the time, not being mixed with other wastes, thus there was no extra labour required to separate, or segregate, these waste. These wastes were collected and then disposed of in segregated waste skips according to each waste material.

Further financial benefits through increased waste segregation can be realised in the future. The segregation of packaging wastes for return to suppliers, the arrangement of take back agreements, and the development of new recycling facilities for gypsum plasterboard and other waste materials will allow more financial savings to be achieved in the future.

6.26.2 The Problems with Waste Segregation on Site

The segregation of site wastes was confined to soils, timber and metals on case studies 1, 3, and 4, and included the segregation of polystyrene insulation on case study 2. (The segregation of polystyrene insulation was a recommendation made as a result of the findings from this study.) Other wastes such as plastic, cardboard, etc. were not segregated as there was no financial benefits in segregating these wastes, although attempts were made at segregating other wastes on case study 2, as a result of implementing a more formal C & D waste management strategy on site.

The wastes nominated for segregation were segregated due to the financial benefits which could be achieved from decreased disposal costs. Although timber, metal, and insulation wastes were nominated for segregation into specific waste skips (or storage areas for insulation) these wastes continued to find their way into other non-segregated waste skips on all four case studies.

The problem with segregation appears to have resulted mainly from the disposal of wastes by many personnel on site who were not properly informed of the correct disposal techniques for wastes nominated for segregation, although this was not the only way that this problem occurred.

6.26.3 Alternative Approach to Waste Segregation on Site

Because of the research results on case study 1, the contractor who was also carrying out the work on case study 2, implemented a more formal C & D waste management strategy on site. This strategy included the nomination of a waste management operative who was made responsible for the segregation and disposal of all site wastes. As a result of nominating a waste management operative on case study 2, the segregation of nominated site wastes improved, but there were still small quantities of wastes nominated for segregation being found in mixed waste skips.

As a result of the observations made on case study 2, it was found that when wastes were being moved by dumper to be disposed of in waste skips, small quantities of wastes nominated for segregation (timber, insulation, metal wastes) were mixed in with small quantities of other wastes and then dumped into mixed waste skips. These smaller quantities of wastes nominated for segregation were not removed and segregated as the time taken and cost to do this would outweigh the benefits achieved. It appears that the total segregation of any construction waste on site is extremely difficult, and in some cases due to the time and costs involved in total segregation of nominated wastes it is not realistically achievable without a different approach to waste management from the strategies employed on the four case studies in this research.

The segregation of site wastes by subcontractors, where all subcontractors are made responsible for the segregation of their own wastes, while the main contractor is responsible for the disposal of site wastes, is an alternative method which may achieve higher levels of segregation. This method of waste management has yet to be tested.

The segregation of C & D waste does offer decreased disposal costs for contractors. It appears that some quantities of mixed C & D wastes including wastes nominated for segregation will be generated on most construction sites. Only proper supervision and control can maximise the segregation of nominated site wastes. Contractors should investigate the potential for decreased disposal costs for the segregation of all site wastes.

6.27 Conclusions

The conclusions for the examination of the collected C & D waste audit data are as follows:

- It has been established that in order to develop valid, accurate C & D waste rates for various construction project types, C & D waste audits must be performed for the full duration of a construction project. The use of, 'snapshot', C & D waste data for waste estimation, although more desirable than utilising US waste rates, can lead to overestimation, or underestimation, depending on when the waste data was collected during the construction process.

- The necessity for extensive C & D waste characterisation studies to establish accurate C & D waste statistics for the Irish construction industry has been highlighted by the EPA. Waste rates currently used by the EPA were derived from the United States and may or may not be accurate for the Irish construction industry. Establishing valid waste rates for various types of construction projects is of primary importance for future C & D waste estimation by the EPA. The waste rates calculated from this study provided a valid waste rate for case study 4, but as construction the other three case studies was not completed during the waste audit the waste rates calculated are, 'snapshot', C & D waste rates.

- The exploitation of the natural resources of a site (crushing rock on site) can potentially provide an outlet for soil wastes generated on site, significantly reducing disposal costs.

- It appears that the total segregation of any C & D waste stream on site is a difficult goal to achieve. Mixed waste made up one of the largest C & D waste volumes on all four case study construction projects, and included quantities of wastes which were nominated for segregation. The segregation of wastes such as timber, polystyrene, and metal is financially worthwhile and has proved to be a successful C & D waste management initiative. Hazardous wastes must be disposed of with more care on site.

- It has been established that C & D packaging waste is a significant contributor to the overall volume of waste produced on the case study construction projects. There is no enforcement of the packaging waste regulations on the case study construction projects, and this appears to be the industry standard. Contractors must exercise their rights under the packaging waste regulations to decrease their waste disposal costs.

- There is a lack of data on the benefits of best practice C & D waste management. There was no formalised C & D waste management strategies on the case study construction projects examined. The introduction of some successful C & D waste management initiatives on case study 2, highlights some of the benefits that efficient C & D waste management can achieve. This study has established the necessity for the continued examination of the benefits arising from the implementation of a C & D waste management strategy by a construction company/project to promote the benefits of good waste management practices.

Chapter 7
Conclusions and Recommendations

7.1 Introduction

The conclusions and recommendations for this study will be established in the following manner. Each objective for this research will be addressed individually, and any limitations to the research will also be included.

The main aim of this research project was to examine C & D wastes being generated on selected case study construction projects in the Galway Region. This included a detailed and extensive assessment of relevant areas associated with the management of C & D wastes. The primary aim of the research was to establish the following:

1. The composition and volumes of C & D wastes generated on typical, case study construction projects in the Galway Region, and the resulting waste rates.

2. The reasons for waste generation on site, and the identification of potential C & D waste management strategies and initiatives to prevent, reduce, reuse or recycle wastes on site.

7.2 The Project Objectives

To achieve the aims established a number of objectives had to be met:

1. Identify the various definitions, legislation and policy actions specifically related to the management of C & D wastes.

2. Evaluate existing best practice guidelines for the successful management of C & D wastes on construction sites.

3. Examine existing C & D waste audit methodologies, and select the most appropriate methodology, to perform the waste audit on the selected case study construction sites.

4. Examine the case study construction project details and the C & D waste management practices and strategies used on site.

5. Analyse and quantify the various C & D waste streams and volumes generated on site using the selected C & D waste audit methodology, and calculate the waste rate for each case study.

6. Recommend necessary improvements, and alternative C & D waste management strategies to ensure effective and efficient C & D waste management on site.

7.3 Conclusions

Objective No. 1

- Identify the various definitions, legislation and policy actions specifically related to C & D waste.

This was achieved by examining national C & D waste management legislation. In the examination of Irish C & D waste management legislation specific emphasis was placed on analysing the obligations placed on building contractors and those responsible for the day to day management of C & D wastes.

Conclusions

- Significant changes have occurred in waste management legislation in Ireland since the formation of the EPA and the introduction, and implementation, of the 1996 Waste Management Act. The 1996 Waste Management Act is the foundation for the legal framework in Ireland and since 1996, the storage, transportation, recovery and disposal of C & D waste has been regulated.

- The publication of policy statements by the Department of the Environment, Heritage and Local Government has acted as a catalyst to improve and direct C & D waste management legislation in Ireland by setting ambitious national recycling targets for C & D waste.

- The continuation of new developments and improvements in C & D waste management legislation, and resource use efficiency, is essential to ensure a sustainable environment for the future.

Objective No. 2

- Evaluate existing best practice guidelines for the management of C & D wastes on construction sites.

This aim was achieved by performing a literature review, examining relevant C & D waste management guidelines, and assessing the available outlets and disposal options for C & D waste in the Galway area.

Conclusions

- Establishing a knowledge of recommended best practice C & D waste management allows a building contractor to determine the efficiency of their existing practices, and highlights the areas which require improvement. The efficiency of a building contractors waste management strategy is essential to prevent, minimise, reduce, reuse and recycle C & D wastes generated.

- Although there are fundamentals systems which are common to all waste management strategies, there is no definitive C & D waste management strategy suitable for all construction companies, or sites. A C & D waste management strategy is dependent on the waste disposal facilities and treatment options available in the locality of a site. A contractor developing a C & D waste management strategy should do so using the waste management hierarchy as a guide for dealing with site wastes.

- Waste management within a construction company must be initiated, and driven, from top management level with the appointment of an appropriate member of staff as the company waste manager. The success of any C & D waste management strategy depends on the acceptance of new initiatives by all company employees who must be trained and inducted accordingly.

- The initiation of a formalised C & D waste management strategy and the proper management of site wastes through training and research can make the management of C & D wastes more sustainable and decrease costs. As new waste treatment facilities become available, and the adoption of minimising C & D wastes through design becomes more widespread, the quantities of site wastes generated should decrease.

Objective No. 3

- Examine existing C & D waste audit methodologies and select the most appropriate methodology to perform the C & D waste audits on the selected case study construction sites.

This objective was achieved by examining a number of existing C & D waste audit methodologies.

Conclusions

- Currently there are two methodologies used by the Environmental Protection Agency to calculate C & D waste volumes for the Irish construction industry. The first methodology used by the EPA for C & D waste estimation utilises waste factors from the United States (*USEPA, 1998*). The relevance of US waste rates to the Irish construction industry has never been tested, so they may or may not be accurate. A number of important construction industry associated activities are not included in the calculation of C & D waste quantities for the Irish construction industry. (e.g. DIY waste, waste reused on construction sites, waste buried on site, and wastes burned on site.)

- The second methodology used by the EPA for C & D waste estimation assumes that all wastes accepted at local authority sites are recovered, and includes the estimated deposit of 500,000 tonnes of soil at unauthorised sites in one local authority. These assumptions expose the necessity for more detailed reporting of C & D wastes disposed of by landfill.

- The estimation of 500,000 tonnes of waste soils disposed of at unauthorised sites highlights the need for more stringent enforcement against illegal waste disposal.

- The C & D waste classification system developed by Skoyles highlighted the complexities in examining C & D waste generation on construction sites.

- The selection of a C & D waste audit methodology to conduct a C & D waste audit is largely dependent on the comprehensiveness of the information required from the audit, and the resources available for performing the waste audit. Visual waste audits and desktop waste audits require the least resources when compared to physical waste audits, or the weighing of wastes, to collect C & D waste data.

- One of the core problems in performing a C & D waste audit is waste bulking which is a significant issue if individual waste streams are not being segregated and weighed. Waste conversion factors to convert C & D waste volumes to weights have been compiled for some construction industries in other countries. Conversion factors included in the Irish landfill levy regulations are very general and do not include conversion factors for all individual C & D waste streams. As visual waste audits are the least resource intensive waste audit methodologies they are the most likely to be used on site. As the visual waste audit methodology records C & D waste quantities by volume the development of a set of comprehensive and accurate C & D waste conversion factors specific to the Irish construction industry is a necessity for the future.

- Waste audits must be carefully planned prior to commencement, and management approval and cooperation is essential for a successful audit. The selection of a waste audit methodology is specific to the requirements, or objectives, set out for a waste audit. Many existing waste audit methodologies are not flexible, or comprehensive, enough for some waste assessments, so in some cases a method of waste data collection must be devised to meet the specific requirements of a C & D waste analysis.

Objective No. 4

- Examine the case study construction project details and the C & D waste management practices, and strategies, used on site.

Conclusions

- The examination of the C & D waste quantities, and management details, on each of the case studies identified a number of waste management activities that were common to all four case studies. No formal C & D waste management strategy, or waste management plan, was in operation on any case study site at the commencement of the C & D waste audit. This established that the use, and implementation, of formal C & D waste management strategies are in their infancy in the Galway area. Each waste material was disposed of, within the legislative framework, by the most economical option available, or the most financially beneficial disposal option that the building contractor was aware of.

Objective No. 5

- Analyse and quantify the various C & D waste streams and volumes generated on site using the selected C & D waste audit, and calculate the waste rate for each case study.

Conclusions

- It has been established that packaging waste is a significant contributor to the overall volume of C & D waste produced on the case study construction projects. There is no enforcement of the packaging waste regulations on the case study construction projects, and this appears to be the industry standard.

- It has also been established that in order to develop valid, accurate C & D waste rates for various construction project types, C & D waste audits must be performed for the full duration of a construction project. The use of, 'snapshot', C & D waste data for waste estimation, although more desirable than utilising US waste rates, can lead to overestimation, or underestimation, depending on when the waste data was collected during the construction project.

- The necessity for extensive C & D waste characterisation studies to establish accurate C & D waste statistics for the Irish construction industry has been highlighted by the EPA. Waste rates currently used by the EPA were derived from the United States and may or may not be accurate for the Irish construction industry. Establishing valid waste rates for various types of construction projects is of primary importance for future C & D waste estimation by the EPA. The waste rates calculated from this study provided a valid waste rate for case study 4, but as construction on the other three case studies was not completed during the waste audit, the waste rates calculated are, 'snapshot', C & D waste rates.

Objective No. 6

- Recommend necessary improvements and alternative C & D waste management strategies to ensure effective and efficient C & D waste management on site.

Conclusions

- The exploitation of the natural resources of a site (crushing rock on site) can potentially provide an outlet for soil wastes generated on site, significantly reducing disposal costs. Contractors must exercise their rights under the packaging waste regulations to decrease their waste disposal costs.

- It appears that the total segregation of any C & D waste stream on site is a difficult goal to achieve. Mixed waste was one of the largest C & D waste volumes on all four case study construction projects, and included quantities of wastes which were nominated for segregation. The segregation of wastes such as timber, polystyrene, and metal is financially worthwhile and has proved to be a successful C & D waste management initiative. Hazardous wastes must be disposed of with more care on site.

- The introduction of some successful C & D waste management initiatives on case study 2, highlighted some of the benefits that efficient C & D waste management can achieve. This study has established the necessity for the continued examination of the benefits arising from the implementation of a C & D waste management strategy by a construction company/project to promote the benefits of good waste management practices.

7.4 Limitations

This research project was conducted in a logical and comprehensive manner, within a number of limitations. The conclusions must be evaluated taking each of the limitations into consideration. The limitations to the research were as follows:

1. Each case study was visited once daily. This restricted the observation of waste skips as they were being removed from site, which lead to the development and use of an assumed waste quantity classified as Unknown Waste. This waste quantity formed part of the waste audit results and was assumed when the following occurred.

   Day 1: The waste skip arrives on site. The skip is audited and the volume of waste is estimated to be 25%.
   Day 2: The skip is audited and the volume of waste for this day is estimated to be 30%. The total volume of waste in the skip on day two is 55%.
   Day 3: The skip is audited and the volume of waste for this day is estimated to be 35%. The total volume of waste in the skip on day three is 90%.
   Day 4: The skip has been removed from site before the auditor arrives to carry out the daily waste audit.

- On the previous day (Day 3) the total waste volume in the skip was estimated to be 90%.
- It was assumed that all skips were 100% full when they were being removed from site if they had not been seen as they were being taken away.
- Unknown waste (in this situation) = 100% (Assumed volume of waste in the skip when being removed from site.) – 90% (The actual volume of waste estimated and recorded.) = 10% (Unknown Waste.)

Unknown waste occurs because the auditor could not be present on site as each skip was being removed.

2. The waste quantities audited only includes C & D wastes which were removed from site by waste skip, or by truck in the case of excavated soil wastes. Other C & D wastes which were generated on site and reused e.g. waste concrete blocks, which were reused as low grade fill for landscaping were not included.

3. The financial costs for the disposal of C & D wastes included for each of the case study construction projects is not a total definitive C & D waste management cost. All available information on the disposal costs for C & D wastes on site were utilised to calculate the total C & D waste disposal cost. The total waste management costs (including the costs of all resources used for waste management, labour, plant, transport costs, material costs, etc.) for each case study could not be calculated as records for labour and plant used on site were not maintained by the building contractors on any of the four case study sites.

4. The use of a Mixed Waste classification category was necessary when performing the C & D waste audits as all wastes generated on the case study sites were not being segregated, resulting in large quantities of mixed wastes being disposed of in waste skips. Over the course of the waste audits mixed wastes consisted of small, or un-auditable, quantities of all other wastes found on each of the case study sites. Clearly all quantities of wastes estimated for all individual waste streams would be higher than reported if it were possible to identify and quantify the consistency of the mixed waste category.

5. Three of the case study construction projects had been carrying out work on site for a number of weeks prior to the commencement of the C & D waste audits. The building contractors had disposed of a number of waste skips on these sites before the start of the waste audits, and some waste soils were also removed from site. (Waste excavated material quantities were acquired from site staff and included in the waste audit results.)

Records of the number and sizes of the waste skips removed from site, prior to the commencement of the waste audit, were acquired. A waste quantity for the material contained in these skips was calculated based on the size of the skips removed. This waste quantity was classified as mixed waste as no details of the individual types and quantities of these wastes were available.

6. The lack of national C & D waste data for various types of construction projects prevented the comparison of industry waste generation standards with the actual quantities of wastes generated on the case study construction projects.

   There was also a difficulty in converting the calculated C & D waste rates for comparison with the USEPA waste rates utilised by the EPA. This was due to inadequate waste conversion factors to convert waste volumes to weight.

7. In retrospect it would have been beneficial, following the completion of construction, to acquire site records for all core materials delivered to site e.g. concrete blocks, roof tiles, bricks, etc, and to compare the total quantities of materials delivered to site with the actual quantities of these materials used, to allow the calculation of a waste quantity for these materials. (The ideal time to carry out this waste calculation would be at the end of construction as all site records would be available and the inaccuracies caused by site variables during construction would be avoided.) This procedure was recommended to the building contractors involved to calculate waste volumes for waste materials reused, or disposed of on site.

7.5 Recommendations

1. The implementation of C & D waste management strategies by construction companies is essential for the successful management of C & D wastes. The contractors involved in this study should maintain a close working relationship with their waste management contractors and their materials suppliers to minimise their waste generation on site, and maximise the potential savings from efficient C & D waste management.

2. Contractors must enforce their rights under the packaging waste regulations and develop more take back schemes where, reusable, or recyclable, packaging wastes are generated, e.g. timber pallets.

3. The building contractors involved in this study should continue to perform C & D waste audits on their sites to develop baseline C & D waste data. This would allow the results of new waste management initiatives to be compared with previous C & D waste audit data, establishing the financial savings and reductions in waste generation achieved.

4. The maintenance of site records e.g. skips used on site, contents of waste skips, labour used for waste management, plant used for waste management, must be maintained to provide a full picture of the total costs for C & D waste management on a construction project. This will allow the comparison of data with projects carried out in the past, and will provide important information for estimating waste management costs for future projects.

5. Research is required to develop standard national C & D waste rates for the various types of construction projects undertaken in Ireland, e.g. residential, commercial, educational, etc. It has been established in this study that C & D waste generation on construction sites is erratic and varies widely from construction project type, to construction project type, and within similar project types. To develop valid wastage rates for utilisation by the EPA to estimate C &

D waste volumes on a national basis, C & D waste audits must be performed across a wide base of construction projects, and for the full duration of each project.

6. Research is also required to investigate the waste quantities generated on sites which are reused. Waste minimisation through good design, prefabrication, and efficient materials management also needs to be investigated as these activities can have significant effects on waste generation.

7.6 Summary

It has been identified that there is significant potential for building contractors to improve the management of C & D wastes generated on their sites, and that with efficient waste management and close working relationships with their waste management contractors and materials suppliers, significant financial savings can be achieved.

The examination of C & D waste generation on the construction projects selected for this study has concluded that there is a necessity for conducting extensive full project duration C & D waste audits on construction sites to develop valid C & D waste data for the accurate estimation of C & D wastes on a national basis.

The main contributions to knowledge in the area of C & D waste management that have been derived from this study are:

1. The establishment of a valid waste rate for one construction project type, and the establishment of, 'snapshot', waste rates for three other construction projects, will assist in the estimation of C & D waste generation for similar future construction projects. This data will prove useful not only for the building contractors involved, but also for the EPA.

2. The implementation of a C & D waste management strategy, the efficient management of that strategy, and the utilisation of the natural resources on a construction site can provide economic benefits for a building contractor.

3. The available C & D waste disposal options offering the most financial benefits, and the procedures to maintain the successful and efficient management of C & D wastes on construction sites in the Galway Region have been highlighted.

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Appendix A

The Development of the European Waste Catalogue and Hazardous Waste List, 2002.

The Development of the European Waste Catalogue and Hazardous Waste List, 2002.

1. Commission Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EC on Waste.

2. Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste.

3. Waste Catalogue and Hazardous Waste List, EPA, 1996.

4. Commission Decision 2000/532/EC of 3 May 2000 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive91/689/EEC on hazardous waste.

5. Commission Decision 2001/118/EC amending Decision 2000/532/EC as regards the list of wastes.

6. Commission Decision 2001/119/EC amending Decision 2000/532/EC replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste.

7. Council Decision 2001/573/EC amending Commission Decision 2000/532/EC as regards the list of wastes.

Appendix B

European Waste Catalogue and Hazardous Waste List, 2002.

Section 17 – Construction and Demolition Waste.

17 CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES).

1701	**concrete, bricks, tiles and ceramics**
17 01 01	concrete
17 01 02	bricks
17 01 03	tiles and ceramics
17 01 06*	mixtures of, or separate fractions of concrete, bricks, tiles and ceramics containing dangerous substances
17 01 07	mixture of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06
17 02	**wood, glass and plastic**
17 02 01	wood
17 02 02	glass
17 02 03	plastic
17 02 04*	glass, plastic and wood containing or contaminated with dangerous substances
17 03	**bituminous mixtures, coal tar and tarred products**
17 03 01*	bituminous mixtures containing coal tar
17 03 02	bituminous mixtures containing other than those mentioned in 17 03 01
17 03 03*	coal tar and tarred products
17 04	**metals (including their alloys)**
17 04 01	copper, bronze, brass
17 04 02	aluminium
17 04 03	lead
17 04 04	zinc
17 04 05	iron and steel
17 04 06	tin
17 04 07	mixed metals
17 04 09*	metal waste contaminated with dangerous substances
17 04 10*	cables containing oil, coal tar and other dangerous substances
17 04 11	cables other than those mentioned in 17 04 10
17 05	**soil (including excavated soil from contaminated sites), stones and dredging spoil**
17 05 03*	soil and stones containing dangerous substances
17 05 04	soil and stones other than those mentioned in 17 05 03
17 05 05*	dredging spoil containing dangerous substances
17 05 06	dredging spoil other than those mentioned 17 05 05
17 05 07*	track ballast containing dangerous substances
17 05 08	track ballast other than those mentioned in 17 05 07
17 06	**insulation materials and asbestos-containing construction materials**
17 06 01*	insulation materials containing asbestos
17 06 03*	other insulation materials consisting of or containing dangerous substances
17 06 04	insulation materials other than those mentioned in 17 06 01 and 17 06 03
17 06 05*	construction materials containing asbestos
17 08	**gypsum-based construction material**
17 08 01*	gypsum-based construction materials contaminated with dangerous substances
17 08 02	gypsum-based construction materials other than those mentioned in 17 08 01
17 09	**other construction and demolition waste**
17 09 01*	construction and demolition wastes containing mercury
17 09 02*	construction and demolition wastes containing pcb (for example pcb-containing sealants, pcb-containing sealed glazing units, pcb-containing capacitors)
17 09 03*	other construction and demolition wastes (including mixed wastes) containing dangerous substances
17 09 04	mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03

Appendix C

Properties of Wastes Which Render them Hazardous.

Extract from Council Directive 91/689/EC on hazardous waste

Annex III

PROPERTIES OF WASTES WHICH RENDER THEM HAZARDOUS

H1 'Explosive': substances and preparations which may explode under the effect of flame or which are more sensitive to shocks or friction than dinitrobenzene.

H2 'Oxidising': substances and preparations which exhibit highly exothermic reactions when in contact with other substances, particularly flammable substances.

H3-A 'Highly Flammable'

- liquid substances and preparations having a flash point below 21 C (including extremely flammable liquids)' or
- substances and preparations which may become hot and finally catch fire in contact with air at ambient temperature without any application of energy, or
- solid substances and preparations which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition, or
- gaseous substances and preparations which are flammable in air at normal pressure, or
- substances and preparations which, in contact with water or damp air, evolve highly flammable gasses in dangerous quantities.

H3 B 'Flammable': liquid substances and preparations having a flash point equal to or greater than 21 C and less than or equal to 55 C.

H4 'Irritant': non-corrosive substances and preparations which, through immediate, prolonged or repeated contact with the skin or mucous membrane, can cause inflammation.

H5 'Harmful': substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may involve limited health risks.

H6 'Toxic': substances and preparations (including very toxic substances and preparations) which, if they are inhaled or ingested or if they penetrate the skin, may involve serious, acute or chronic health risks and even death.

H7 'Carcinogenic': substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence.

H8 'Corrosive': substances and preparations which may destroy living tissue on contacts.

H9 'Infectious': substances containing viable micro-organisms or their toxins which are known or reliably believed to cause disease in man or other living organisms.

H10: 'Teratogenic': substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce non-hereditary congenital malformations or increase their incidence.

H11 'Mutagenic': substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce hereditary defects or increase their incidence.

H12 Substances and preparations which release toxic or very toxic gasses in contact with water, air or an acid.

H13 Substances and preparations capable by any means, after disposal, of yielding another substance, e.g. a leachate, which possesses any of the characteristics listed above.

H14 'Ecotoxic': substances and preparations which present or may present immediate or delayed risks for one or more sectors of the environment.

Appendix D

Sub-Categories of Direct Wastes (Skovles).

SUB-CATEGORIES OF DIRECT WASTE

Delivery waste.
All losses in transit to the site (and from the site in the case of transfers from one contractors site to another), unloading and placing into the initial storage. (It does not cover items for which credits are given).

Site storage and internal site transit waste.
From bad stacking and initial storage, including movement and unloading around the site, to stack at the work place or placing into position.

Conversion waste.
Losses due to cutting uneconomical shapes, e.g. timber, sheeted goods, etc.

Fixing waste.
Materials dropped, spoiled or discarded during the fixing operation.

Cutting waste.
Losses caused by cutting material to size, bond and irregular shapes.

Application and residue waste.
Materials in containers or cans such as mortar for brickwork, plaster and paint spilled or dropped. Similarly, material left in containers or cans which are not resealed. Mixed material like mortar and plaster to harden at the end of a working day.

Waste due to the uneconomic use of plant.
This covers plant left running when not in use, or not employed to its optimum use.

Management Waste.
Losses arising from incorrect decision or indecision and not related to anything other than poor organisation or lack of supervision.

Waste caused by other trades.
Losses arising from events like 'borrowing' by trades (for purposed other than the work, and not returning the plant or material), or damage by succeeding trades.

Criminal waste.
This covers pilfering, theft from sites and vandalism.

Waste due to wrong use.
When the wrong type or quality of materials are used.

Waste stemming from materials wrongly specified.
Waste due to errors, particularly in the bills of quantities and specification.

Learning waste.
Usually by apprentices, unskilled 'tradesmen', and tradesmen on new operations.

Appendix E

Skyoles Waste Audit Record Form.

DIRECT WASTE CALCULATION RECORD

SITE:______________________________. **DATE:**______________________.

MATERIAL:__________________________. **RECONCILIATION NO:**________.

______________________________.

No/m²/m³

A Total delivered. ____________________.

B Total transferred (from site). ____________________.

C Total available. [ ]

D Total measured (as specified). ____________________. ____________________.

E Allowances for Indirect Waste	**%**	**No/m²/m³**	**No/m²/m³**
i Substitution			
ii Negligence Waste			
iii Production usage			
Adjustment for Indirect Waste			

[ ]

F Total in stock on site. ____________________. ____________.

i Less frozen stock (if present). ____________________. ____________.

ii Stock available for use. ____________.

G Materials accountable for on site. [ ]

H =________________. **% Waste (H) = C – G as % of C.**

Direct waste calculation record.

1. The procedures to be adopted to calculate direct, indirect and consequential waste on site. Three inputs of data are required to calculate the waste for each material. A logical sequence of events has to be followed. The waste percentage is calculated on a basis of deliveries (in this programme) – hence the need to allow for 'frozen' stocks to avoid undue distortion of interim results.

2. The calculation of consequential waste is not part of this sequence and in any case has only an indicative value as feedback, being particular to each project – firstly, because it normally involves labour, plant and other costs for material too; secondly, it may not have occurred at the time of the reconciliations; and thirdly, part of the additional costs may be in extractable from other data forming the basis of claims at interim valuations.

Appendix F

<u>Waste Conversion Rates, from Percentage of Waste Estimated to Volume of Waste in m^3.</u>

35 Cubic Yards			12 Cubic Yards			8 Cubic Yards		
Total Vol=	26.8m3	(35c.y)	Total Vol=	9.2m3	(12c.y)	Total Vol=	6.1m3	(8c.y)
% Full		**Volume**	**% Full**		**Volume**	**% Full**		**Volume**
5%	To	1.338	**5%**	To	0.4587	**5%**	To	0.3058
10%	To	2.676	**10%**	To	0.9175	**10%**	To	0.6117
15%	To	4.014	**15%**	To	1.3762	**15%**	To	0.9175
20%	To	5.352	**20%**	To	1.835	**20%**	To	1.2234
25%	To	6.6901	**25%**	To	2.2938	**25%**	To	1.5292
30%	To	8.0281	**30%**	To	2.7525	**30%**	To	1.835
35%	To	9.3661	**35%**	To	3.2113	**35%**	To	2.1409
40%	To	10.7041	**40%**	To	3.67	**40%**	To	2.4467
45%	To	12.0421	**45%**	To	4.1288	**45%**	To	2.7526
50%	To	13.3802	**50%**	To	4.5876	**50%**	To	3.0584
55%	To	14.7182	**55%**	To	5.0463	**55%**	To	3.3642
60%	To	16.0562	**60%**	To	5.5051	**60%**	To	3.6701
65%	To	17.3942	**65%**	To	5.9638	**65%**	To	3.9759
70%	To	18.7322	**70%**	To	6.4226	**70%**	To	4.2818
75%	To	20.0703	**75%**	To	6.8814	**75%**	To	4.5876
80%	To	21.4083	**80%**	To	7.3401	**80%**	To	4.8934
85%	To	22.7463	**85%**	To	7.7989	**85%**	To	5.1993
90%	To	24.0843	**90%**	To	8.2576	**90%**	To	5.5051
95%	To	25.4223	**95%**	To	8.7164	**95%**	To	5.811
100%	To	26.7604	**100%**	To	9.1752	**100%**	To	6.1168

6 Cubic Yards			4 Cubic Yards			1.5 Cubic Yards		
Total Vol=	4.6m3	(6c.y)	Total Vol=	3.1m3	(4c.y)	Total Vol=	1.1m3	(1.5c.y)
% Full		**Volume**	**% Full**		**Volume**	**% Full**		**Volume**
5%	To	0.2294	**5%**	To	0.1529	**5%**	To	0.0573
10%	To	0.4588	**10%**	To	0.3058	**10%**	To	0.1147
15%	To	0.6881	**15%**	To	0.4588	**15%**	To	0.172
20%	To	0.9175	**20%**	To	0.6117	**20%**	To	0.2294
25%	To	1.1469	**25%**	To	0.7646	**25%**	To	0.2867
30%	To	1.3763	**30%**	To	0.9175	**30%**	To	0.3441
35%	To	1.6057	**35%**	To	1.0704	**35%**	To	0.4014
40%	To	1.835	**40%**	To	1.2234	**40%**	To	0.4588
45%	To	2.0644	**45%**	To	1.3763	**45%**	To	0.5161
50%	To	2.2938	**50%**	To	1.5292	**50%**	To	0.5735
55%	To	2.5232	**55%**	To	1.6821	**55%**	To	0.6308
60%	To	2.7526	**60%**	To	1.835	**60%**	To	0.6881
65%	To	2.9819	**65%**	To	1.9879	**65%**	To	0.7455
70%	To	3.2113	**70%**	To	2.1409	**70%**	To	0.8028
75%	To	3.4407	**75%**	To	2.2938	**75%**	To	0.8602
80%	To	3.6701	**80%**	To	2.4467	**80%**	To	0.9175
85%	To	3.8995	**85%**	To	2.5996	**85%**	To	0.9749
90%	To	4.1288	**90%**	To	2.7526	**90%**	To	1.0322
95%	To	4.3582	**95%**	To	2.9055	**95%**	To	1.0896
100%	To	4.5876	**100%**	To	3.0584	**100%**	To	1.1469

20 Cubic Yards		
Total Vol=	15.3m3	(20c.y)
% Full		**Volume**
5%	To	0.7645
10%	To	1.5292
15%	To	2.2935
20%	To	3.0583
25%	To	3.8229
30%	To	4.5875
35%	To	5.3521
40%	To	6.1166
45%	To	6.8812
50%	To	7.6458
55%	To	8.4104
60%	To	9.175
65%	To	9.9395
70%	To	10.7042
75%	To	11.4687
80%	To	12.2333
85%	To	12.9979
90%	To	13.7625
95%	To	14.5271
100%	To	15.29

Appendix G

Waste Audit Record Form for the Collection of Construction and Demolition Waste Audit Data.

Site Location:				Job No.		Auditor:	
Job Description:							
Date	Skip Size Ref.	Area Code	C N	Waste Material	%Waste	Quantity m3	Notes
Compacted = C. Non-Compacted = N.							

Appendix H

Construction and Demolition Waste Data for Case Study 1.

Case Study 1

Construction and Demolition Wastes Arising on Case Study 1

Development Type:	Residential
Percentage of Works Complete :	95%
Total Floor Area Complete:	24060 m^2

Waste Material	Aug 03 (m^3)	Sept 03 (m^3)	Oct 03 (m^3)	Nov 03 (m^3)	Dec 03 (m^3)	Jan 04 (m^3)	Feb 04 (m^3)	Mar 04 (m^3)	Apr 04 (m^3)	May 04 (m^3)	Jun 04 (m^3)	Jul 04 (m^3)	Aug04 (m^3)	Sep 04 (m^3)	Oct 04 (m^3)	Nov 04 (m^3)	Dec 04 (m^3)	Jan 05 (m^3)	Feb05 (m^3)
Soil	-	-	-	-	-	-	-	-	-	-	-	-	1760	-	-	-	-	-	-
Mixed Waste	<280	24	36	34	21	38	39	96	58	50	69	52	41	44	41	22	14	34	32
Timber	-	21	25	8	2	10	4	15	1	10	100	4	31	139	28	36	-	134	6
Unknown Mixed Waste		19	14	12	22	32	29	13	31	19	18	24	9	35	7	25	17	10	17
Insulation	-	45	23	11	17	24	28	23	5	9	16	6	2	9	5	1	3	9	18
Plasterboard	-	28	19	21	4	12	14	17	7	18	7	7	17	13	3	8	3	3	2
Plastic Sheeting	-	42	15	6	8	4	6	15	5	14	8	8	5	7	4	4	3	1	-
Cardboard	-	22	6	5	6	3	8	10	7	7	10	2	15	7	6	6	4	1	3
Canteen Waste	-	11	6	8	2	7	2	11	7	6	7	5	2	7	7	7	5	5	5
Off Site Waste	-	10	2	1	1	3	1	9	5	6	16	5	6	6	3	3	1	1	7
Cement Bags	-	17	4	3	2	3	3	2	4	1	5	3	1	1	1	1	1	1	-
K-Rend Bags	-	15	4	2	3	3	2	6	8	3	-	4	-	-	-	-	-	-	3
Plaster Bags	-	5	1	1	4	-	4	2	-	1	2	1	-	1	2	-	-	1	2
Paper	-	4	2	4	1	2	1	1	-	-	1	-	-	-	1	1	1	-	-
Ceramic Tiles	-	1	1	-	-	-	1	1	1	1	1	1	1	1	-	1	-	-	1
Steel	-	1	-	-	-	-	-	1	1	2	2	-	1	1	-	-	-	-	4
Soffit & Fascia	-	3	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Waste Totals	<280	268	159	116	93	141	142	222	140	148	262	122	*131	271	108	115	52	200	100

* Waste Total/s do not include soil wastes.

Case Study 1

Construction and Demolition Wastes Arising on Case Study 1

Development Type:	Residential
Percentage of Works Complete :	95%
Total Floor Area:	24060 m^2

Waste Material	Mar 05 (m^3)	Apr 05 (m^3)	EWC Code	Total Waste %	Total Waste (m^3)
Soil	-	-	17 05 04	-	1760
Mixed Waste	25	-	17 09 04	33.4	1050
Timber	24	-	17 02 01	19	598
Unknown Mixed Waste	2	-	17 09 04	11.3	355
Insulation	5	-	17 06 04	8.2	259
Plasterboard	-	-	17 08 02	6.5	203
Plastic Sheeting	-	-	17 02 03	4.9	155
Cardboard	1	-	17 09 04	4.1	129
Canteen Waste	3	-	17 09 04	3.6	113
Off Site Waste	6	-	17 09 04	2.9	92
Cement Bags	2	-	17 09 04	1.8	55
K-Rend Bags	-	-	17 09 04	1.8	53
Plaster Bags	-	-	17 09 04	0.9	27
Paper	-	-	17 09 04	0.6	19
Ceramic Tiles	2	-	17 01 03	0.4	14
Steel	-	-	17 04 05	0.4	13
Soffit & Fascia	-	-	17 02 03	0.2	5
Waste Totals	70	-	-	100%	*3140

Construction and Demolition Waste Rate (Excluding Soil)	=	$3140m^3$ / $24060m^2$ =	$0.13m^3/m^2$
Construction and Demolition Waste Rate (Including Soil)	=	$4900m^3$ / $24060m^2$ =	$0.20m^3/m^2$

* Waste Total/s do not include soil wastes.

Appendix I

Construction and Demolition Waste Data for Case Study 2.

Case Study 2

Construction and Demolition Wastes Arising on Case Study 2

Development Type:	Residential
Percentage of Works Complete :	70 %
Total Floor Area Complete:	m^2

Waste Material	Dec 03 (m^3)	Jan 04 (m^3)	Feb 04 (m^3)	Mar 04 (m^3)	Apr 04 (m^3)	May 04 (m^3)	Jun 04 (m^3)	Jul 04 (m^3)	Aug 04 (m^3)	Sep 04 (m^3)	Oct 04 (m^3)	Nov 04 (m^3)	Dec 04 (m^3)	Jan 05 (m^3)	Feb 05 (m^3)	Mar 05 (m^3)	Apr 05 (m^3)	May 05 (m^3)	Jun 05 (m^3)
Soil	6101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mixed Waste	10	9	10	8	-	12	50	32	25	49	53	41	34	29	56	44	-	-	-
Timber	3	2	2	4	4	6	29	27	63	48	7	59	22	35	80	32	-	-	-
Insulation	-	-	5	14	11	14	29	33	12	40	4	12	3	9	3	7	-	-	-
Unknown Mixed Waste	1	3	11	6	5	6	16	12	18	10	12	37	12	29	26	16	-	-	-
Plasterboard	-	-	-	-	-	11	12	9	8	11	10	7	12	6	8	6	-	-	-
Cement Bags	-	1	5	6	5	7	11	8	5	4	6	7	1	6	5	5	-	-	-
Canteen Waste	1	4	4	4	4	5	7	4	4	5	5	3	4	5	4	7	-	-	-
Plastic Sheeting	-	1	2	2	1	4	2	4	14	4	10	16	1	2	1	1	-	-	-
Cardboard	1	1	1	1	-	2	1	6	4	2	5	2	-	3	2	3	-	-	-
Steel	-	1	3	4	-	-	-	-	1	8	-	-	-	1	3	-	-	-	-
Off Site Waste	1	1	1	1	-	2	2	1	-	1	2	2	1	1	1	1	-	-	-
Plaster Bags	-	-	-	-	-	1	7	1	1	1	-	-	-	1	-	-	-	-	-
K-Rend Bags	-	-	-	-	-	1	2	1	-	1	2	1	6	-	1	4	-	-	-
Ceramic Tiles	-	-	-	-	-	-	-	1	-	1	1	1	-	-	-	1	-	-	-
Waste Totals	*17	23	44	50	30	71	168	139	155	185	117	188	96	127	190	127	-	-	-

* Waste Total's do not include soil wastes.

Case Study 2

Construction and Demolition Wastes Arising on Case Study 2

Development Type:			Residential			
Percentage of Works Complete :			70 %			
Total Floor Area:			m^2			
Waste Material	July 05 (m^3)	Aug 05 (m^3)	EWC Code	Total Waste %	Total Waste (m^3)	
Soil	-	-	17 05 04	-	6101	
Mixed Waste	-	-	17 09 04	26.8	462	
Timber	-	-	17 02 01	24.5	423	
Insulation	-	-	17 06 04	11.3	196	
Unknown Mixed Waste	-	-	17 09 04	12.7	220	
Plasterboard	-	-	17 08 02	5.8	100	
Cement Bags	-	-	17 09 04	4.7	82	
Canteen Waste	-	-	17 09 04	4.1	70	
Plastic Sheeting	-	-	17 09 04	3.8	65	
Cardboard	-	-	17 09 04	2	34	
Steel	-	-	17 04 05	1.2	21	
Off Site Waste	-	-	17 09 04	1	18	
Plaster Bags	-	-	17 09 04	0.7	12	
K-Rend Bags	-	-	17 04 04	1.1	19	
Ceramic Tiles	-	-	17 01 03	0.3	5	
Waste Totals	-	-	-	100%	*1727	
Construction and Demolition Waste Rate (Including Soil) = m^3 / m^2 =						m^3/m^2
Construction and Demolition Waste Rate (Excluding Soil) = m^3 / m^2 =						m^3/m^2

* Waste Total/s do not include soil wastes.

Appendix J

<u>Construction and Demolition Waste Data for Case Study 3.</u>

Case Study 3

Construction and Demolition Wastes Arising on Case Study 3

Development Type: Hotel.

Percentage of Works Complete : 70%

Total Floor Area: ????? m^2

Waste Material	Nov 03 (m^3)	Dec 03 (m^3)	Jan 04 (m^3)	Feb 04 (m^3)	Mar 04 (m^3)	Apr 04 (m^3)	May 04 (m^3)	Jun 04 (m^3)	Jul 04 (m^3)	Aug 04 (m^3)	Sept 04 (m^3)	Oct 04 (m^3)	Nov 04 (m^3)	Dec 04 (m^3)	Jan 04 (m^3)	Feb 04 (m^3)	Mar 04 (m^3)	Apr 04 (m^3)
Soil	-	-	<23000	-	-	450	-	-	-	-	-	-	-	-	-	-	-	-
Rock	-	-	<2500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mixed Waste	<173	8	11	3	2	1	2	16	15	0	9	32	25	40	49	69	60	-
Timber	-	4	17	13	33	17	15	20	-	15	21	40	52	33	57	42	17	-
Plasterboard	-	-	-	-	-	-	-	-	-	1	11	6	40	12	4	48	8	-
Unknown Mixed Waste	-	1	-	4	7	6	4	2	3	5	4	10	12	14	15	17	15	-
Steel	-	1	4	1	6	6	9	22	2	-	6	15	24	1	10	3	4	-
Canteen Waste	-	2	3	4	3	2	5	4	2	5	2	1	2	1	0	1	3	-
Insulation	-	-	-	-	-	-	-	9	-	-	2	11	1	3	2	1	5	-
Cardboard	-	-	1	-	1	-	1	-	-	4	-	1	-	-	2	-	4	-
Plastic Sheeting	-	-	-	-	1	1	-	1	-	-	1	-	-	1	1	-	1	-
Off Site Waste	-	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Rubble	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-
Paper	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Waste Totals	173	16	*37	26	53	*33	37	75	23	30	57	116	156	105	140	181	117	-

* Waste Total/s do not include soil and rock wastes.

Case Study 3

Construction and Demolition Wastes Arising on Case Study 3

Development Type:	Hotel
Percentage of Works Complete :	70%
Total Floor Area:	[illegible] m^2

Waste Material	May 05 (m^3)	Jun 05 (m^3)	EWC Code	Total Waste %	Total Waste (m^3)
Soil	-	-	17 05 04	-	23450
Rock	-	-	17 05 04	-	2500
Mixed Waste	-	-	17 09 04	37	515
Timber	-	-	17 02 01	29	396
Plasterboard	-	-	17 08 02	10	130
Unknown Mixed Waste	-	-	17 09 04	8	119
Steel	-	-	17 04 05	8	114
Canteen Waste	-	-	17 09 04	3	40
Insulation	-	-	17 06 04	3	34
Cardboard	-	-	17 09 04	1	14
Plastic Sheeting	-	-	17 02 03	0.5	7
Off Site Waste	-	-	17 09 04	0.2	3
Rubble	-	-	17 01 07	0.2	2
Paper	-	-	17 09 04	0.1	1
Waste Totals	-	-	-	100%	*1375

Construction and Demolition Waste Rate (Including Soil) = m^3 / m^2 =	m^3/m^2
Construction and Demolition Waste Rate (Excluding Soil) = m^3 / m^2 =	m^3/m^2

Waste Total/s do not include soil and rock wastes.

Appendix K

Construction and Demolition Waste Data for Case Study 4.

Case Study 4 **Construction and Demolition Wastes Arising on Case Study 4**														
Development Type:	Educational.													
Percentage of Works Complete :	100%													
Total Floor Area:	1125 m^2													
Waste Material	Sep 03 (m^3)	Oct 03 (m^3)	Nov 03 (m^3)	Dec 03 (m^3)	Jan 04 (m^3)	Feb 04 (m^3)	Mar 04 (m^3)	Apr 04 (m^3)	May 04 (m^3)	Jun 04 (m^3)	Jul 04 (m^3)	EWC Code	Total Waste %	Total Waste (m^3)
Soil	694	-	-	-	-	-	-	-	-	-	-	17 05 04	-	694
Mixed Waste	-	9	9	16	25	30	20	10	25	28	19	17 09 04	47.5	191
Timber	-	2	8	13	11	17	14	8	8	15	4	17 02 01	25	100
Unknown Mixed Waste	-	-	-	1	4	3	6	3	11	9	12	17 09 04	12.3	49
Cardboard	-	-	-	-	-	-	2	1	4	4	1	17 09 04	3	12
Steel / Metal	-	-	-	1	1	-	2	2	3	1	1	17 04 07	2.8	11
Canteen Waste	-	-	-	-	-	1	6	1	1	-	-	17 09 04	2.3	9
Plastic Sheeting	-	-	-	-	2	1	1	1	1	3	-	17 02 03	2.3	9
Insulation	-	-	-	-	1	-	-	2	2	1	2	17 06 04	2	8
Plasterboard	-	-	-	-	-	-	2	1	2	1	-	17 08 02	1.5	6
Off Site Waste	-	-	-	1	-	-	1	-	-	1	2	17 09 04	1.3	5
Waste Totals	694	11	17	32	44	52	54	29	57	63	41	-	100%	*400
Construction and Demolition Waste Rate (Excluding Soil) = 400m^3 / 1125m^2 =													0.36 m^3/m^2	
Construction and Demolition Waste Rate (Including Soil) = 1094m^3 / 1125m^2 =													0.97 m^3/m^2	

* Waste Total/s do not include soil wastes.

Appendix L

Monthly Breakdown of Construction and Demolition Waste Data for the Case Study Construction Projects.

Monthly Construction and Demolition Wastes Arising on the Case Study Construction Projects																				
Total Monthly Waste Arisings. (Cubic Meters.)	Aug 03 (m^3)	Sept 03 (m^3)	Oct 03 (m^3)	Nov 03 (m^3)	Dec 03 (m^3)	Jan 04 (m^3)	Feb 04 (m^3)	Mar 04 (m^3)	Apr 04 (m^3)	May 04 (m^3)	Jun 04 (m^3)	Jul 04 (m^3)	Aug 04 (m^3)	Sept 04 (m^3)	Oct 04 (m^3)	Nov 04 (m^3)	Dec 04 (m^3)	Jan 05 (m^3)	Feb 05 (m^3)	Mar 05 (m^3)	Total (m^3)
Case Study 1	<280	268	159	116	93	141	142	222	140	148	262	122	131	271	108	115	52	200	100	70	3140
Case Study 2	-	-	-	-	17	23	44	50	30	71	168	139	155	185	117	188	96	127	190	127	1727
Case Study 3	-	-	-	<173	16	37	26	53	33	37	75	23	30	57	116	156	105	140	181	117	1375
Case Study 4	-	-	11	17	32	44	52	54	29	57	63	41	-	-	-	-	-	-	-	-	400

<: Waste Generated prior to commencement of Waste audit.
Case Study 1: Residential.
Case Study 2: Residential.
Case Study 3: Hotel.
Cases Study 4: Educational.
Excavated soil wastes generated on site are not included above.

Construction and Demolition Waste Rates Calculated Using Collected Construction and Demolition Waste Audit Data			
Case Study.	Development Type.	C & D Waste Rate Including Soil Wastes. (m^3 per m^2 of Floor Area.)	C & D Waste Rate Excluding Soils Wastes. (m^3 per m^2 of Floor Area.)
Case Study 1	Residential	0.20	0.13
Case Study 2	Residential	0.57	0.13
Case Study 3	Hotel	1.27	0.06
Case Study 4	Educational	0.97	0.36