An Analysis of the Use of Photogrammetric Sorting to Audit Construction and Demolition Waste Production on Site

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This thesis is submitted in satisfaction of the requirements for the degree of

Master of Science in Construction Management
At the Galway-Mayo Institute of Technology

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Submitted to the Higher Education and Training Awards Council

September 2007

Declaration

01/09/07

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

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Abstract

This study analyses the area of construction and demolition waste (C&D W) auditing. The production of C&D W has grown year after year since the Environmental Protection Agency (EPA) first published a report in 1996 which provided data for C&D W quantities for 1995 (EPA, 1996a). The most recent report produced by the EPA is based on data for 2005 (EPA, 2006). This report estimated that the quantity of C&D W produced for that period to be 14 931 486 tonnes. However, this is a 'data update' report containing an update on certain waste statistics so any total provided would not be a true reflection of the waste produced for that period. This illustrates that a more construction site-specific form of data is required.

The Department of Building and Civil Engineering in the Galway-Mayo Institute of Technology have carried out two recent research projects (Grimes, 2005; Kelly, 2006) in this area, which have produced waste production indicators based on site-specific data. This involved the design and testing of an original auditing tool based on visual characterisation and the application of conversion factors. One of the main recommendations of these studies was to compare this visual characterisation approach with a photogrammetric sorting methodology.

This study investigates the application of photogrammetric sorting on a residential construction site in the Galway region. A visual characterisation study is also carried out on the same project to compare the two methodologies and assess the practical application in a construction site environment. Data collected from the waste management contractor on site was also used to provide further evaluation.

From this, a set of waste production indicators for new residential construction was produced:

- 50.8 kg/m² for new residential construction using data provided by the visual characterisation method and the Landfill Levy conversion factors.
- 43 kg/m² for new residential construction using data provided by the photogrammetric sorting method and the Landfill Levy conversion factors.

- 23.8 kg/m^2 for new residential construction using data provided by Waste Management Contractor (WMC).

The acquisition of the data from the waste management contractor was a key element for testing of the information produced by the visual characterisation and photogrammetric sorting methods. The actual weight provided by the waste management contractor shows a significant difference between the quantities provided.

Acknowledgements

I would like to thank the following people for their assistance and guidance throughout the course of my research.

I would like to thank my supervisors Mr. John Hanahoe and Dr. Mark Kelly for their continued guidance, encouragement and support over the course of my research.

I would like to thank the directors and staff of O' Malley Construction especially the site management on the Roscam site for accommodating and assisting me throughout the research.

I would like to thank Mr. David Grimes, Mr Marcus Feely and Mr. Joseph Kelly for their help and assistance.

I would like to thank Fiona Coyle of DIT for her help and the useful information that she provided me with.

Finally I would like to thank my family and friends for their continued patience and encouragement throughout the duration of my research.

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Acronyms

AER	Annual Environmental Report
BAT	Best Available Technology
BRE	British Research Establishment
CIRIA	Construction Industry Research and Information Association
C&D W	Construction and Demolition Waste
DAF	Data Acquisition Form
DoEHLG	Department of the Environment, Heritage and Local Government
EU	European Union
EPI	Environmental Performance Indicator
EC	European Commission
EWC	European Waste Catalogue
EEA	European Environment Agency
EPA	Environmental Protection Agency
EIS	Environmental Impact Statement
ERTDI	Environmental Research, Technological Development and Innovation

FAC	Florida Administrative Code
GIS	Geographical Information System
GMIT	Galway-Mayo Institute of Technology
IPPC	Integrated Pollution Prevention and Control
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
MCORM	McCrossan, O' Rourke and Manning Architects
NAHB	National Association of Home Builders
NCDWC	National Construction Demolition and Waste Council
OECD	Organisation for Economic Co-Operation & Development
PCB	Polychlorinated Biphenyls
PPE	Personal Protective Equipment
SMARTWaste	Site Methodology to Audit, Reduce and Target Waste
UNIVIE	University of Vienna, Austria
USEPA	United States Environmental Protection Agency
WMC	Waste Management Contractor
WMP	Waste Management Plan

Chapter 1 Introduction and Research Methodology

1.1 Introduction

The best estimates provided by the Environmental Protection Agency (EPA) (1996a, 2000, 2003, 2005a, 2006) show an increase in construction and demolition waste (C&D W) production from 1.52 million tonnes in 1995 to 14.93 million tonnes in 2005. These figures are derived from a number of audit methodologies, none of which measure actual waste production on Irish construction sites.

This study will examine the application of photogrammetric sorting on site to develop waste production indicators. It will examine previous research carried out by Grimes (2005) and Kelly (2006) in this area and will compare methodologies and results.

1.2 Scope of the Study

A lack of site-specific data was highlighted by both Grimes (2005) and Kelly (2006). It was this lack of site-specific data that provided the motivation for carrying out this research. A recommendation was made by Kelly (2006) to explore the area of waste characterisation through photogrammetric sorting. This was seen as an opportunity to create an alternative and possibly a more advanced method of waste analysis. To carry out such a task, the following steps were taken:

- The C&D W legislation in place in this country had to be identified.
- Examination of the characteristics of the C&D W.
- Investigation of the current audit methodologies in use in this country by both the EPA and the research department of GMIT and apply an appropriate method to a case study.
- Look at a methodology for C&D W auditing using photogrammetric sorting to identify the components of C&D W which was applied in Florida, USA (Medeiros, 2001)
- Provide indicators for C&D W production for residential construction based on the site analysed in the case study.

1.3 Main Aims and Objectives

The main aims of this thesis are to:

1. Design and test a waste audit methodology using photogrammetric sorting on an Irish construction project.

2. Provide waste production indicators for C&D W volumes arising from a case study where the method was used.

To achieve these aims, a number of objectives needed be met:

- Identify the legal responsibilities associated with the production and management of C&D W.
- Outline the characteristics of the waste stream.
- Examine the development and testing on an original C&D W auditing tool on construction sites in Ireland (Grimes, 2005 and Kelly, 2006).
- Investigate the use of photogrammetry applications in the construction industry.
- Develop and test a photogrammetric sorting methodology on a residential construction site in Ireland.
- Present the results for analysis and comparison.

1.4 Research Methodology

This research was based on two methods of C&D W auditing: a visual characterisation method (Grimes, 2005 & Kelly, 2006) and the use of photogrammetric sorting. This was a test of a new methodology to examine its viability in a site-specific context.

The initial chapters provide an extensive literature review of the legal responsibilities and the characteristics of the waste stream that were considered to be drivers for the successful management of C&D W in Ireland. The purpose of this literature review was to focus the research to develop more insightful questions about the topic. The examination of previous work (Chapter 3) carried out in this area (Kelly, 2006) provided a focus for the thesis, as one of the main recommendations was to examine the feasibility of photogrammetric sorting as an auditing tool on construction projects

in Ireland. The next logical step was to develop and test a photogrammetric sorting methodology on a selected case study.
Chapter 4 gives an overview of the area of photogrammetry and its application in various disciplines. This chapter examines the development of a C&D W photogrammetric sorting method that was tested in the US (Medeiros, 2001). A critical analysis of this work highlights a number of limitations, which were considered in the development of a photogrammetric sorting audit tool for use in Ireland.

Chapter 5 gives a detailed overview of the procedures followed in creating a framework for the implementation of the practical elements of the original site-based method of C&D W auditing on a case study in Ireland. The chapter presents an overview of the methodology that was created and used, the manner in which the results would be presented and the time scale involved.

Chapter 6 outlines the results provided by the visual characterisation and photogrammetric sorting methods. This chapter provides a comparative analysis with work already carried out in this area (Medeiros, 2001; Grimes, 2005; Kelly 2006). The total weights of each skip are also utilised to identify the differences between the methodologies used.

Conclusions

This study is an investigation of the feasibility of photogrammetric sorting as a method for auditing C&D W on site. The application of the photogrammetric sorting method was run in conjunction with the use of the visual characterisation method to allow for comparison. There is also provision for comparison of results produced by both method with the data provided by the WMC.

The initial visual characterisation method, which was used, was put in to practice not only to test its accuracy but to also test another method against the results it provides. The visual characterisation method was applied to 62 C&D W skips on a selected case study over a period of thirteen months. Results for each skip cycle analysis were recorded.

The photogrammetric sorting and characterisation methods were applied to the same 62 C&D W skips on a residential construction site. The contents of the skip were determined by analysis of photographs taken of the skips C&D W. In all, 324 photographs were taken across the cycles of the 62 skips. Over 180 hours alone were spent analysing photographs of C&D W and steps were also taken to reduce the workload associated with each skip cycle and increase the volume of data produced.

The next chapter examines the main legislative and characteristic drivers associated with C&D W management in Ireland.

Chapter 2 Legislative and Characteristic Drivers in the Management of Construction and Demolition Waste.

2.1 Introduction

The obligations placed on C&D W producers by the current legislation and policies are the main motivation for monitoring C&D W. This legislation provides the incentive for contractors to reduce their C&D W, which in turn encourages the analysis of various methodologies for measuring waste production. These legislative instruments govern the area of waste management that reach out to several industries with the main discipline here being the construction industry.

The main aims of this chapter are to:

- Examine the current C&D W legislation and regulations and explain the impact that these regulations have on the construction industry in Ireland.
- Identify the characteristics of C&D W.
- Provide an overview of composition and production estimates of C&D W throughout Europe and Ireland.

2.2 Legislation and Policy Actions in Europe

In 1989 the Commission for European Communities set out a community wide waste management policy. Its aim was to implement Directives to place obligations on Member States to encourage methods that would help prevent and minimise the flow of waste. This was encouraged by the policies of the waste management hierarchy (Figure 2.1).

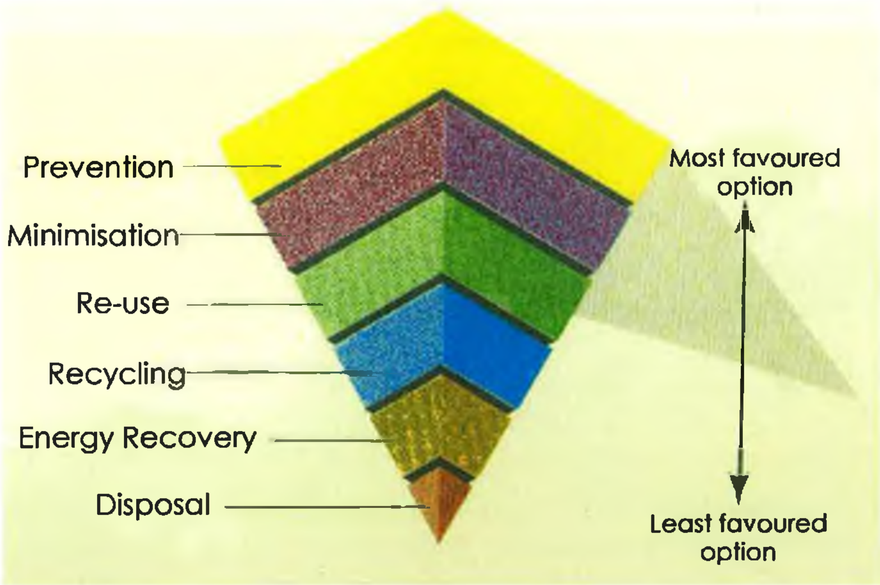


Figure 2.1 Waste Management Hierarchy

The waste management hierarchy set the precedent by which all waste management policy and legislation was developed within the EU and Ireland. Its intention was to promote the most desirable methods of dealing with waste. The European Commission defined waste as:

"any substance or object in the categories set out in Annex 1, which the holder discards or intends to discard, or is required to discard."

(Council of European Communities, 2006)

In Ireland, a definition was provided in the *National Waste Database Report 1998* (EPA, 2000), which defined C&D W:

"*to include all waste that arises from construction, renovation, and demolition activities and all waste 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 and dredge spoil*[1] ".

[1] Dredge spoil was described as being made up of two primary types of dredging materials: maintenance and capital dredging. Maintenance dredging is conducted regularly in Irish ports for navigation purposes and this activity gives rise to predominantly erodible materials such as silt and sand. Capital dredging occurs when significant removal of seabed material is required during major engineering operations. Capital dredgings are generally bulky non-erodible materials such as rock and gravel.

The European Commission also applied Directives to ensure that waste was dealt with as close as possible to the source without endangering human health or the environment with a special emphasis on water, soil, plants and animals. There was a provision set out in the Directives to encourage self-sufficiency in waste disposal. These policies were revised in the *1991 Amendment* but it still applied the general duties to Member States (Council of European Communities, 1991) including:

- The introduction of clean technologies to increase prevention and reduction of waste.
- The recovery and recycling of waste materials as a secondary raw material.
- The creation of waste management plans by competent authorities.
- The creation of a network of disposal installations with special emphasis on the best available technology (BAT) that will enable the community to become self-sufficient.
- The recording of waste transactions for inspection by competent authorities for the creation of reports.

The European Commission set up the *Priority Waste Streams Programme* in 1992 to help create a community policy for addressing the following waste types.

- Used tyres.
- End of life vehicles.
- Chlorinated solvents.
- Health care wastes.
- Construction and demolition waste.
- Waste from electric and electronic equipment.

This led to the establishment of the *Construction and Demolition Waste Project Group*. This group comprised of representatives of all areas of the construction industry. From this a European report was published (Symonds Travers Morgan/ARGUS, 1995) that outlined recommendations for waste prevention, clean technologies, market creation, cost effectiveness and protection of the environment.

In 1996 a review of the *Strategy for Waste Management* (Commission of European Communities, 1996) was carried out. It outlined the following points:

- The introduction of targets to substantially reduce the amount of waste generated and to achieve high waste recovery objectives.
- The incorporation of producer responsibility to help get the producers of waste actively involved in the management of the waste associated with their products.
- Suggestions for guidelines on the use of economic instruments for waste management including the harmonisation of waste statistics and a common methodology for life-cycle analysis (LCA).

The review reported that the priority waste streams initiative had been abandoned due to slow progress. This led to the Commission and the Member States devising a list of priority actions for improving the competitiveness in the construction industry. The aims were to encourage the use of:

- Environmentally friendly construction materials.
- Energy efficiency in buildings.
- Construction and demolition waste management.

The Task Group 3 (TG3) task group was set up to establish a report for C&D W. In September 2000 a report was presented outlining the following recommendations (EU Sustainable Working Group for Sustainable Construction, 2001):

- Waste prevention orientated planning and design.
- Recovery orientated construction.
- Design for multiple uses.

The task group also recommended that the governments of each Member State draw up a national waste management plan (WMP) for C&D W. All Member States were required to report annually on:

- Targets.
- Collection of data on waste arising, prevention, recovery, incineration and landfill.
- The current and required landfill facilities.
- Actions undertaken to achieve targets.

- The constraints presented by national standards.

The *European Waste Catalogue* was revised and implemented on January 1st 2002. This revision placed C&D W in chapter 17 of the catalogue. It listed 38 waste types, 16 of which were considered to be hazardous (Appendix A). The EWC identified and classified waste in a standard format for all waste management contractors and operators in Ireland and across the EU.

2.3 Waste Management Policy in Ireland

Apart from the *Litter Act, 1982* (DoEHLG, 1982), no legislation existed in Ireland to address the issue of waste management prior to 1990. The first step in changing attitudes towards waste management was the introduction of the *Environmental Protection Agency Act, 1992* (DoEHLG, 1992). This Act paved the way for the establishment of the Environmental Protection Agency (EPA), which implemented the following policies:

- The establishment of a national waste database by the EPA.
- The specification and publication of criteria and procedures for the selection, management, operation and termination of use of landfill sites.
- Provision made for the introduction of integrated pollution control (IPC), which addressed generation, recovery and disposal of wastes by relevant activities and emphasised progressive waste minimisation.

The *Waste Management Act, 1996* (DoEHLG, 1996) was enacted into Irish legislation in May 1996. Along with the *Waste Management (Amendment) Act, 2001* (DoEHLG, 2001) they remain the primary pieces of legislation governing waste management in Ireland. The main objectives of these Acts are:

- To provide organisation of public authority functions in relation to waste management, which includes new roles for the EPA and local authorities.
- To introduce measures to improve performance in relation to waste prevention and recovery of waste.
- To provide a comprehensive framework for the application of higher environmental standards. This is in response to EU and national requirements.

- The creation and constant review of waste management plans in relation to non-hazardous wastes.
- Authorisation and control of commercial waste collection activities.
- Authorisation of waste exports and monitoring of internal movements of hazardous wastes.
- Authorisation of waste-permitting of small-scale recovery and disposal activities.
- To ensure that adequate waste collection, recovery and disposal arrangements in their functional areas.
- General enforcement, monitoring and inspection of waste activities.
- To provide the statutory basis for all C&D W management legislation in Ireland (Box 2.1).

Box 2.1 Construction and demolition waste management legislation (DoEHLG, 1998c, 1998b, 1998d, 2000a, 2001a, 2002b, 2003b)

- The Waste Management (Permit) Regulations, 1998.
- The Waste Management (Hazardous Waste) Regulations, 1998
- The Waste Management (Transfrontier Shipment of Waste) Regulations, 1998.
- The Waste Management (Licensing) Regulations, 2000 and Amendments, 2002
- The Waste Management (Collection Permit) Regulations, 2001
- The Waste Management (Landfill Levy) Regulations, 2002
- The Waste Management (Packaging) Regulations, 2003

The *Waste Management (Permit) Regulations, 1998* (DoEHLG, 1998c), were introduced into Irish law to address the issue of permits and certificates of registration. Its relevance to C&D waste was set out by a provision made in the legislation for the requirement of a permit from the local authority for the operation of a mobile crusher. These permits are usually required for activities, which, are generally considered to pose a low pollution risk, and deal with small volumes of waste. This legislation has also addressed the lack of C&D W processing infrastructure available and has set out the following options:

- All persons wishing to recover or dispose of waste under a certain quantity (5 000 tonnes per annum) need to obtain a permit from the relevant local authority.
- No upper limit for recovery of waste was set out in the Act, provided 100 per cent recovery is achieved, but in most cases the local authority issuing the waste permit will specify a maximum allowable volume of waste to be recovered.

The legislation also provided for situations where the activity undertaken is exempt from the requirement of a waste permit.

- The recovery of hazardous waste and the composting of waste, where the quantity of waste and compost on site exceeds 1 000m^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 and reused on that site.

The *Waste Management (Hazardous Waste) Regulations, 1998* (DoEHLG, 1998b) were introduced into Irish Law as a result of a EU directive on hazardous waste. This put a duty on hazardous waste producers to keep a specified record of any hazardous waste on their premises. The producer is also obliged by the legislation to monitor and track the movement of hazardous waste from its source to its disposal or treatment facility.

The introduction of this legislation did have an effect on contractors and how they went about their construction activities. The legislation outlined that waste material mixtures from a C&D W site that contains dangerous substances would be classified as a hazardous waste. Therefore, such material cannot be used on sites as fill even if a waste license is held. Disposal can only take place at a licensed hazardous waste facility. Transfer of the waste off site requires the contractor to obtain a waste collection permit and a consignment note (C1 form) (Appendix B).

The Waste Management Hazardous Waste (Amendment) Regulations, 2000 replaced the initial *Waste Management (Hazardous Waste) Regulations, 1998*. The main changes relative to the management of C&D W were that it addressed the mercury content of batteries.

The *Transfrontier Shipment of Waste Regulations, 1998* (DoEHLG, 1998d) apply to any business (usually waste collectors) exporting waste (hazardous or non-hazardous) for recovery or disposal. As far as the exporting of waste is concerned, the EPA is the competent authority and should be contacted before any waste is exported. Contractors have a number of duties under this legislation:

- The contractor is generally considered to be the producer of the waste and is therefore ultimately responsible for ensuring that the waste being shipped is dealt with in compliance with all relevant legislation in the various jurisdictions.
- Each shipment of waste must be notified to the competent authority in both the country receiving the waste and the country of origin. This being the EPA in the Republic of Ireland and the relevant district council if the destination is Northern Ireland.

The *Waste Management (Licensing) Regulations 2000 and Amendments 2002* (DoEHLG, 2000a) provide for the operation of a licensing system, which is controlled by the EPA. The licensing regulations are in place to control the activities of waste treatment and disposal facilities with a view to the granting of waste licenses to such facilities. The following waste facilities require a license:

- Landfills.
- Hazardous waste disposal facilities (other than local authority facilities who have a Certificate of Registration issued by the EPA).
- Composting facilities holding more than 1 000m^3 of compost at any given time.
- Non-landfill disposal facilities that handle in excess of 5 000 tonnes per annum, e.g. transfer stations.
- Recovery facilities (other than those at landfills), operated by or on behalf of local authorities (other than those covered by certificates of registration).

A waste license from the EPA is generally required for all waste related activities involving large volumes of material that pose a risk to the environment. A private contractor can only dispose of C&D W by landfill when the facility has a valid waste license. It should also be noted that where a private sector waste transfer station has an intake of greater than 5 000 tonnes per annum, a waste license is required.

The main purpose of the *Waste Management Amendment Act, 2001* (DoEHLG, 2001) was to provide a vastly improved waste management planning strategy with the intention of bringing the planning process to an early conclusion. Before the introduction of this legislation, fifteen local authorities, in 3 regional groups, refused to adopt the proposed regional waste management plans subject to conditions. Section 4 of the Act provided for the making of a waste management plan to become a management function. The Act provides for:

- An environmental levy which was initially €0.15 (now at €0.22) on retailer's plastic shopping bags, with the potential to extend to other products which could be considered problematic in waste management terms.
- A levy on landfill waste introduced at €15/tonne.
- The establishment of an environmental fund. The proceeds of the above levies are used to finance beneficial environmental initiatives in a range of areas including waste management, environmental education and awareness.

The *Waste Management (Collection Permit) Regulations, 2001* (DoEHLG, 2001b) govern waste collection activities in this country. Its main aim is to prevent unauthorised haulage of waste. The regulations require that, a waste collector possess a collection permit from the relevant local authority for the collection of waste on a commercial basis. A waste collection permit only allows the collection of waste within the geographical area covered by the waste management plan for the region or county concerned. If the collector wishes to collect and transport waste within a number of areas an application should be made to the nominated lead authority within the region (Table 2.1).

Table 2.1 **Lead Local Authorities (MBCA, 2003).**

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

The introduction of the *Waste Management (Collection Permit) Regulations, 2001* (DoEHLG, 2001b) has had a significant impact on building contractors. The following are the situations where collection permits are required:

- If a contractor wishes to transfer waste to and from a site or to transport waste for disposal or recovery then they must hold a waste collection permit. This would include the transfer of rubble, fill and spoil from a construction project.

- The transfer of inert waste or non-hazardous waste also requires the holding of a collection permit. The *Waste Management (Hazardous Waste) Regulations, 1998* (DoEHLG, 1998b) address the transfer of hazardous waste.
- In situations where the transporting waste axle weight is less than 1 tonne, a collection permit is not required. The same applies when the waste is incidental to the main business activity or when gathering and sorting waste on a site.

The *Waste Management (Landfill Levy) Regulations, 2002* (DoEHLG, 2002b) provide for the introduction and operation of a landfill levy, which was introduced on 1st June 2002. It was considered that the cost of landfilling waste was relatively low and thereby discouraging more desirable waste recovery options. The levy was charged at €15 per tonne and could be increased by a maximum amount of €5 per tonne. The money collected would go into the Environmental Fund, which is used to fund waste management and litter prevention initiatives.

The primary reason for implementing the levy was to encourage and give an incentive to lean towards alternative methods of treatment. The introduction of the levy would also generate revenue, which could support waste minimisation, recycling, and other more desirable waste management initiatives.

There are some disposal activities that are exempt from the landfill levy charge. The materials that would fall under this exemption could be used for site works, restoration, remedial work or maintenance at the landfill (MBCA, 2003). They include:

- Non-hazardous C&D waste (150mm or less).
- Excavated spoil containing clay, sand, gravel etc.
- Dredge spoil from waterways or harbours.

The Government enacted the *Waste Management (Packaging) Regulations 2003* (DoEHLG, 2003b) in March 2003. They became known as the *Packaging Regulations* and are designed to promote the recovery and recycling of packaging waste. Packaging could be anything from plastic wrapping keeping material dry to cardboard containers in which materials were supplied. They allocate specific obligations to producers of packaging who place more than 25 tonnes of packaging onto the Irish market and have a turnover in excess of €1.27 million. Contractors are obliged to register with the approved packaging compliance scheme Repak[2]. Alternatively they can self comply by registering with their local authority and accept packaging waste back from the public.

The important consideration for a contractor is that they are aware whether or not their suppliers of packaged materials to site are members of Repak or if they are self-compliant. If the supplier is self-compliant then they must take back the packaging for recovery purposes. However, if they are Repak members then they are not obliged to do so. Therefore, the contractor must make alternative arrangements for the segregation and collection of any of the seven specified packaging wastes outlined in the packaging regulations by a Repak approved waste contractor.

The *Protection of the Environment Act 2003* (DoEHLG, 2003a) was introduced to help bring the *Environmental Protection Agency Act 1992* (EPA, 1992) and the *Waste Management Act 1996* (DoEHLG, 1996) in line with the integrated pollution prevention and control (IPPC) directive. The Act gives much improved legislation in relation to governing the IPPC licensing regime. It also provides a statutory basis for incorporating improved groundwater protection requirements. The principal waste related provisions of the Act provide for:

- The review, variation or replacement of a waste management plan to be an executive function.
- The introduction of explicit new powers for local authorities to make charges for waste services, as an executive function.
- The introduction of a presumption, for the purposes of prosecutions, that the carrying on of a waste activity other than under and in accordance with any requisite authorisation shall be deemed likely to cause environmental pollution, unless the contrary can be shown.

[2] Repak was established as a result of a voluntary agreement between industry and the DoEHLG in 1997. It was established as a non-profit packaging compliance scheme. It was set up as in response to obligations imposed on Ireland through a EU Directive on packaging waste. If a producer of packaging waste is not self compliant then they are obliged to join such an approved compliance scheme.

- The EPA to determine that, where a waste activity is carried out in a facility connected or associated with an IPCC license activity, a license under either the *Environmental Protection Agency Act 1992* or the *Waste Management Act 1996*, but not both, will be required.

At present (September, 2007), there are two draft pieces of legislation; *the Waste Management (Facility, Permit and Registration) Regulations 2005* (DoEHLG, 2005a) and *the Waste Management (Collection Permits) Regulations 2005* (DoEHLG, 2005b) awaiting approval. These regulations have yet to be approved but if implemented they will replace *the Waste Management (Permit) Regulation 1998* (DoEHLG, 1998c) and *the Waste Management (Collection Permit) Regulations 2001* (DoEHLG, 2001a) *and the Waste Management (Collection Permit)(Amendment) Regulations 2001* (DoEHLG, 2001b) respectively.

The *Waste Management (Facility, Permit and Registration) Regulations 2005* (DoEHLG, 2005a) outlines a number of activities that are subject to a waste facility permit application to the relevant local authority including:

- The recovery of inert waste for the purposes of land reclamation, where the total capacity of waste recovered at the site shall not exceed 100 000 tonnes over the period of which the permit is granted.
- Recovery of inert waste arising from construction and demolition activity, including concrete, bricks, tiles, road planings or other such similar material, at a facility (excluding land reclamation) where the annual intake shall not exceed 100 000 tonnes per annum.
- Recovery of excavation or dredge spoil, comprising natural materials of clay, sand, gravel or stone, which comes within the meaning of inert waste. The total capacity of waste recovered at the site shall not exceed 100 000 tonnes over the period for which the permit is granted.

This legislation also provides for the following construction related activities which are also subject to registration with the relevant local authority or the EPA:

- Recovery of inert waste, for the purpose of land reclamation where the total capacity of waste recovered at the site shall not exceed 25 000 tonnes over the period for which the permit is granted.

- Recovery of inert waste arising from construction and demolition activity, including concrete, bricks, tiles, road planing's or other such material at a facility (excluding land reclamation) where the annual intake shall not exceed 20 000 tonnes per annum.
- Recovery of excavation or dredge spoil, comprising natural materials of clay, sand, gravel, or stone and which comes within the meaning of inert waste. The total capacity of the waste recovered at the site shall not exceed 25 000 tonnes over the period for which the permit is granted.

The motive for the facility permits and local authority regulations are to provide a simpler permitting process and to reduce the lead in time for the examination of applications. A provision for accurate record keeping is deemed essential to regulate the activities in both regulations:

- The draft *Waste Management (Collection Permits) Regulations 2005* (DoEHLG, 2005b) require the maintenance of records outlining the type and quantity of wastes dealt with, the origin and destination of such waste, the treatment, recovery or disposal activities which were applied and when required, the person who collected the waste.
- The draft *Waste Management (Facility, Permit and Registration) Regulations 2005* (DoEHLG, 2005a) requires a summary report be sent to the relevant local authority not later than the 28th of February of each year relating to the activities to which the waste facility permit relates.

The legislation that governs waste management in this country is just one element of the information required for the management of C&D W. The other main facet is the characterisation of the waste stream e.g. nature and source, composition and quantification.

2.4 Characteristics of C&D W

The accurate characterisation of C&D W can help identify the source, composition and quantity of the waste. This information can be used in areas of waste prevention and minimisation. In order to achieve accurate classification of C&D W, the following points must be considered:

1. The nature and source of C&D W.
2. The composition of C&D W.
3. The quantification of C&D W.

2.4.1 Nature and source of construction and demolition waste

An analysis of the principal causes of waste was carried out across 280 building sites by E.R. Skoyles over a twenty-year period from 1963 to 1983. Skoyles (1976d) attempted to determine the source of the C&D W by defining the exact nature of the waste stream as follows.

- Direct waste: represents the complete loss of a material (waste that can be prevented and involves the actual loss or necessary removal and replacement of a material).
- Indirect waste: represents a loss of material's value, usually to the contractor, which was divided into 3 broad classes:
  - Substitution wastes which are materials used for purposes other than those for which they were intended in the specification.
  - Production wastes which represent materials used in excess of those indicated in the bill of quantities, due to the production process.
  - Negligence wastes which are extra materials used in addition to the amount required by the contract due to the contractor's own negligence.

In Europe, Symonds Travers Morgan/ARGUS (1995) identified that C&D W originated from the following:

- Civil engineering infrastructure works including: power generation stations; substations; electricity distribution networks; gas production works; dams; reservoirs; water supply treatment works and sewage treatment works.
- Building and development works including: residential; commercial and industrial development.

- Transport infrastructure works including: road construction and ancillary structures; rail construction and ancillary structures; airports and associated developments; and waterways, canal construction with ancillary structures.
- Renovation, rehabilitation and maintenance aimed at prolonging the life span of the above works.
- Demolition.

Symonds et al. (1999) recognised that the type of construction and/or demolition activity will affect the origin and nature of the C&D W (Table 2.2).

Table 2.2: The different types of site that generate C&D waste in Europe (Symonds *et al.*, 1999)

Site Type	Definition
'Demolish and clear' sites	Site with structures or infrastructures to be demolished, but on which no new construction is planned in the short term.
'Demolish, clear and build' sites	Site with structures or infrastructure to be demolished prior to the erection of new ones.
'Renovation' sites	Site where the interior fittings (and possibly some structural elements as well) are to be removed and replaced.
'Greenfield' building sites	Undeveloped sites on which new structures or infrastructure are to be erected
'Road build' sites	Sites where a new road (or similar) is to be constructed on a green field site or rubble free base.
'Road refurbishment' sites	Sites where an existing road (or similar) is to be resurfaced or substantially rebuilt.

2.4.2 Composition of C&D Waste

European composition studies

Symonds *et al.* (1999) provided an overview of the composition of C&D W in Europe. It involved dividing it into 3 types of waste originating from: new construction, renovation and demolition. Renovation waste and demolition waste were found to be similar in composition (Figure 2.2).

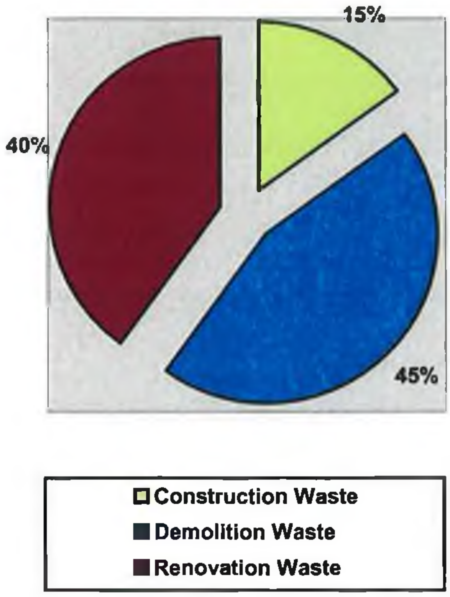


Figure 2.2 Division of European C&D Waste stream (adapted from Symonds *et al.*, 1999).

The inert fraction (including excavated materials) is considered the most important fraction of the C&D waste stream due to its quantity and potential for reuse and/or recycling. It has been estimated that 80 per cent of C&D W consists of stoney materials like concrete and masonry while the rest consists of glass, rubber, plastics, timber, metals and asphalt (Hendricks, 1987). This figure has been estimated as 90 per cent of the waste stream in some EU Member States (Symonds et al., 1999).

The varying type and number of waste components makes it difficult to provide a definite list of each component for composition purposes. It is possible however, to identify a number of key components, which can be expected to occur to some extent in the waste arisings (Symonds Travers Morgan/ARGUS 1995). These are: soils and subsoil; excavated fill and made ground; concrete; asphalt and bitumous materials; bricks and tiles; timber (treated and untreated); plaster, plasterboard and other internal finishes; plastics; metals; architectural features; mixed debris.

A study was carried out in the UK between 1999 and 2001 of the C&D W accepted at landfill sites and waste transfer stations in the Greater Nottingham area (APT Environmental, 2002). The aim of the study was to investigate the potential of using recycled resources in construction. The analysis was split into 2 different surveys. One was known as 'small load' surveys, which were skips with less than 4 tonnes of waste. The other was known as 'large load' surveys, which were skips greater than 4 tonnes of waste. The small load surveys consisted of a hand picked analysis with each component individually weighed, while the 'large load' survey was based on weighbridge receipts (Table 2.3). The inert fraction is 58 per cent of the waste stream composition with the non-inert fraction standing at 42 per cent. The largest non-inert contributors are timber waste at 13 per cent and metals (ferrous and non-ferrous) at 6 per cent.

Table 2.3 Summary of hand picked and bulk survey results (1999-2001) for the Greater Nottingham area, UK (adapted from APT Environmental, 2002)

Material	% of Total
Concrete and concrete blocks	13.92
Bricks – commons, facings and engineering	8.84
Cement	0.06
Ceramic tiles	1.28
Plaster	0.07
Roof tiles	1.69
Rubble/hardcore	30.06
Sand and stone	1.97
Inert sub total	**57.89**
Brick banding	0.02
Cabling	0.31
Carpet	0.55
Fibreglass	0.27
Glass	0.53
Metals – ferrous and non-ferrous	5.83
Miscellaneous	9.42
Paper/cardboard	1.42
Plasterboard	1.80
Plastic and polystyrene	1.33
PVC piping	0.57
Roofing felt	0.81
Tarmac/asphalt	1.35
Timber	12.64
Vegetation	5.26
Non-inert subtotal	**42.11**
Total	**100.00**

Irish composition studies

There was no single body responsible for the generation of waste statistics in Ireland before the EPA was formed. The *National Waste Database Report, 1995* (EPA 1996a) was the first report that produced any statistics on the C&D W stream. The report did not fully address the issue of composition of C&D W but did state that it estimated that 36 per cent of the total estimated C&D W stream comprised of soil and stones. The same fraction was estimated to account for 97 per cent of the total material recovered in 1995.

The *National Waste Database Report, 1998* (EPA, 2000) estimated the composition based on a single survey conducted in 1996 with the inert fraction accounting for 90 per cent of the waste stream (Figure 2.3). The report made a key recommendation that further compositional surveys were required to provide a more comprehensive analysis of the components of C&D W.

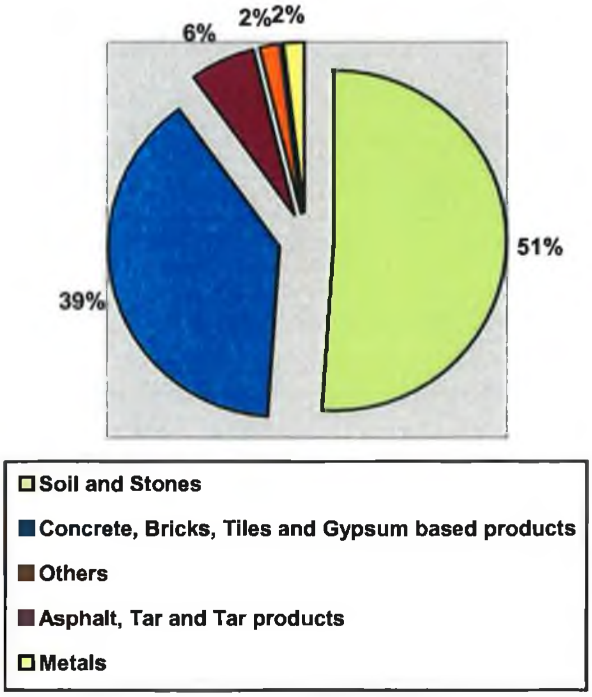


Figure 2.3 Estimated composition of C&D W in Ireland in 1998 (EPA, 2000)

The *National Waste Database Report, 2001* (EPA, 2003) and the *National Waste Report 2004* (EPA, 2005a) did not provide any further compositional studies of the C&D W stream.

The EPA introduced the following categories of building construction, repair and maintenance in the *National Waste Database Report 2001* (EPA, 2003):

- Residential (new private and public housing).
- Private non-residential (private and semi-state industry, commercial, agricultural, tourism and worship).
- Productive infrastructure (water and sanitary services, airports, harbours, energy and telecommunications).
- Social infrastructure (education, health, public buildings, local authority services and the Gaeltacht).

The *National Waste Report 2004* (EPA, 2005) stated that the soil and stone fraction comprised 76 per cent of the total C&D W collected at licensed and permitted facilities and had a recovery rate of 90 per cent while the other fractions i.e. concrete and rubble, wood, glass, metal and plastic had a recovery rate of 69 per cent.

An adequate analysis of the composition of C&D W will help provide accurate data for the quantities of waste analysed. The quantification of C&D W provides the data, which is used to monitor waste activity in the construction industry and can be considered to be the most important characteristic of C&D W.

2.4.3 Quantification of C&D W

European waste production estimates

In a report to the European Commission, Symonds *et al.* (1999) estimated that 'core C&D W[3] production was in the region of 180 million tonnes per annum, which equates to 480 kg per person per year. The report also outlined that only 28 per cent of the estimate was reused or recycled across the EU.

[3] Core C&D W: Is the mix of materials obtained when a building or a civil engineering structure is demolished. It excludes road planings, excavated soil, drainage pipes, service connections (gas, water, electricity) and surface vegetation.

A report prepared by the European Environment Agency (EEA) (Brodersen *et. al.*, 2002), which reviewed selected waste streams in the EU produced a total C&D W estimate of 385 million tonnes. The inclusion of more recent estimates for Greece (Fatta *et al.*, 2003) Ireland (EPA, 2005a), Italy (Sara *et al.*, c.1999) and UK (Smith *et al.*, 2002) increased the total estimate for total waste production to 495 million tonnes (Table 2.4) (Kelly, 2006 adapted from Brodersen *et al.*, 2002).

Table 2.4 Total C&D W production per country based on recent estimates available (Kelly, 2006 adapted from Brodersen *et al.*, 2002)

Country	Year	Quantity (tonnes/annum)	Quantity (tonnes per capita/annum)
Austria	1999	7 500 000	0.9
Denmark	1997	3 427 000	0.6
France	1992	25 000 000	0.4
Germany	1996	219 921 000	2.7
Greece*	2003	3 900 000	0.3
Ireland**	2004	11 200 000	2.6
Italy***	c.1999	40 000 000	0.7
Netherlands	1996	13 650 000	0.8
Spain	1999	20 628 000	0.5
UK****	2002	150 000 000	2.5
Total		**495 226 000**	

* Fatta et al. (2003) estimate C&D waste production in Greece to be 3.9 million tonnes per annum.
** EPA (2005a) estimated that C&D waste production in Ireland in 2004 was 11.2 million tonnes.
*** Sara et al. (c.1999) estimated that construction and demolition activities produce over 40 million tonnes of waste a year in Italy
**** Smith et al. (2002) estimated that the total mass of a solid waste from the U.K. construction industry in 1998 was 50 million tonnes.

Brodersen *et al.* (2002) identified that the waste amounts per capita varied considerably from country to country. This was partly due to cultural and economic diversity as well as the differing definitions:

"There are also differences in definition used, for instance, the reason for the high level in Austria and Germany can be explained by the fact that these countries include excavated soil and stone in their waste data."

(Brodersen *et al.*, 2002)

Jacobsen *et al.*, (2004) followed up with a report which provided an inventory of existing information on the recycling of selected waste materials including plastic, paper, aluminium, steel, glass, rubber, textiles and inert waste. It stated that:

"Inert waste in the form of construction and demolition waste is probably the largest waste stream among the eight materials in kg per capita. However, due to lack of harmonised data it is not possible to prepare good indicators on the EU waste generation."

(Jacobsen *et al.*, 2004)

Irish waste production estimates

In Ireland, the EPA has sole responsibility for preparing data, which help provide figures for waste production within the state. The EPA is dedicated to preparing national surveys every two years under the *Waste Statistics Regulations 2002* (Council of European Communities 2002), to establish key trends on waste flows. The *National Waste Database Reports* (EPA, 1996a, 2000, 2003, 2005a, 2006) have attempted to provide waste estimates for C&D W production in Ireland (Table 2.5).

Table 2.5 National waste database C&D W estimates 1995, 1998, 2001, 2004 and 2005 (adapted from EPA, 2003)

Report	Published	Quantity (tonnes)	% of Total Waste
National Waste Database report, 1995	EPA, 1996	*1 318 908	3.1
National Waste Database report, 1998	EPA, 2000	2 704 958	3.4
National Waste Database report, 2001	EPA, 2003	3 651 411	4.9
National Waste report, 2004	EPA, 2005	11 167 599	13.1
National Waste report, 2005	EPA, 2006	**14 931 486	n/a

* In the National Waste Database Report 1995 (EPA, 1996a), the estimated figure for C&D W production was 1 520 000 tonnes. Table 2.6 was adapted from the National Waste Database report 2001 (EPA, 2003) where the 1995 estimate was recorded a 1 318 908 tonnes.
** The National Waste report, 2005 is a 'data update' report containing an update on certain waste statistics so any total provided would not be a true reflection of the waste produced for that period.

The data presented (Table 2.5) demonstrates the massive increase in waste production over a ten-year period. The introduction of the *Waste Management Act, 1996* (DoEHLG, 1996) which requires greater reporting of waste produced along with the significant economic growth and development over the same period can be deemed partly accountable for the increase in waste production.

Conclusions

The main aims of this chapter were to:

- Examine the current legislation and the various waste regulations relevant to contractors and explain the impact that these regulations have on the construction industry in Ireland and also the current legislation and policies in place in Europe and how they have impacted on Ireland.
- Identify the characteristics of C&D W.
- Provide an overview for the composition of the C&D W stream throughout Europe and Ireland.

The main conclusions are as follows:

- This chapter examined the waste legislation that has been introduced into Irish law since the implementation of the Waste Management Act in 1996.
- The implementation of the various waste legislation and regulations has been successful in raising awareness amongst contractors in the industry about the importance of seeking alternative processing methods for C&D W management.
- There is a lack of accurate reporting of waste activities within the construction industry. The draft *Waste Management (Collection Permits) Regulations 2005* (DoEHLG, 2005b) and *the draft Waste Management (Facility, Permit and Registration) Regulations 2005* (DoEHLG, 2005a) due for implementation by the end of 2007 have recognised the lack of this information. This legislation also provides processing alternatives for the industry.
- The characteristics of C&D W were examined looking at the nature and source, composition and quantification of C&D W and it was concluded that there is a lack of reliable and accurate data on C&D W production worldwide. One of the main reasons for this is the lack of a harmonised reporting framework that would provide consistent data (Jacobsen *et al.*, 2004 cited in Kelly, 2006)

- EPA reports have shown that there has been a significant increase in C&D W production in Ireland over the past ten years, from 1.52 million tonnes in 1995 to 14.9 million tonnes in 2005.

The estimates used in the EPA reports did not include any waste production data from construction sites in Ireland. The next chapter will examine research carried out in the Department of Building and Civil Engineering in the Galway-Mayo Institute of Technology, which produced waste production indicators based on 58 point source assessments of construction projects in Ireland over a two-year period (Grimes, 2005 & Kelly, 2006).

Chapter 3 An Analysis of the Development and Testing of an Original C&D W Auditing Tool in Ireland

3.1 Introduction

The introduction of the *Environmental Protection Agency Act 1992* (DoEHLG, 1992) was the first step towards providing national estimates for C&D W production in Ireland. The EPA produced *The National Waste Database Report 1995* (EPA, 1996a) and a report was produced every three years thereafter (EPA 2000, 2003, 2005a, 2006).

The Galway-Mayo Institute of Technology Building and Civil Engineering Research Department carried out two research projects as part of the Environmental Research, Technological Development and Innovation (ERTDI) Programme under the Productive Sector Operational Programme 2000 – 2006. The ERTDI programme is financed by the Irish Government under the National Development Plan. The programme is administered on behalf of the Department of Environment, Heritage and Local Government by the EPA, which has the statutory function of coordinating and promoting environmental research (EPA, 2007). These research projects designed and tested an original waste-auditing tool on 58 construction sites. The audit guidelines adapted from Patterson (1999) were used to design the audit methodology.

The aims of this chapter are to:

- Provide a comprehensive overview of the C&D W analyses carried out by Grimes (2005) and Kelly (2006) and list the limitations and recommendations that were identified by these studies.

3.2 C&D W Production Estimate Methodologies used in Ireland

The methodologies employed by the EPA over the past ten years to estimate C&D W production consist of:

- Questionnaires, either paper-based and/or electronically based, sent out to relevant parties in the construction, demolition, waste management industries and local authorities.

- Data collected from licensed waste collectors and facilities or sites licensed or permitted to accept C&D W through questionnaires and environmental reports.
- Conversion of US unit waste factors (Franklin Associates, 1998) applied to construction output to produce national estimates.

The National Waste Database Report 1995 (EPA, 1996a) carried out a survey of the construction and demolition industry using questionnaires with a view to establishing statistics for C&D W production. A response of only 11 per cent was received. The report provided an estimate that 1.52 million tonnes of C&D W was produced.

The National Waste Database Report 1998 (EPA, 2000) focused on the local authorities. A digital national waste database module was issued to each local authority containing information reported by the local authority in 1995 and a digital questionnaire for completion in 1998. The local authorities were required to report on the flow of waste arising in their functional area. The report estimated that 2.71 million tonnes of C&D W was produced in 1998.

The National Waste Database report 2001 (EPA, 2003) applied a methodology to calculate construction and demolition waste output based on the application of US EPA waste factors to construction industry outputs for 2001. A methodology involving the use of records of C&D W accepted for recovery and disposal at all EPA-licensed and local authority-permitted facilities was also applied. The report estimated that 3 651 412 tonnes of C&D W was produced in 2001. This represented 4.9 per cent of the total waste produced and 21 per cent of all non-agricultural waste produced.

The National Waste Report 2004 (EPA, 2005a) provided estimates based on the information local authorities provided from the reports they received from waste collection permit holders. The EPA audited the 6 local authorities with the highest volume of C&D W collected. The audits involved checking the annual environmental report (AER) returns from waste permit and collection permit holders. The audits covered 42 per cent of the C&D W, which had been reported as having been collected. The local authorities reported that the total quantity of C&D W collected in

- Skip volume analysis form developed by the Construction Industry Research and Information Association (CIRIA) (Coventry *et al.*, 2001).

After examining the methodologies used by the EPA and the UK models, Kelly (2006) decided that the best strategy was to develop and test an original audit tool on sites in Ireland using the best aspects of the examined UK tools and guidelines developed by Patterson (1999).

3.4 Considerations in the Development of a Site-Based Waste Audit Methodology for use on Irish Construction Projects

The guidelines adapted from Patterson (1999) were the first step in the development of a site-based waste audit methodology. Each of these guidelines was considered individually as follows:

- Project framework.
- Waste measurement.
- Audit format.
- Waste categories.
- On site arrangements.
- Data analysis.
- Audit cost.
- Definition.

3.4.1 Project framework

The primary source of data collection used by Kelly (2006) were the students from the Bachelor of Science in Construction Management course in the Building and Civil Engineering Department of the Galway-Mayo Institute of Technology. Each student from this course had to provide C&D W data when on their work placement. Four case studies were also examined, producing a more in-depth analysis over a longer period of time (Grimes 2005).

3.4.2 Waste measurement

The three methods for measurement considered for use were as follows;

- Visual assessment or characterisation: where the skips contents were visually observed and assigned an estimated percentage volume distribution.
- Mass or physical sorting: where the composition of the C&D W was measured by physically sorting each component of the total skip contents or by sorting and measuring a representative sample.
- Photogrammetry: which is the art, science and technology of obtaining reliable information about physical objects and the environment through a process of recording, measuring and interpreting photographic images (Slama *et al.,* 1980). This involved a combination of metrical photogrammetry (quantitative measurements obtained from a photograph) and photo interpretation (qualitative analysis focusing on interpretation and identification of images).

It was clear from the outset that time was a mitigating factor. Reinhart *et al.* (2002) compared these options and concluded that:

- Visual characterisation as a method required approximately 0.5 man-hours per waste load and could be done by one person.
- The physical sort method required approximately 25 man-hours per waste load and usually required 5 to 6 people.
- The photogrammetric sorting methodology required approximately 5 man-hours per waste load and could be done by one person.

The visual characterisation method was selected, as it was the most cost effective and efficient process with minimal exposure to waste materials. Studies had shown that an experienced auditor could produce estimates comparable with physical sorting on site (Coventry *et al.*, 2001). Reinhart *et al.* (2002) also concluded that the visual characterisation method is capable of analysing approximately ten to fifty times as many waste loads compared to photogrammetric and mass sorting techniques respectively for the same analysis cost. However, considering that the photogrammetric method was estimated as requiring 5 man-hours, it was deemed worthwhile to test as a second method. The use of visual characterisation highlighted three important considerations:

- The classification of skips contents.

- The bulking of wastes.
- The use of conversion factors to convert estimated volumes m^3 to estimated weight (kg).

Classification

The identification of the components of the waste stream required a general material description and an appropriate EWC code for each one.

Bulking of Wastes

Waste bulking is where the consistency of a skip's total contents varied due to:

- The degree of compaction the waste has undergone (if any).
- The poor placement of waste materials creating air voids.
- The irregular density of some waste types.
- The irregular shape of some waste containers.

The estimation of the percentage air voids contained in a waste skip meant that the visual characterisation method was a limiting factor in the accuracy of the measurement especially where the skips contents were not compacted.

Conversion factors

The conversion factors outlined in the *Waste Management (Landfill Levy) Regulations 2002* (DoEHLG, 2002b) were used in the study to convert volumes of waste (m^3) to weights (tonnes). The factors were originally used to calculate the amount of landfill levy payable for certain materials. They are not specific to the C&D W stream, although they do provide factors for ten potential C&D W fractions.

Table 3.1 Waste conversion factors to convert m³ to tonnes (Landfill Levy Regulations, 2002)

Material	**Landfill Levy Regs. (2002)**
Paper/cardboard	0.15
Food waste	0.40
Wood/timber	0.60
Textiles	0.40
Plastic	0.15
Clean Soil	1.50
Concrete/bricks	1.50
Plasterboard	0.40
B&C Waste**	0.60
Others	1.00

*** Building and construction waste*

3.4.3 Audit format

The data collected on site was recorded in an audit book (Figure 3.1). The layout of the audit sheet within the book had to provide for the inclusion of basic information to help interpret the data that was collected. Such information included:

- Site location.
- Job description including the project category and method of construction.
- Skip size reference. Each skip was given its own individual reference number for each cycle or filling, e.g. 34WW12. This is a random reference for a skip. The 34 represents the page number from the audit book on which the data from this skip was recorded. The WW represents Walsh Waste who were the waste management company involved and the 12 represents the area volume of the skip i.e.12yd³ (9.175m³).
- Area code. This was used to identify the various areas on the site where the skips were located.

- Compaction or non-compaction of the skip contents.
- Date.
- Material description.
- An appropriate EWC code (if available for the waste type in question).
- Percentage full by visual assessment.
- Conversion to volume (m^3).
- Conversion to weights (tonnes).
- Notes/comments identifying any observations or a reference for a photograph taken.

The audit book contained useful information, which was helpful to the auditor:

- Contact numbers for fellow researchers, EPA, waste contractors and local authorities.
- The EWC and hazardous waste list for C&D W.
- Project categories as used in the *National Waste Database Report 2001* (EPA, 2003).
- A set of conversion factors for the different skip/container sizes i.e. volume percentages to m^3.
- A set of conversion factors derived from the *Waste Management (Landfill Levy) Regulations 2002* (DoEHLG, 2002b) to convert volumes m^3 to weights (tonnes).
- Procedures for carrying out an audit on site

Please complete fully as per instructions

SITE LOCATION:

JOB DESCRIPTION:

SKIP SIZE REFERENCE: **AREA CODE:** **COMPACTED/NON-COMPACTED**

AUDITOR: 0041

Date	Material	EWC Code	% Full	Quantity (m^3)	Weight (tonnes)	Notes/Comments

Figure 3.1 Audit sheet example

There was a set of 50 sheets contained in an audit book, which were in triplicate format. One audit book could cater for the visual assessment of 50 skips (Appendix C). The reason for the triplicate format allowed for distribution of the data to relevant parties involved, one copy for the research data, one copy for the contractor (if requested) and the final copy remained in the audit book for record keeping (Photograph 3.1).

Photograph 3.1 Audit book

3.4.4 Waste categories

The auditor was required to provide a detailed description of the components of the skip and their appropriate EWC code (if applicable).

3.4.5 On-site arrangements

Arrangements were made with the contractors employing the auditors. Assurances were given that the data collected was for research purposes only, and that it would remain strictly confidential.

3.4.6 Data Analysis

The purpose of the audit from the auditor's point of view was to collate the data in order to prepare a monthly audit report. A pie chart was also required which would outline the composition of the monthly waste production in percentages (Figure 3.2).

Project Description:	Residential development of 125 units		
Completed Floor Area:	2 850	**Project Stage:**	35%
Total Waste (m^3)	109.656	**Total Waste (tonnes):**	32.605
Unit Waste Factor (m^3/m^2)	0.039	**Unit Waste Factor (kg/m^2):**	11.44
Date:	01/04/05	**Auditor:**	

Materials	EWC Code	Volume (m^3)	Conversion Factor	Weight (tonnes)
Inactive or inert waste	170100	0	1.50	0
Paper and Plastics	170203	68.200	0.15	10.230
Plasterboard	170802	7.164	0.40	2.866
Canteen Waste		5.500	0.40	2.200
Timber/Wood	170201	4.100	0.60	2.460
Building & Const.Waste	170904	19.458	0.60	11.675
Glass	170202	0	0.60	0
Bituminous mixtures	170302	0	1.00	0
Metals	170400	1.800	1.00	1.800
Insulation materials	170604	3.434	0.40	1.374
Total		**109.656**		**32.605**

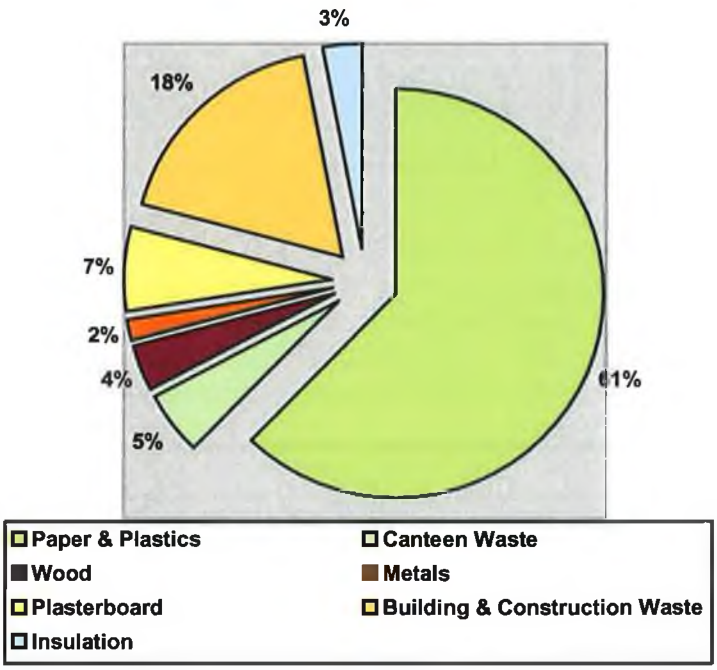


Figure 3.2 An example of a monthly report submitted to the contractor (Kelly, 2006)

Table 3.2 summarises the development of the audit tool using the guidelines adapted from Patterson (1999)

Table 3.2 GMIT audit guidelines developed (Kelly, 2006 adapted from Patterson, 1999).

Guidelines	GMIT Audit
Project Framework	All the point source assessments were 'snapshot' audits over a six-month period.
Waste Measurement	Visual assessment in intervals of 5 per cent using *Landfill Levy* conversion factors and a general material description.
Audit Format	Paper based audit book.
Waste Categories	Detailed material description with relevant EWC code if applicable.
On-Site Arrangements	Part-time auditor
Data Analysis	Simple monthly report format produced from Microsoft word.
Audit Cost	No actual cost, only the time spent carrying out the audit.
Definition	C&D W defined as all materials deposited to waste skips on site.

3.5 Audit Methodology

The main objectives of the point source assessments were to:

- Characterise the C&D W present on site
- Quantify the waste being removed from site in skips and to identify their true weight in tonnes from the WMC taking the waste off-site. This involved acquiring a copy of the WMC invoices from the main contractor on site.

There were three phases in carrying out the point source assessments on site:

1. Pre-audit information.
2. Audit data collection.
3. Post audit data analysis.

3.5.1 Pre-audit information

Each audit page in the audit book was numbered (1-50). These numbers were used to identify the skips from day-to-day as they were audited. This meant that it was essential that only one individual skip be entered on any one-audit sheet. The following information was recorded:

- Type of construction e.g. identifying whether it is residential, commercial, civil etc.
- Methods of construction. This is a very important fact in residential construction because it would be important to identify any differences in waste production.
- Floor area in m^2.
- The main contractors waste management protocol. This makes the auditor aware of any waste management or recycling initiatives that may be encountered on site. This would also make the auditor aware of the method of waste management:
  - Are general waste skips being used?
  - Is there a designated waste area or are there mini skips dispersed all over the site?
  - Are material segregation practices taking place?
  - If so, what materials are being segregated?
  - Is it being policed/enforced by the main contractor?

All of these factors outlined had some affect on the auditor's methodology and the overall quality of the audits.

3.5.2 Audit data collection

The basic requirements for a best practice skip analysis are as follows:

- The date on which the audit took place.
- An accurate material description of the components in the skip.
- A percentage estimate of the volume of each component in the skip by visual assessment. It was essential to begin this process when the skip was empty.
- Record whether the skip was compacted or non-compacted.

The following steps also needed to be carried out after the site audit had been carried out. This would usually be at a later date because the auditor would not have the relevant information on site when carrying out the audit.

- A EWC code was applied to the material description, if a suitable code existed. If no code existed then an accurate material description was given.
- The percentage volume estimate was converted into (m^3) using the skip size conversion factors provided (Kelly, 2006) (Appendix D).
- The volume estimate (m^3) was converted into a weight estimate (tonnes) using the *Waste Management (Landfill Levy) Regulations 2002* (DoEHLG, 2002b) conversion factors provided.
- Notes/comments on the causes of the waste should be included.

3.5.3 Applying the visual characterisation method on site

A visual audit was conducted on a daily basis. It involved the assessment of the contents of each skip on the chosen site (Photograph 3.2 to 3.5)). The focus of the research on the site was to analyse the contents of the C&D W skips daily throughout the cycle of the skip (Figure 3.3). The cycle of the skip can be defined as the period of time from when the skip's volume is 0 per cent until the skip's volume reaches 100 per cent and is removed by the waste management contractor (WMC).

Photograph 3.2 **Mixed Waste Skip.** **Day 1**

Photograph 3.3 **Mixed Waste Skip.** **Day 2**

Photograph 3.4 **Mixed Waste Skip.** **Day 3**

Photograph 3.5 **Mixed Waste Skip.** **Day 4**

SKIP SIZE REFERENCE: 22WW12 AREA CODE: N/A ~~COMPACTED~~/NON-COMPACTED

AUDITOR: 0022

Date	Material	EWC Code	% Full	Quantity (m^3)	Weight (tonnes)	Notes/Comments
24-5-06	Mixed Waste		30%	2.753		Photo 1
	Cardboard		25%	2.294	0.918	
	Plastic		2.5%	0.229	0.034	
	Timber		2.5%	0.229	0.137	
25-5-06	Mixed Waste		45%	4.129		Photo 2
	Cardboard		5%	0.459	0.134	
	Aeroboard		5%	0.459	0.459	
	Sweepings		5%	0.459	0.275	
30-5-06	Mixed Waste		55%	5.046		
	Cardboard		2.5%	0.229	0.092	
	Blocks		2.5%	0.229	0.344	
	Plastic		2.5%	0.229	0.034	
	Timber		2.5%	0.229	0.137	
1-6-06	Mixed Waste		100%	9.175		Photo 1 & 2
	Cardboard		15%	1.376	0.550	
	Plastic		15%	1.376	0.206	
	Sweepings		15%	1.376	0.826	
	TOTAL		100%	9.175	4.196	

Figure 3.3 An example of a completed audit sheet for a skip cycle

3.5.4 Post-audit analysis

The auditor was required to prepare a report at the end of each month outlining the findings of the skip analysis. The data collected throughout the month was brought together to provide a total for each material for the month. The monthly report contained the following information:

- Project description included the project category and method of construction as described previously.
- Total floor area expressed in m^2 of the overall project.
- The project stage expressed in percentages i.e. 0 per cent denoted the commencement with 100 per cent implying completion.
- The completed floor area expressed in m^2 for relevant month. This was extrapolated from the percentage work done in any month multiplied by the overall project floor area e.g. if 10 per cent of the work was completed in the month of April and the total floor area was 15 000 m^2, then the completed floor area for the month of April is 1 500 m^2.
- The monthly skip analysis totals consisted of: material description; EWC codes; volume (m^3) and weight (tonnes).
- Total number of skips identifying skip volumes. This was easily calculated by counting the number of audit sheets that were used in the month.
- Total waste expressed in m^3 and tonnes.
- Unit waste factors calculated by:

$$WF^V = V / FA^C$$

where: WF^V = Volume waste skip factor expressed in m^3/m^2
V = Volume of waste in m^3 and
FA^C = Completed floor area in m^2

Equation 3.1 Calculation of volume unit waste skip factors (m^3/m^2) (Kelly, 2006)

and

$$WF^M = M / FA^C$$

where: WF^M = mass unit waste skip factor expressed in kg/m^2

M = mass of waste in kg and

FA^C = Completed floor area in m^2

Equation 3.2 Calculation of mass unit waste skip factors (kg/m^2) (Kelly, 2006)

3.5.5 Results

The research carried out by Kelly (2006) provided the following results:

Table 3.3 New residential construction results (Kelly, 2006)[4]

Total weight waste factors (kg/m^2)/no. of sites = 1 335.180/19 =	**70.3 kg/m^2**
Total volume waste factor (m^3/m^2)/no. of sites = 2.041/19 =	**0.107 m^3/m^2**

Table 3.4 New private non-residential construction results (Kelly, 2006)[5]

Total weight waste factors (kg/m^2)/no. of sites = 1 909.983/22 =	**86.82 kg/m^2**
Total volume waste factors (kg/m2)/no. of sites = 2.883/22 =	**0.131 m^3/m^2**

Table 3.5 New social infrastructure construction results (Kelly, 2006)[6]

Total weight waste factors (kg/m^2)/no. of sites = 1 250.491/9 =	**138.94 kg/m^2**
Total volume waste factors (m^3/m^2)/no. of sites = 1.746/9 =	**0.194m^3/m^2**

Table 3.6 New productive infrastructure construction results (Kelly, 2006)[7]

Total weight waste factors (kg/m^2)/no. of sites = 145.430/3 =	**48.48 kg/m^2**
Total volume waste factors (m^3/m^2)/no. of sites = 0.292/3 =	**0.098 m^3/m^2**

Table 3.7 New residential demolition results (Kelly, 2006)[8]

Total weight waste factors (kg/m^2) * =	**813.788 kg/m^2**
Total volume waste factors (m^3/m^2)* =	**0.603 m^3/m^2**

[4] Based on 19-point source assessments.
[5] Based on 22-point source assessments.
[6] Based on 9-point source assessments.
[7] Based on 3-point source assessments.
[8] Based on 1-point source assessment.

3.6 Limitations

The following limitations were identified:

- The accuracy of the visual audit was heavily dependent on the competency of the auditor and the level of precision at which they carried out the audit.
- The influx of a large volume of C&D W into skips during a time of high construction output had an effect on the accuracy of the visual audit. The volume of a skip rising from 10 per cent to 90 per cent full between 2 audits made it difficult to account for the waste being disposed which meant some components might be under or over estimated which effects data accuracy.
- The removal of the C&D W skip before the final audit was carried out was another frequent occurrence that effected data accuracy. This often led to the final 10 – 20 per cent of the skip's volume being left unaccounted for.

3.7 Recommendations

- A photographic record of the day-to-day contents of a skip could be seen as a backup to the visual audit information. Such photographs could be referred to if there were issues with the visual audit data presented. These photographs could also be used for the possible application on another method of auditing.
- In times or high levels of construction output the solution might be to increase the number of visual audits carried out each day. This would be necessary when it becomes clear that that a single audit per day will not suffice.
- When the final audit is missed due to the removal of the skip before it is carried out, it is probably the most significant occurrence to affect the accuracy of the data throughout the entire auditing process. This may however be avoidable. Liasing with both the main contractor on site and the WMC on a set time for waste removal may help the issue. The use of photographs as a data back up could also be used because any member of a site team could take a photograph of the contents of the skip.

Conclusions

The aims of this chapter were to:

- Provide a comprehensive overview of the C&D W analyses carried out by Grimes (2005) and Kelly (2006) and list the limitations that were identified by these studies.

The main conclusions are as follows:

- The different methodologies employed by the EPA (1996a, 2000, 2003, 2005a, 2006) were not site specific and produced inconsistent results for C&D W production. The limitations identified by the 1995 report are repeated in the in the 2004 report. The most significant of these is the lack of reliable data for C&D W production available from the local authorities.
- Grimes (2005) and Kelly (2006) addressed this lack of data by designing and testing an original C&D W model based on visual characterisation on 58 Irish construction projects over a two-year period.
- The use of the visual characterisation method was heavily reliant on the auditor's ability to carry out the audit accurately. This was specifically relevant when assessing air voids in non-compacted waste.
- The use of the Landfill Levy conversion factors (DoEHLG, 2002b) was an issue because it was not specifically focused on C&D W. There is a requirement for specific C&D W conversion factors.
- The investigation of the use of photogrammetric sorting for skip analysis was recommended by Kelly (2006). This forms the basis of this study.

The following chapter looks at photogrammetry and its application across various disciplines. A photogrammetric sorting method of C&D W characterisation and quantification that has been used in Florida (Medeiros, 2001) is also analysed.

Chapter 4 The Development of Photogrammetry and its Applications

4.1 Introduction

Photogrammetry has been described as a measurement technology in which the three-dimensional coordinates of points on an object are determined by measurements made in two or more photographic images taken from different positions (Terra Dat[9], 2006). Photography and the analysis of photographs have been practiced throughout the last century. The analysis of photographs has been widely used in numerous fields for various applications. The aims of this chapter are to:

- Provide a definition for photogrammetry.
- Give a general overview of photography and photogrammetry, looking at developments and areas of application with special emphasis on the construction industry.
- Examine areas where photogrammetry has been applied in the analysis of C&D W.

4.2 Definitions

Photogrammetry is a method of photographic analysis that can used to obtain information from a photograph through accurate measurement techniques or by general object identification methods. Slama (1980) defined photogrammetry as:

" the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images."

(Slama, 1980).

[9] Terra Dat Geomatics and Imaging, in association with Topcon.

4.3 The History of Photogrammetry

Early Developments

The development of modern day photogrammetry can be traced as far back as 350 B.C., long before the introduction of photography. Aristotle is known to have referred to the process of projecting images optically (Wolf, 1974).

The development of photography began in 1829 when Louis Daguerre formed a partnership with Joseph-Nicéphore Niepce. They began experimenting with metal plates. After Niepce died in 1833, Daguerre continued the work they had begun, experimenting with copper plates and silver iodide, which he discovered was light-sensitive and in 1839 he discovered that mercury vapor could develop images. Daguerre had placed a silver iodide plate in a cabinet containing various chemicals, later discovering a clear picture on the plate and by the process of elimination he determined that the miracle he had been seeking was brought by mercury vapor from a broken thermometer.

Arago, a geodist from the French Academy of Science followed on from Daguerre's invention by demonstrating the use of photographs in topographic surveying. In 1849 the first actual experiments in using photogrammetry for topographic mapping were carried out under the supervision of a Colonel Aime Laussedat of the French Army Corps of Engineers. New developments in instrumentation contributed to the growth of photogrammetry. There were improvements in cameras and films and in 1861 a three-colour photographic process was developed. In 1891, roll film was perfected by George Eastman.

In 1909, an experiment took place in Germany with stereo pairs of photographs. This was carried out by Dr. Carl Pulfrich and it formed the foundation for many modern day instrumental-mapping techniques.

The invention of the airplane at the beginning of the 20th century aided the emergence of the modern aerial photogrammetry. The airplane was first used for mapping purposes in 1913 (Wolf, 1974).

4.4 Photography Devices

A photographic image can also be described as a 'central perspective'. The explanation behind this is that every ray of light, which reached the film surface during exposure, passed through the camera lens, which is considered the single point or also known as the perspective centre. In order to take measurements of objects from photographs, the ray bundle must be reconstructed. Therefore, the internal geometry of the camera used (which is defined by the focal length, the position of the principal point and the lens distortion) has to be precisely known. The focal length is called 'principal distance', which is the distance of the projection centre from the image plane's principal point. Depending on the availability of this knowledge, the photogrammetrist divides photographing devices into three categories (University of Vienna (UNIVIE), 2007):

- Metric cameras.
- Stereo cameras.
- Amateur cameras.

4.4.1 Metric cameras

Metric cameras have stable and precisely known internal geometries and very low lens distortions. The principal distance is constant and as a result the lens cannot be focused when taking photographs. This essentially means that metric cameras are only suitable for use when there is a limited distance from camera to object. The image coordinate system is defined by fiducial marks[10], which are permanent markings within the frame of the camera. Terrestrial cameras can be combined with theodolites to extract base measurements to obtain unknown dimensions (e.g. total station). A total station is a combination of electronic transit and electronic distance measuring. The use of this device can help determine angles and distances from the instrument to points being surveyed. The angles and distances may be used to calculate actual positions in space in coordinate format (x,y,z) of the surveyed points with the aid of trigonometry. In Photograph 4.1, the total station is set up at position C. The operator and the instrument are aware of the coordinates of point C and also point A. Therefore, the instrument can calculate the coordinates of point B using the angle

[10] Fiducial marks are small registration marks exposed on the edges of a photograph. The distances between fiducial marks are precisely measured when a camera is calibrated

(<ACB) and the distance measured between point C and point B using trigonometry (UNIVIE), 2007).

Photograph 4.1 The set up position of the total station.

The other feature of the total station is the electronic distance-measuring device, which measures from the instrument to its target.

4.4.2 Stereo cameras

An object can be photographed from 2 positions and the line between the two projection centres is called the base. If both photographs are directed at the image parallel to each other and at right angles to the base, then they have similar properties as the images seen by the human retina.

Photograph 4.2 Typical stereo camera (Smith, 2007)

These two photographs become known as a stereopair and their overlapping area can be seen in 3D, simulating a human stereoscopic vision. A stereopair can also be produced with a single camera from two positions or using a stereometric camera, which consists of two cameras mounted at both ends of a bar, which has a precisely measured length. This bar is functioning as a base. Both cameras have the same geometric properties.

4.4.3 Amateur cameras

A camera can be labelled amateur when its internal geometry is not stable and is unknown. This is the case with any commercially available camera, film or digital camera.

4.5 An Overview of Photogrammetry Application

Photogrammetry has been described as the technique of measuring 2D and 3D objects (UNIVIE, 2007). These objects can be contained within photographs or stored within computer disks or memory. Such data can also be acquired through radiation sensors such as scanners. From these images information like coordinates of the required object points can be obtained. One of the best features of photogrammetry is the fact that the objects are measured without ever being touched. There are two distinct types of photogrammetry:

- Metric photogrammetry, which involves the use of precise measurements and calculations to determine sizes and shapes of objects.
- Interpretive photogrammetry, which consists of recognising and identifying objects.

Photogrammetry can be applied to answer a number of questions about a photograph, or more so the object or objects contained within the photograph. It can help identify:

- The contents of the photograph.
- The quantity of the photograph's contents.
- The quality of the item in question.

Terrestrial or close range photogrammetry is used in many different disciplines:

- In construction and civil engineering, architects and engineers use photogrammetry to supervise buildings, document their condition and any deformation or damages to a structure.
- Archaeologists use photogrammetry in a similar fashion. They would use it to document an area under investigation before and throughout an analysis.
- Forensic investigation departments can use photogrammetry to document the scene of traffic accidents or crime.

4.6 Photogrammetric Techniques

The type of photogrammetry used for any task is dependent on the camera type available (metric, stereo or amateur), the results required (2D or 3D) and the level of accuracy required.

4.6.1 Stereo-photogrammetry

As its name suggests, stereo-pairs are used as input data. If a single camera is used then two photographs are taken from different positions, attempting to match the conditions of human vision. A good example would be vertical aerial photographs. They can be created using metric cameras built into aircraft and the aspect they provide is looking straight downward. When taking the photograph, the aircraft flies over a certain area in a specific way, so that the whole area is covered by overlapping photographs. This overlapping part of the stereo-pair can be viewed in 3D and in turn can be mapped in 3D (Figure 4.1).

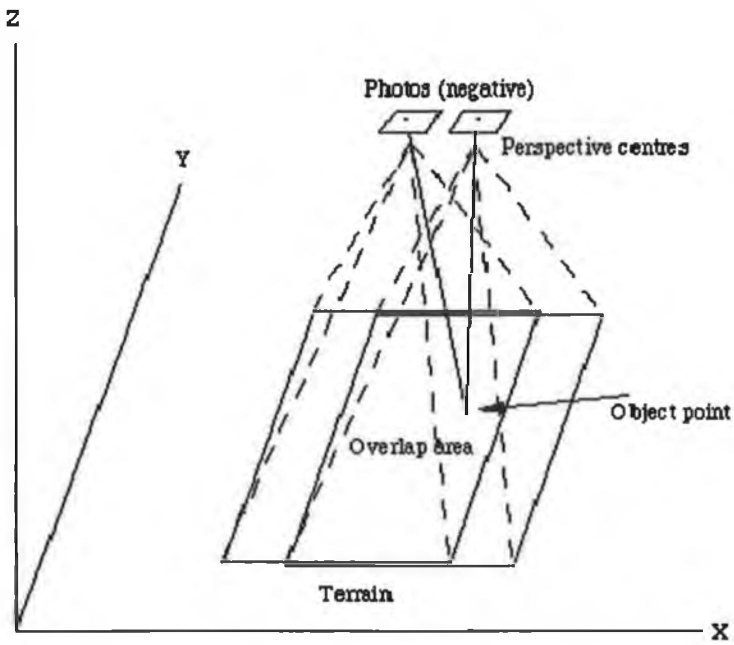


Figure 4.1 The principle of stereo-photogrammetry (UNIVIE 2007b)

Digital mapping assigns each picture element or pixel a known position and measured intensity value. The dimensions are gathered for quantitative information.

4.6.2 Mapping from several photographs

The use of computers has made 3D plotting possible from multiple photographs. These multiple photographs are taken from several positions located around the object where any object point should be visible on at least two or more objects. The important issue is that the object does not move when taking such an array of photographs of an object or scene to be used in a photogrammetric project. If the object were to move, the use of coordinates for plotting purposes could no longer be considered.

It is with the use of known control points and triangulation points that the geometry of the whole group of photographs can be reconstructed with high precision. The image coordinates of any desired object-point measured in at least two photographs can be intersected. The results are the coordinates of the required points. In this way the 3D object can be digitally reconstructed (UNIVIE, 2007).

4.6.3 Software

PhotoModeler Pro is a windows based programme, which facilitates the creation of accurate high quality 3D models and measurements from photographs. The latest release of this package provides for a variety of file export formats, enhanced photo texturing and a camera calibration function.

PhotoModeler Pro also provides features for extracting data from a single photograph. This is a useful feature for forensic applications and accident scene reconstruction. PhotoModeler has the capabilities to:

- Create diagrams and maps of the scene.
- Generate 3D models of vehicles and objects for court animations (Figure 4.2).
- Perform measurements of distance, crush, and placement.
- Create ortho-photos of skid marks and other surfaces.
- Utilise photographs from unknown sources such as bystanders and adjusters.
- Reconstruct accident scenes with just a single photograph, using either control points or object constraints.

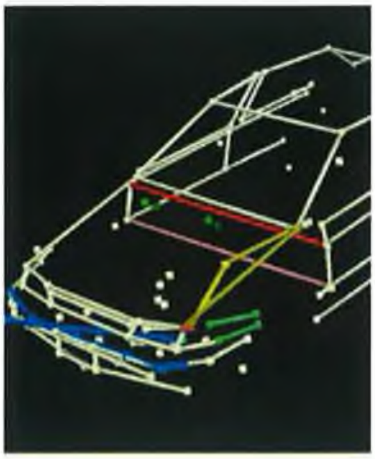


Figure 4.2 Model of a vehicle created using Photomodeler (photomodeler.com)

4.7 Close-Range Photogrammetry in Vehicle Accident Reconstruction

In 2003, a method of close-range photogrammetry was devised as part of a research project at the Dublin Institute of Technology to analyse the effects a low velocity accident has on a motor vehicle (Coyle, 2003).

The main aim for devising this technique of close range photogrammetry was to develop an accurate and fast method of measuring the damage caused to a vehicle from the impact of a collision. To measure such damage, a crush profile of the damage was created using digital photogrammetry. Photographs are taken of the damaged vehicle as soon as possible after the accident or impact. A number of photographs were also taken when the vehicle was undamaged which would be after it has been repaired. One basic requirement of this method of photogrammetry is that any point on the object that is required by the analyser to appear in the model, must appear in at least two photographs (Figure 4.3).

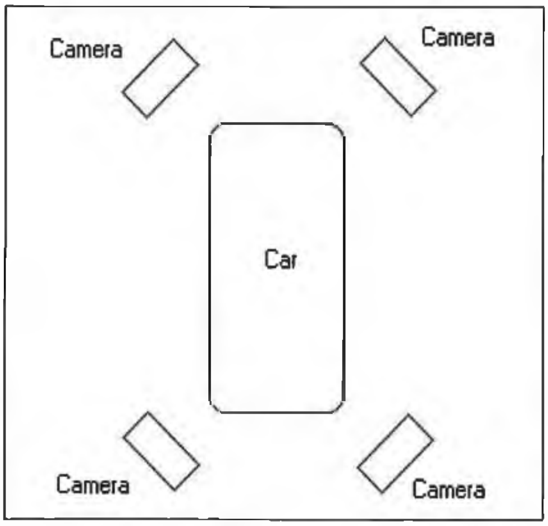


Figure 4.3 Camera locations that ensure that all points appear in two photographs (Coyle, 2003).

The photographs are then imported into a software package. The software package used for this method of photogrammetry is Photomodeler Pro 4.0. A series of targets had been placed on the vehicle and these were then marked and cross-referenced between the photographs they appear on (Photograph 4.3).

Photograph 4.3 The arrangement of targets placed on the vehicles and the indexing system in the surrounding area (Coyle, 2003).

The software calculates the 3D co-ordinates of each target and plots them, giving a 3D model of the vehicle. A model is created for both sets of photographs taken. The damaged and undamaged models are then merged together by joining the points of the targets from the damaged model, which were not involved in the impact and had not been displaced to their corresponding points on the undamaged model. The different shapes created are referred to as the crush profile.

Photogrammetry has been used in traffic management and traffic accident investigations. In accident investigation, the photographs resulting from the investigation can be useful if something was overlooked or information that may be needed to reconstruct the accident. The use of photographs will also speed up the on-site investigation and therefore restore normal traffic flow quickly.

4.8 Other areas of Photogrammetry Application

Other photogrammetry applications include: the preparation of soil maps; forest maps; geological maps and maps for city and regional planning and zoning. Aerial photographs are used in the fields of astronomy, architecture, archaeology, geomorphology, oceanography, hydrology and water resources, conservation, ecology and mineralogy. Stereoscopic photography helps bring the outdoor environment into the confines of the laboratory or office for viewing in three dimensions.

4.9 The Application of Photogrammetry in the Construction and Civil Engineering Industry

The earliest application of photogrammetry was in topographic mapping, which is still a common area of use. There are also many other categories of specialised maps which are created using photogrammetry. These maps, which vary in scale from large to small, are used in planning and designing railroads, bridges, pipelines, aqueducts, transmission lines, hydroelectric dams, flood-control structures, river and harbour improvements, urban renewal projects etc.

The field of highway planning and design uses aerial photographs to prepare and assist in area and corridor studies and to select the best route; large-scale topographic maps are compiled for use in final design; and earthwork cross sections are taken to obtain contract quantities (Wolf, 1974).

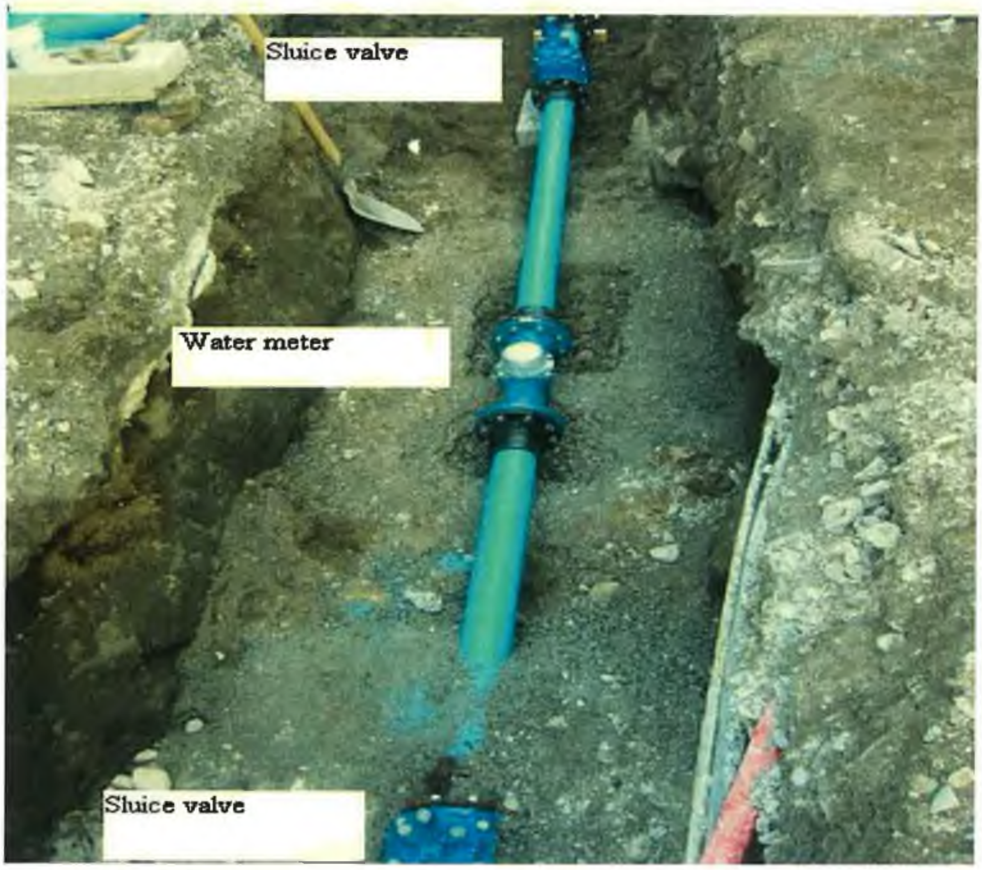
Photogrammetry has been used in the fields of archaeology and architecture. In archaeology it has been used to document archaeological excavations. It has been used in architecture to document facades of buildings in need of renovation.

Digital close-range photogrammetry is a measurement technology that can be used to obtain 3D spatial information about an object or construction site. This technology derives measurements from digital images of an object, rather than measuring the object directly. Digital close range photogrammetry has many potential applications in construction. They include accurate as-built dimensional data for remodelling, quality control of building dimensions and monitoring distortion and displacement of structures (Trupp *et al.,* 2004).

Research at the University of California at Berkeley and at the Technical University of Berlin has demonstrated that photogrammetry has the potential of an automated system for recording and documenting historical buildings (Debevec *et al.,* 1996 and Wiedmann and Rodehorst 1997). Further digital close range photogrammetry has also been used in structural tests in order to record and measure cracks in concrete during laboratory tests (Whiteman *et al.,* 2002).

Interpretive photogrammetry can be used to good effect on various construction projects where the relative local authority or planning department requires accurate as-constructed drawings after completion of the project. This is usually stipulated in the terms of planning permission. A project that would involve a connection to the public sewer or a connection to the public water main would require such drawings to be prepared. These drawings are required by the local authority for identification and location purposes and to accommodate future planning in the area.

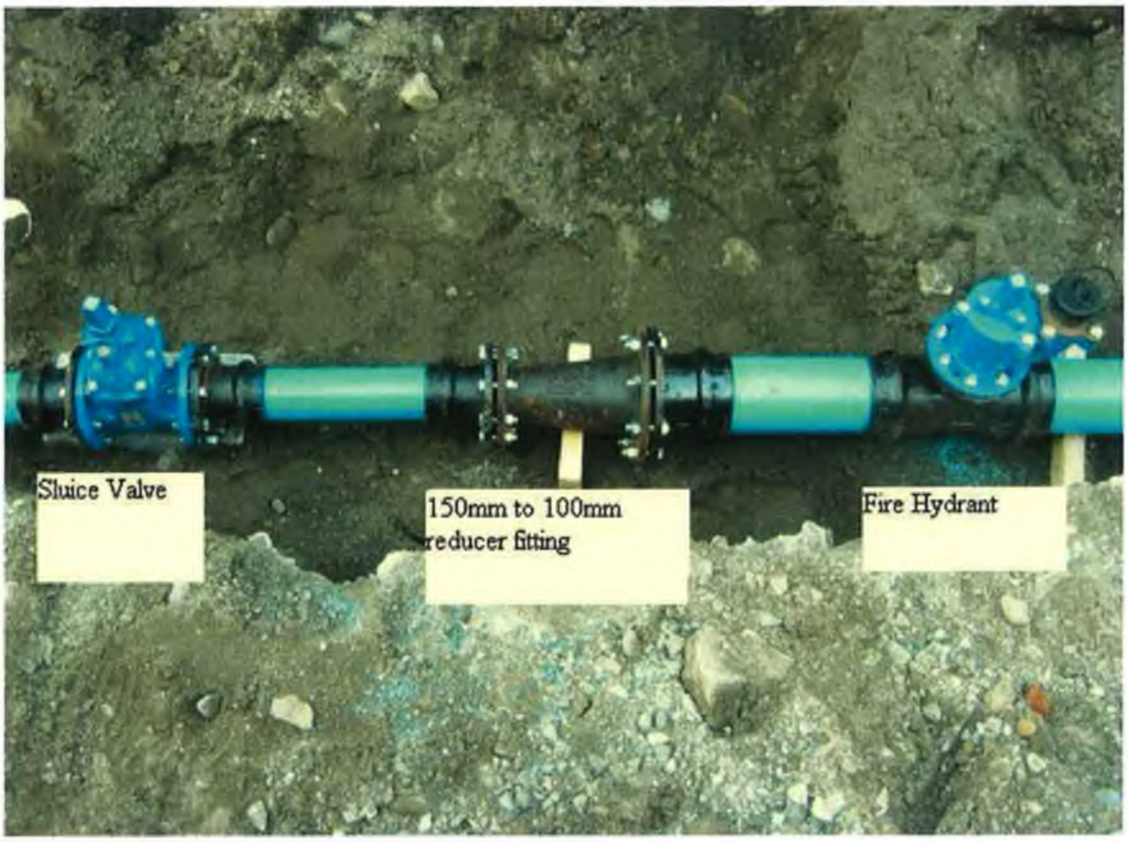
Photogrammetry can be used to record location and direction of underground services as they are being laid. It can be difficult to document every thing in an open trench with the timescale available and therefore the speed of taking a photograph is a great advantage (Photographs 4.4 & 4.5).



Photograph 4.4 Water main fixtures and fittings (Courtesy of O' Malley Construction, Oranmore Commercial Development, 2007).

In Photograph 4.4 we can see an open trench in a construction site where a water main has just been laid. The water main is equipped with sluice valves, which are located at the bottom and top of the photograph and a water meter, which is located in the centre of the photograph.

In photograph 4.5 we can see the remaining items installed on the water main. The item on the left hand side is the sluice valve, which was located at the top of photograph 4.4. This item was used as the link between both photographs for orientation purposes to help identify the sequence in which they appear. The item located in the centre of the photograph is a reducer, which helps accommodate the differing pipe sizes. The item on the right hand side of the photograph is a fire hydrant. All of these fixtures had to be recorded on the as-constructed drawing and these two photographs were used to document this on the drawing. An example of how these items appeared on the as-constructed drawing can be seen on in Figure 4.4



Photograph 4.5 Water main fixtures and fittings (Courtesy of O' Malley Construction, Oranmore Commercial Development, 2007).

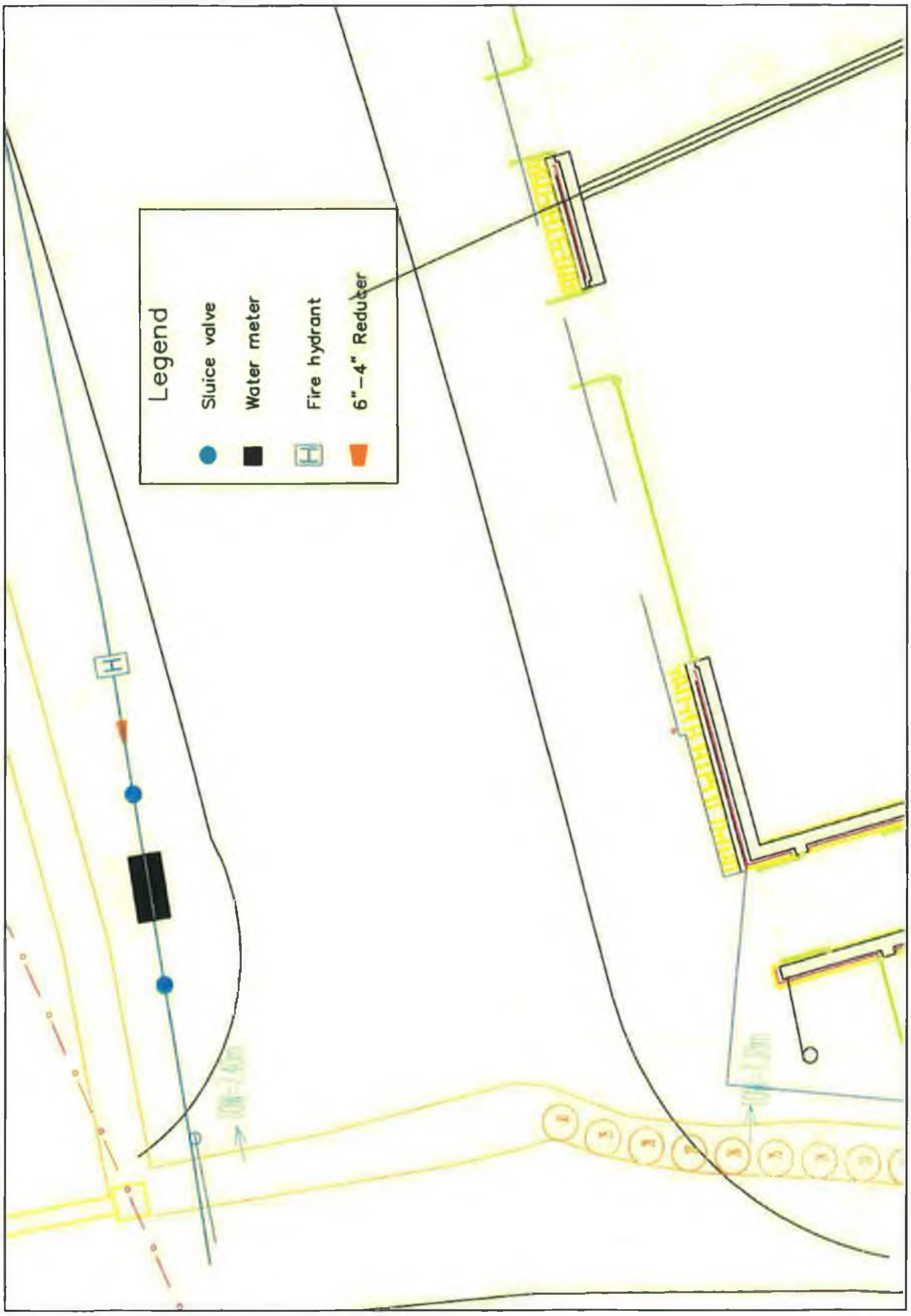


Figure 4.4 As constructed drawing created using data from photographs (MCORM, 2005) (Courtesy of O' Malley Construction, Oranmore Commercial Development, 2007)

4.10 Photogrammetric Study of C&D W in Florida, USA

4.10.1 Introduction

In 2001 a requirement was placed on the owners and operators of waste facilities by the Florida Administrative Code (FAC) to submit annual reports. These reports summarised the amounts and types of waste disposed of or recycled at licensed and permitted facilities (Medeiros, 2001). A research project was carried out in Florida, USA to test new methods of determining C&D W component composition. The motivation for the research was to provide owners and operators of C&D W facilities with methods for quantifying the quantity and composition of the waste that were being accepted on their sites (Medeiros, 2001). The study examined two methodologies:

- Mass Sort, which is the manual sorting of the contents of a C&D W load.
- Photogrammetric sorting, which is a method where a grid is superimposed on a photograph of a C&D W load to allow the auditor to determine the contents of the load.

The method of photogrammetric sorting involved the interpretation of photographs of C&D W to determine the components. This required a photograph to be taken of a truckload of waste tipped, from ground level, at a distance allowing the entire load to be visible in the image. The objectives of the study were:

- Identify and provide a weight for the C&D W categories present using the mass sort method.
- Provide figures for the volume distribution of ten C&D W loads using photogrammetric sorting.

4.10.2 Development of a mass sort methodology

A report was prepared in 2000 for the Florida Department of Environmental Protection (FDEP) where 171 loads of C&D W were visually characterised to determine the composition by volume (Townsend, 2000). The visual characterisation analysed the load at landfill and estimated the percentage volume distribution for each component present in the load.

The loads were broken down into 14 individual waste components: Dimensional Wood 44 %; Cardboard 11 %; Drywall 8 %; Roof Shingles 6 %; Concrete 5 %; Metal 5%; Pallets 4 %; Insulation 3 %; Cinder Blocks 2%; Plaster 2 %; Plastic 2 %; Buckets 1 %; Brick 1 %; Other 6 %.

Methodology

The *mass sort method* used on the research in Florida, was modelled on two previous studies carried out by The National Association of Home Builders (NAHB), 1995 and Cunningham Environmental Consulting *et al.,* 1997. The mass sort involved the following procedure:

- A load of C&D W was tipped in an area allocated for sorting.
- Both sides of the waste load were photographed for the photogrammetric sorting to be conducted at a later date.
- Each waste type was segregated into individual piles to distinguish each of the component types from themselves.
- These piles of waste would then be weighed to determine the weight of each waste component.

The research carried out in Florida was based on landfills in Citrus and Brevard County (Medeiros, 2001). The following equipment was used:

- Containers of known volume.
- Gloves for all researchers.
- Sledgehammers for breaking up large pieces of concrete.
- Weighing scales with 200 lbs (90.7 kg) capacity.
- Data collection materials (notebook).

The first step was to create piles of waste on a tipping floor for each individual waste component. These components (Table 4.1) were then placed into containers of known volume until the container was full or until the component became eliminated. The utilisation of the container was then recorded, which is the percentage of the container used. An example of a utilization percentage would be if a container were half full, it would be recorded as 50 per cent. The containers were then weighed when they were full or the flow of the waste component had ceased. This process continued for every component until the entire load was sorted and every item was accounted for, including fine materials that were collected and weighed.

Table 4.1 The components of waste examined by Medeiros (2001)

Waste Type	Composition
Wood	Plywood, strand board, particleboard, wooden pallets.
Plastic	Plastic buckets, mesh, strapping and PVC, HDPE or ABS pipe.
Concrete	Concrete rubble, walls, foundations, beams, slabs, plaster and mortar.
Flooring materials	Carpet, padding, tile (clay or marble) and linoleum
Paper/Cardboard	Corrugated cardboard boxes and packaging materials
Roofing materials	Asphalt shingles, tarpaper, roofing compound and clay tile shingles.
Municipal Solid Waste	Food waste, food wrappers and containers, beverage containers paper bags etc.
Drywall (plaster slab)	Drywall, greenboard, wonderbord, blueboard and gypsum wallboard
Land clearing	Rocks, soil, trees, branches, brush and stumps.
Metal	Re-bar, pipe, sheetmetal, wire/cable, fasteners, metal buckets, mesh, strapping, trim, flashing and gutters
Other	Items that are a byproduct of a construction or demolition project e.g. rubber hose and glass. Also objects that cannot be identified in the image.
Insulation	Foam board, fibreglass insulation
Background	Areas in the image not occupied by C&D W.

4.10.3 Photogrammetric sorting method

Methodology

The method of photogrammetric sorting used in Florida involved the interpretive analysis of photographs of the C&D W loads. These loads of C&D W were photographed from a distance that allowed the entire load to be visible in the image. At least 3 researchers photogrammetrically sorted each load. However two particular loads were different, the load referred to as Citrus 1 was analysed by six researchers and the load referred to as Citrus 3 was analysed by four researchers (Appendix E). All the results obtained were averaged. This provided the volume distribution of the load.

The software used for this research was Adobe Photoshop 6.0 but it was stated that any image editing software that has the capability to superimpose a grid on to an image could be used. However, the ability to zoom into certain areas of the image proved useful when analysing the photograph.

The most suitable grid to be superimposed to the image of the C&D W load required the following:

- Sizing: the grid was sized so that there were an equal number of rows and columns. The amount of cells present in the grid was determined by researcher preference.
- Visibility: The colour of the grid was selected to ensure that it did not blend in with or obscure any object in the image.
- Subdividing: Adobe Photoshop 6.0 has the capability to subdivide the grid cells into smaller sections called subdivisions. This aspect of the grid scheme was specified according to preference. The subdivisions using Adobe Photoshop 6.0 appear as dotted lines within the grid lines. It was important that the researchers were careful not to subdivide the grid to the extent that it obscured the image of the C&D W load (Photograph 4.6). It was also essential that the researcher had a grasp of the mathematics of each grid, especially the subdivisions and what they represented. Each subdivision represented a percentage of the total image area.

Photograph 4.6 The effect of a superimposed grid

A data acquisition form (DAF) was designed for recording the data extracted from the image (Figure 4.5). One data acquisition form was completed for each row in the image. The form would cover all the columns in that row. It should be noted that *"background"* is presented as a C&D W component on the data acquisition form. This was included for calculation purposes only and is not an actual C&D W component. Background can be explained as the areas of the photograph, which do not contain any C&D W.

A percentage was inserted into each cell of the data acquisition form. This percentage represents the percent of the total cell area occupied by that particular component. For example, if the researcher determined that 40 per cent of row 5, column 5 is cardboard, then the number 40 would occupy the space on the data acquisition form for row 5, under the column 5 heading and across from the *"cardboard"* item. Once the entire row with all the columns had been sorted, the results were averaged for row. The desired values are the average area percentage of all of the columns for each component (including background, if present). The sum of these averages should equal to 100.

Picture	
Grid	
Date	
Location	

Row	

		Column									
		1	2	3	4	5	6	7	8	9	10
Wood	Dimensional										
	CCA										
	Plywood & OSB										
	Pallets										
	Spools										
Concrete	Block										
	Mortar										
Paper	Paper										
	Cardboard										
Drywall	Drywall										
	Greenboard										
Metal	Ferrous metal										
	Non-Ferrous metal										
	Buckets										
	Wires										
	Other										
	Insulation										
Roofing	Asphalt Shingles										
	Clay Tile Shingles										
	Tarpaper										
Plastic	Wrap										
	PVC										
	Buckets										
Flooring	Tile										
	Carpet										
	Padding										
	MSW										
	Dirt/Rubble										
	Land clearing										
	Other										
	Background										
	Check										

Figure 4.5 Medeiros' (2001) Photogrammetric Sorting Data Entry Form (One Row)

Once a data acquisition form was completed for each row, the results were then entered into a computer spreadsheet version of the data acquisition form. At this point, the percentage areas for each component in each column were averaged. This yielded the percentage of the total area occupied by a component in a particular row. Once the area percentages for each component were obtained for each row, they were averaged to form a surface area distribution for the entire image.

The load itself occupied a certain portion of the image area, which was known, as the load area. The data was adjusted so that the background area was removed from the calculation, i.e. the final percentage of the component was derived only from the load area. The total area percentage occupied by a component without the background was calculated using the following proportion (Equation 4.1):

$$\frac{\text{Component }\%^{\text{adjusted}}}{100\%} = \frac{\text{Component }\%^{\text{observed}}}{(100 - \%\text{ Background})}$$

Equation 4.1 Procedure for the removal of the background

The term Component % $^{\text{observed}}$ is the area percentage originally determined by the researcher during the photogrammetric sort, i.e. it includes the background areas. The Component % $^{\text{adjusted}}$ is the equivalent to the area percentage of the component without background, i.e. the percentage of the load area that a component occupies. The results from the photogrammetrically sorting on both sides of the load (two images) were averaged to form the percent area composition of the load.

The key assumption in the photogrammetric sorting is that the area distribution of the image is directly proportional to the volume distribution of the load. Therefore, to determine the volume of each component, the final percentage of the component was multiplied by the total load volume. As a check, the sum of all the component volumes should equal the total load volume.

4.11 Limitations

The following limitations were identified:

- Shadowed areas presented difficulties in identifying the C&D W components in the image. Such areas would be dark in appearance, which would make it difficult to identify the C&D W component.
- The assumption for photogrammetric sorting that the area distribution of the image is directly proportional to the volume distribution of the load is a very questionable assumption. For such an assumption to be true would require the use of scaling factors for the image.
- The volume of waste being missed or not being included in the final tally would have been high. The use of just two photographs, one from either side, made it difficult to record the waste situated internally in the pile of waste. The use of a series of photographs should have been considered. Photograph 4.7 is an example of a typical pile of waste on an Irish construction site. It illustrates how difficult it would be to identify all the C&D W present especially those at the centre of the pile. This raises a case for a sequence of photographs to be taken as the waste accumulates.

Photograph 4.7 A pile of C&D W (Grimes, 2005)

4.12 Results

Medeiros presented his results (Table 4.2) in the following format:

- The volume distribution estimates were presented and the accuracy of these estimates provided by photogrammetric sorting and the mass sort methodologies were examined.
- The individual weight predictions were:
    - Individual component volume distribution from the mass sort methodology.
    - Individual component volume distribution from the photogrammetric sorting methodology.

Table 4.2 Average volume distribution estimates generated by photogrammetric sorting and a mass sort for ten case studies in Florida (Medeiros 2001)

Waste Component	Photogrammetric Sort Distribution (percent)	Mass Sort Distribution (percent)	Relative Error to the Mass sort[11] (percent)
Wood	23.5	26.9	12.6
Concrete	8.0	9.9	19.2
Paper	31.9	29.8	7.0
Drywall	6.1	2.9	110.3
Metal	2.5	3.6	30.6
Insulation	4.1	4.3	4.6
Roofing	7.5	6.3	19.0
Plastic	11.9	10.8	10.2
Flooring	1.6	1.3	23.1
MSW	1.5	1.9	21.1
Land Clearing	0.8	1.5	46.7
Other	0.6	0.7	14.3
TOTAL	**100**	**100**	

[11] For the component wood, the photogrammetric sort figure (23.5) is subtracted from the mass sort figure (26.9) which gives 3.4. This is divided by the mass sort figure (26.9) and multiplied by 100 to express it as a percentage of the mass sort figure 12.6%.

The initial mass sort and the results that it provided are the actual values that photogrammetric sorting predictions are compared to. The error between the prediction method and the results of the mass sort determines the accuracy of the each method. When looking at the results, there is an indication of similarities between the results provided by both methods. The volume percentage for wood shows a difference of 3.4 per cent. However, when this is difference of 3.4 per cent is expressed as a percentage of the mass sort it shows a difference of 12.6 per cent This is still a relatively small difference between the two results when compared to the difference between the two results for drywall. There is a difference of 110.3 per cent for the two figures listed. An observation can also made on the relationship between the components paper, drywall, roofing, plastic and flooring. The volume percentages for these components are greater for the photogrammetric method. These components could be made of sheets and objects with a large surface area and a relatively low volume. The mass sort would identify this but the photogrammetric method may not.

The results from each of the ten case studies carried out in Florida using photogrammetric sorting and mass sort methodologies are found in Appendix E.

Conclusions

The aims of this chapter were to:

- Provide a definition for photogrammetry.
- Analyse the numerous areas in which photogrammetry is used with special emphasis on the construction industry.
- Look at areas where photogrammetry has been applied to the analysis of construction and demolition waste and determine whether it is a viable application.

The main conclusions are as follows:

- Slama (1980) defined photogrammetry as:

  "the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images"

  (Slama, 1980)

- Areas such as mapping, civil engineering, planning, archaeology and environmental studies were identified as disciplines where photogrammetry can be applied with a special emphasis on interpretive photogrammetry. It was concluded that photogrammetric analysis has a function across various disciplines and that the interpretive branch of photogrammetry could provide a suitable means for C&D W analysis.

- Medeiros (2001) analysis of C&D W composition and quantity using photogrammetric sorting provided an increasing platform from which to develop a methodology for testing on Irish construction sites.

The following chapter looks at the development and application of a photogrammetric sorting method for C&D W analysis on a selected case study in Ireland.

Chapter 5 The Application of a Photogrammetric Sorting Methodology to Audit Construction and Demolition Waste.

5.1 Introduction

The application of photogrammetric sorting to audit C&D W skips on site is a new initiative in Ireland. This follows from a landfill site study carried out in the USA by Medeiros (2001) and recommendations outlined by Kelly (2006) in his development of waste production indicators for the Irish construction industry.

A photograph allows the auditor to analyse the skip's contents for as long as deemed necessary, which may not be possible with a visual audit.

The main aims of this chapter are to:

- Provide a full overview of how visual characterisation and photogrammetric sorting were applied to estimate C&D W production on a selected residential construction site in Galway.
- Discuss the validity of the methods used.

5.2 Waste Audit Methodology & Case Study Description

A waste audit can be defined as:

"*A tool for measuring the composition and quantity of wastes arising from construction activities.*"

(Patterson, 1999)

The photogrammetric sorting and visual characterisation methods of C&D W auditing were selected as the most appropriate methods and were applied to the C&D W skips on a residential construction site consisting of mainly two-storey housing, over a fifteen-month period. The mass sort method required a number of researchers to apply the method properly, which was not an option for this study. The photogrammetric method required a series of photographs to be taken capturing the contents of a C&D W skip throughout its cycle, which is the time it takes for the skip's volume to go from zero to 100 per cent. Every C&D W skip was audited daily with 2 photographs taken of the skips contents during each audit. The number of photographs that accumulated over the cycle of the skip depended on:

- How many daily audits were carried out, which was determined by how days it took for the skip's volume to reach 100 per cent capacity.

5.2.1 Pre-audit equipment checklist

The following is a list of the equipment required to analyse the contents of a C&D W skip using photogrammetry:

- A Digital Camera.
- Adobe Photoshop 7.0. This is a readily available software package used for the editing and manipulation of images.
- Microsoft Excel 2000. This package would be used to input data collected from the photographs to set up an electronic format for statistical analysis. The excel programme catered for any adjustments or comparisons required.
- Personal Computer (PC). A Dell dimension 4400. The software that is supplied with the camera is loaded on to the PC, which allows the photographs to be uploaded from the camera. The Adobe Photoshop software package was also uploaded to the PC where it was used to study and analyse the photographs in question. The PC also required the Microsoft Excel 2000 software for the electronic storage of data.

5.2.2 Pre-audit preparation

The method of auditing waste through photogrammetry was run concurrently with the visual audit analysis. The main reason for this was that it would be possible to compare and contrast the two different methods. A series of pre-audit checks were required before the photogrammetry method was used examining the:

- Site environment and on-going activities
  - The level of construction being carried out at the time of waste auditing.
  - The access to the site, especially the areas where the C&D W skips were located.
  - The wishes of the contractor, if any, in relation to suitable times to visit the site.

- The current waste management system in place.
  - The number of skips in use on site and their quantity in m^3.
  - Waste segregation practices that may be in place.
  - The types of waste being segregated on site.

- The waste management contractor.
  - The name, address and contact number for the company or companies removing C&D W from the site.

It was soon discovered that the accuracy of the study could be significantly affected by the quality of photographs being presented. It was important to detect what calibre of photograph could be produced before any photography took place on site. This identified the need for some on-site assessment of the environment. The following issues with regard to the photography environment on site were looked at:

- The level of elevation above the skip that the photographs could be taken from.
- The safety of the environment around the skip area whilst the photographs are taken.

Health and safety is a concern on any construction site. It was important to address this issue before any audit was carried out on site. A site induction was received from the main contractor on the site where the audits would take place. This is a general briefing of all new personnel or visitors to a site. It involves:

- Raising awareness of the dangers that are present on site.
- The type of machinery on site.
- Site rules.
- First aid on site.
- The various accident and emergency procedures and assembly points.
- Personal protective equipment required.
  - Hard hat.
  - High visibility vest.
  - Steel toe cap boots.

After receiving this induction along with wearing the appropriate personal protective equipment (PPE), the auditor was deemed equipped to carry out an on site audit.

Initially all of the pre-audit checks were a time consuming factor, however as an every day routine became established, these pre–audit checks did not require the same attention for each audit.

5.3 On–site procedures

The number of skips that were analysed on this site over the duration of the research was sixty-two. There were 2 skips on site permanently, which were audited every day. This meant that at each audit, four photographs were taken including two photographs per skip, one from the front and one from the rear.

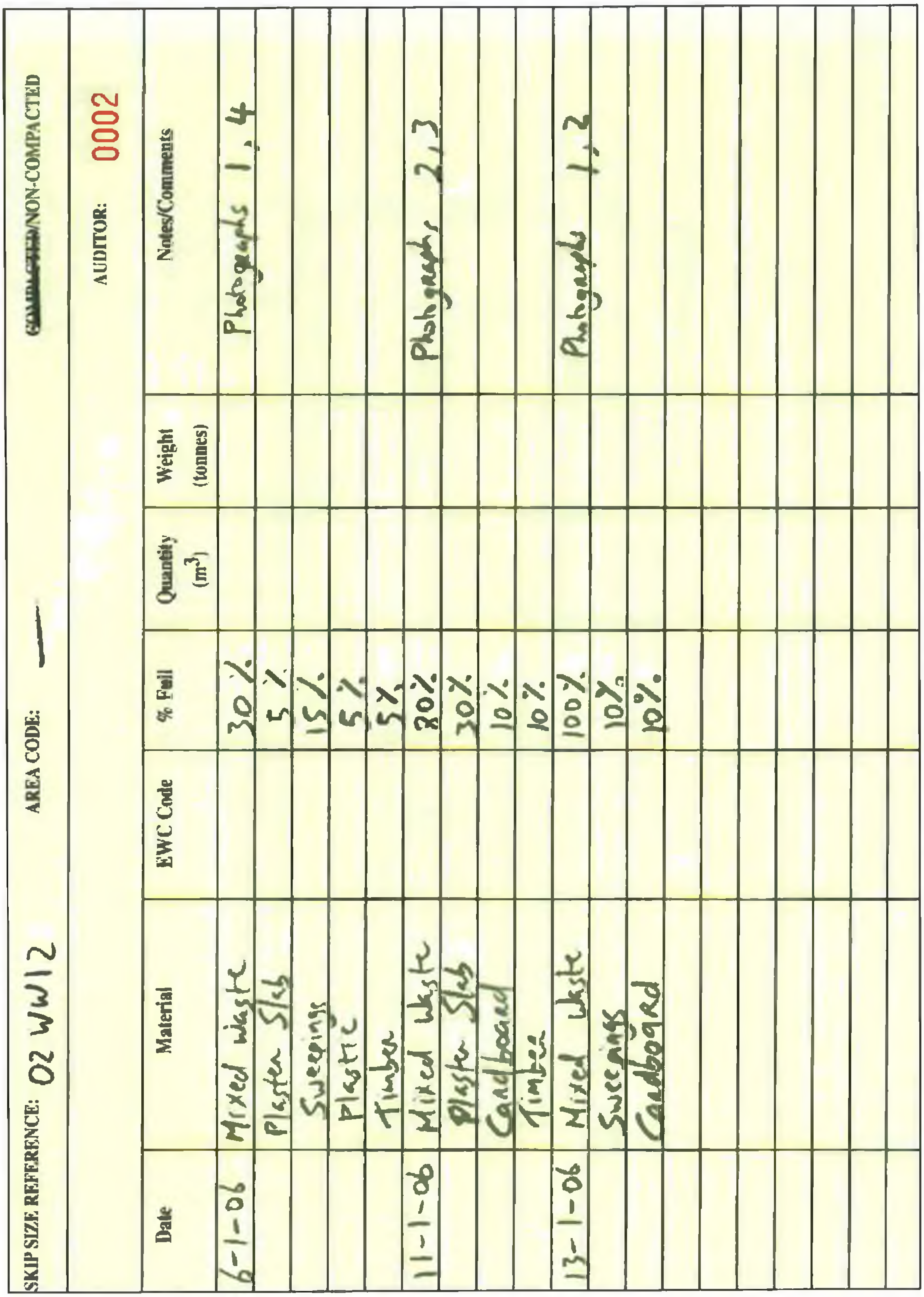
A system of indexing the photographs was required to avoid any confusion between the two skips being analysed and the four photographs being taken. The following method was developed:

- A system of numbering the photographs was devised e.g. 6-1-06(1) this was the first photograph taken on 6th January 2006 (Photograph 5.1).
- The numbers were then recorded in the audit book used for the visual audit across from the visual audit entry for that day in the remarks column. (Figure 5.1)

Photograph 5.1 The positions from where the photographs of each skip were taken. Numbers 1 and 4 indicate the positions from where the photographs were taken for the first audit.

The photography process on site took no longer than 5 minutes every day. This included taking the required amount of photographs of the waste within the skip and indexing these photographs in the audit book for identification purposes.

These photographs were later up-loaded on to the PC. A designated file was created on the PC and the photographs were labelled with the date they were taken and the number they were allocated. e.g. 11-1-06(3) – this was the third photograph taken on January 11th, 2006 and the skip that it was taken from could be identified from the audit book in the remarks column containing the number 3 from this same date (Figure 5.1).



SKIP SIZE REFERENCE: 02 WW12 AREA CODE: — ~~COMPACTED~~/NON-COMPACTED

AUDITOR: 0002

Date	Material	EWC Code	% Full	Quantity (m^3)	Weight (tonnes)	Notes/Comments
6-1-06	Mixed waste		30%			Photographs 1, 4
	Plaster Slab		5%			
	Sweepings		15%			
	Plastic		5%			
	Timber		5%			
11-1-06	Mixed Waste		30%			Photographs 2, 3
	Plaster Slab		30%			
	Cardboard		10%			
	Timber		10%			
13-1-06	Mixed Waste		100%			Photographs 1, 2
	Sweepings		10%			
	Cardboard		10%			

Figure 5.1 The photographic numbering system as recorded in the remarks column of the audit book.

5.4 Desk Analysis

When the on-site elements of the auditing procedure were complete, the procedure to obtain the data from the photographs could then begin. The analysis of the photographs was not carried out the same day as the visual audit. The reason for this was to ensure that the auditor was not biased by the data collected from visual audit. The photographs were usually analysed at the end of each skip cycle. However, before this data could be obtained there were several issues that needed to be resolved.

5.4.1 Preliminary adjustments to photograph using Photoshop

By now the photographs would be uploaded into a file on the PC from the digital camera and these photographs could be opened and analysed on the Photoshop 6.0 package on the PC. The motive for using Photoshop was that this software package provides a facility whereby the photograph can be divided into equally sized cells, which is essentially a grid (Medeiros, 2001). The factors that determine the quality of a grid are:

- The number of cells that the grid will contain.
- The density of the grid.
- The neutrality of the grid colour against the colours present in the photograph.

Number of cells

To achieve the desired grid was time consuming and required adjustments to be made to the Photoshop programme. The software allows for the changing of settings within the programme that adjust the size of the cells simultaneously. The geometry of the photograph taken with the digital camera proved to be problematic when dividing the grid into an appropriate number of cells. The fact that the photograph was rectangular in shape and not a square meant that it would contain more columns than rows in the grid. The most suitably sized grid that the photograph would permit was a seventy-cell grid. This comprised of a grid with ten columns and seven rows. This grid sat perfectly on the photograph and the cells were suitably sized. Therefore, it was decided to use this grid application (Photograph 5.2).

Photograph 5.2 The cyan coloured grid applied to the photograph

Density of cells

The density of cells contained in the grid had an effect on the quality of the image when the grid was applied. If too many cells were applied to the photograph, they may become superimposed on the images contained within the photograph. This would lead to an unwanted obstruction when analysis of the photograph began (Photograph 5.3).

Photograph 5.3 The effect of a superimposed grid and its density on the photographic analysis

Grid colour

When the grid was applied to the photograph it needed to be displayed in a colour that was not relative to the images contained within the photograph. Using Photoshop for the first time it became apparent that the default colour for the grid was cyan. However, this colour was not always suitable due to differing skip contents and brightness or glare due to weather conditions. The Photoshop software has a system whereby the default colour of the grid can be changed to cater for user preferences.

The time scale involved in finding the best possible grid to suit the photographs being analysed was similar in a way to the pre-audit checks. These adjustments only had to be carried out at the very outset before any flow analysis commenced. Therefore the time it took to make these changes would not be applied to timeframe involved in analysing each individual skip. The grid adjustments are documented as an administrative function and did take two hours to complete at the outset. However, the Photoshop software has the capability to store a grid size for reuse at different times and so these adjustments were not made for every skip cycle. Therefore, the two hours taken to create this grid should be applied to the timeframe involved in analysing each individual skip. This was documented as two minutes per skip cycle (120mins (2 hrs) / 62 skips audited = 2 minutes per skip).

5.4.2 Analysing the contents of the photograph

The primary task for the analysis of the photograph was to analyse each cell individually. By identifying the waste component in each cell it was then possible to allocate a percentage to each C&D W component in each cell, which by now had been indexed e.g. in Photograph 5.4 column 6, row 4 is depicted by a red X.

1 2 3 4 5 6 7 8 9 10

Photograph 5.4 Identifies the cell on row 4, column 6 being depicted by a red X

As the photograph was being analysed and the percentages that each C&D W component represented in the cells was determined, the data was recorded on a data sheet which was laid out in the same format as the grid imposed on the photograph with the exact number of rows and columns. This is known as a *Data Acquisition Form* (DAF) (Figure 5.2). It was from these forms that the data collated was transferred on to a Microsoft Excel spreadsheet at a later stage.

Row \ Column	1	2	3	4	5	6	7	8	9	10
1										
2										
3										
4										
5										
6										
7										

Figure 5.2 **Data Acquisition Form (DAF)**

5.4.3 Identifying the C&D W components in the cells

In order for this method of waste auditing to be tested and its viability determined, a high degree of accuracy was required in every element of the study. This started with the accurate identification of the component(s) present in the cells. As the photogrammetric analysis developed in the early stages and various patterns began to emerge, the level of experience in photograph analysis increased and the process of identification began to mature.

The cells were examined in a logical format. It was the intention that every effort would be made to keep the method as simple and user friendly as possible. An example of how the waste was identified and quantified can be seen in photograph 5.5. The cell located in row 2, column 2 is surrounded by a *red circle* for identification purposes. The contents of this cell were recorded as plastic occupying 60 per cent and the background occupying 40 per cent of the cell. As an auditor or the person who examines the photographs gets accustomed to identifying waste through a photograph, they will find the process easier to undertake.

Occasionally the scenario arose that some cells would contain only one component – e.g. timber. This is documented on the DAF as timber 100 per cent in the corresponding cell on the form (Photograph 5.6, column 4, row 4). The analysis of all the cells on the photograph continued until all seventy cells have been studied and entered into their respective cells on the DAF (Figure 5.3). A complete set of photographs and their respective completed DAFs can be found in Appendix F.

1 2 3 4 5 6 7 8 9 10

Photograph 5.5 Column 2, row 2 is surrounded by a red circle

1 2 3 4 5 6 7 8 9 10

Photograph 5.6 Column 4, row 4 is surrounded by a red circle

Column

Row	1	2	3	4	5	6	7	8	9	10
1	Background 100%	Plastic 30% Background 70%	Plastic 90% Background 10%	Plastic 60% Background 40%	Plastic 5% Sweepings 10% Background 85%	Cardboard 30% Sweepings 20% Background 50%	Cardboard 100%	Background 40% Cardboard 60%	Background 60%	Background 100%
2	Plastic 15% Background 85%	Plastic 100%	Plastic 100%	Plastic 100%	Plastic 90% Cardboard 10%	Cardboard 100%	Cardboard 20% Sweepings 80%	Sweepings 70% Cardboard 30%	Background 50% Cardboard 50%	Cardboard 10% Background 90%
3	Plastic 15% Background 85%	Plastic 90% Cardboard 10%	Plastic 100%	Plastic 30% Cardboard 70%	Plastic 5% Cardboard 95%	Plastic 50% Aeroboard 50%	Plastic 90% Sweepings 10%	Plastic 95% Sweepings 5%	Plastic 10% Cardboard 90%	Cardboard 100%
4	Cardboard 70% Background 30%	Cardboard 100%	Cardboard 100%	Cardboard 100%	Cardboard 100%	Aeroboard 40% Cardboard 50% Plastic 10%	Plastic 30% Cardboard 70%	Plastic 100%	Plastic 50% Cardboard 50%	Cardboard 100%
5	Cardboard 40% Background 60%	Cardboard 100%	Cardboard 100%	Cardboard 100%	Plastic 100%	Plastic 100%	Plastic 80% Cardboard 20%	Cardboard 100%	Plastic 50% Cardboard 50%	Plastic 100%
6	Plastic 15% Background 85%	Plastic 85% Cardboard 15%	Plastic 100%	Plastic 40% Cardboard 60%	Cardboard 90% Plastic 10%	Plastic 50% Aeroboard 50%	Plastic 70% Sweepings 30%	Plastic 90% Sweepings 10%	Plastic 30% Cardboard 70%	Cardboard 100%
7	Background 100%	Cardboard 100%	Plastic 100%	Plastic 90% Cardboard 10%	Plastic 10% Cardboard 90%	Cardboard 100%	Cardboard 100%	Cardboard 100%	Cardboard 100%	Cardboard 100%

Figure 5.3 Completed Data Acquisition Form

When analysing the cells it was essential that the volume distribution for each cell's content's was the sum of 100 per cent. If for example, a cell contains two different C&D W components, the sum of these two components must equal 100 per cent. Both these figures would be entered in their corresponding cell on the DAF.

When the analysis of the photograph is complete and a fully completed DAF has been produced for that one photograph, the process is repeated until a DAF has been completed for all the photographs taken of the C&D W content in the skip during its cycle.

The timescale involved in analysing the contents of one photograph or what can also be described as completing the DAF took on average fifteen minutes. This could vary from time to time. There could be various contributing factors:

- The quality of the photograph.
- The number of components present.
- The volume of waste within the skip at the time the photograph was taken.

The time it would take to complete all DAF for the cycle of a skip would be dependent on the number of photographs taken.

5.4.4 Non-C&D W components

A major decision, which had been taken early on in the auditing process, was that any areas in the photograph that were obscured, where it was virtually impossible to identify the waste content, would be documented as the C&D W component referred to as *background*. The documentation of the *background* as a C&D W component was used to good effect by Medeiros (2001). This meant that these obscured areas in the skip would be documented alongside the background landscape of the construction site where the waste skips were stationed and the wall structure of the skip itself. The component background could be phased out through the calculation process at a later stage.

5.5 Designing an Electronic Template using Microsoft Excel

The next step was to enter the data into a Microsoft Excel spreadsheet. However, a suitable template needed to be designed to take this data. Microsoft Excel has many useful functions contained within its programme.

5.5.1 Calculations

The facility to create formulae with one or more of these functions and transfer them throughout the spreadsheet proved to be a very useful tool. A formula was created for the purpose of this data analysis and was designed to do the following:

- Add a list of numbers and provide a total.
- Divide this total by the figure that will give an average.

A calculation was carried out to facilitate the removal of the data for individual C&D W components. This formula can be explained in the following example:

- After a full analysis of a skip is complete, the waste component labelled *background* is equal to 45.5. The process of removing the background begins. Subtract from one hundred the figure representing the background component that the auditor wished to remove from the results of the research e.g. (100 - 45.5 = 54.5)

The formula could then be used to divide this answer (which represented the remaining C&D W components in the skip) into each figure representing all the other C&D W components and multiply it by one hundred to present them as a percentage of that total. For example timber is estimated at 24.5 per cent of the skips contents, which implies: (24.5 / 54.5 * 100 = 44.9%)

Therefore, after the background is removed from the data recorded, timber is now recorded as 44.9 per cent of the skips contents.

These formulae were copied and reused continuously on the spreadsheet or on a different spreadsheet when collating the data from a different skip analysis. This may seem like a simple function that was not essential, but, when analysing the C&D W activity within sixty-two C& D W skips through a series of three hundred and twenty-four photographs, any time saving initiative was very much welcomed.

5.5.2 Listing the C&D W components

When designing this template the use of a universal template for all C&D W skips being analysed was initially the preferred option. However, this became untenable when it was realised that there was no two skips with the same waste types contained in each e.g. one skip may have plastic and another skip may not. The use of this universal template was ruled out completely when the ever-growing list of C&D W components could not be catered for comfortably on the excel spreadsheet.

The total number of components that had been encountered by the end of the study was twenty-five: Cardboard; Plastic; Sweepings[12]; Floor Covering Linoleum; Timber; Tiles; Tile Adhesive Bags; Polystyrene; Felt; Slab; Carpet; Mattress; Wire; Concrete; Grass; Paint Cans; Metal; Canvas; Gravel/Clay; Rockwool; Cotton; Glass; Paper; Rubber; Other. This resulted in each template, for each skip cycle being adjusted to cater for the differing C&D W components that had been encountered by the analysis of that skip cycle.

5.5.3 Template layout

Designing the Microsoft Excel template in a way that it would collaborate with the layout of the DAF was a difficult process. It was decided to handle each row in the DAF individually on the spreadsheet. The spreadsheet comprised of 7 pages, one for each row of the photograph's grid or essentially one for each row in the DAF. It was then possible to enter the data for the ten cells on each of the respective rows (Table 5.1) (Appendix G).

[12] Sweepings could describe many different C&D W types. Generally it was made up of bags of waste containing dust and sweep up material and waste that was bagged when cleaning out houses. Sweepings were also used to describe waste contained in sealed bags which could not be opened for health and safety reasons.

Table 5.1 An example of the Microsoft Excel template designed for putting the results from the DAF into an electronic format (one row).

Row 1												Average Over the Photograph
Column no.	1	2	3	4	5	6	7	8	9	10	Total	
Timber												
Plastic												
Cardboard												
Sweepings												
Aeroboard												
Blocks												
Background												

5.5.4 Facilitating the varying photographs per skip ratio

The varying C&D W composition was not the only issue. The differing number of photos taken of the skip's contents during its cycle meant that the mathematical functions also needed to be adjusted in each template. An example of a change would be if one skip had been audited 4 times, which automatically meant that 8 photographs had been taken and 8 DAFs were completed. Then, the next skip had been audited 5 times resulting in ten photographs being taken and ten DAFs were completed. Therefore, the template geared to facilitate 8 DAFs had to be adjusted to cater for ten photographs when transferring the data for the next skip. Also, any cell containing a formula had to be moved or be reproduced. The number of audits and photographs produced by the cycle of a skip was determined by the time it took for the skip to be filled.

The Microsoft Excel template was created before any figures from a DAF were transferred. Therefore, the time frame involved in the creation of this template was an administrative function. However, due to all the variations with differing C&D W components and numbers of photographs taken per skip as listed above, the template always needed slight adjustments for each skip cycle. This would take ten minutes before every transfer of data from the DAF.

5.5.5 Transferring the data into Microsoft Excel

A practical example of transferring the data can be appreciated by analysing photograph 5.4 row 7 (the last row). The data is taken from the completed DAF (Figure 5.3) and entered into the excel spreadsheet in the following format (Table 5.2) (A complete DAF for this skip cycle is presented in Appendix G). This process is repeated for all seven rows for every photograph taken.

The time frame involved for entering the data from one DAF to the corresponding Microsoft Excel spreadsheet would take on average 5 minutes. This is however just for one DAF and would increase with the number of photographs taken.

Table 5.2 Data collection format showing the data collected from the analysis of the photograph, and recorded on a data acquisition form, is then entered into excel format for calculation.

Row 7												
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	Total	**Average over the Photo**
Timber											**0**	0.0
Plastic			100	90	10						**200**	2.9
Cardboard		100		10	90	100	100	100	100	100	**700**	10.0
Sweepings											**0**	0.0
Aeroboard											**0**	0.0
Blocks											**0**	0.0
Background	100										**100**	1.4
											1000	14.3

5.6 Data calculation

An issue that was initially raised when first attempting to convert the data into useful information was the fact that the photograph could only be divided into seventy cells. It was important that the data for all photographs taken in the cycle of a skip was processed in a way that it would provide useful information at the end of the analysis and show a trend in C&D W flow. The information had to be presented in such a manner that it could be compared to the data recorded from the visual audit case study. The figures recorded on the DAF had to be processed so that there was a percentage for each C&D W component in the photograph in question. Looking again at Table 5.2 we can agree the following:

- Plastic, cardboard and the background of the photograph occupy the area covered by this row of cells (row 7).
- There are ten cells in each row and the contents of each cell must equal 100 per cent.
- The total percentage that each C&D W component accumulates is then listed in the totals column of the template (green).
- With ten cells in each row and 100 per cent in each cell the total for one row is 1000 per cent of the photograph area.
- Each cell in the grid only represents one seventieth (1/70) of the total area of the photograph (70 cells).
- Therefore the totals for each component must be divided by seventy.

To sum up, the three figures, for the three waste components identified in the row that are listed in the 'average over photo' column are:

- The actual percentage of the surface area of the photograph that they occupy.
- These figures are reached when the totals are divided by seventy.

The 14.3 per cent is achieved by dividing the 1000 by 70. Another way of understanding this is that 14.3 per cent is one seventh of the 100 per cent total area of the photograph.

In the cycle of this C&D W skip that all the above tables and figures are taken from, four photographs were taken. The decision to carry out the analysis of the photographs with the utmost accuracy was a major factor when deciding the best course of action. When all of the data recorded from the photographs had been transferred into Microsoft Excel format the following points were considered:

- The most accurate audit would be achieved using the data from all 4 photographs collectively.
- The data from all photographs had to be brought together as opposed to taking cases of individual photograph analysis that would not provide the best possible results.
- The data for all the C&D W components encountered in all seventy cells, in all 4 DAFs would be totalled.

5.7 Using the Data from all Photographs to Reach a Final Result

After all the data recorded in the DAF was entered into the Microsoft Excel spreadsheet, the following steps were taken:

- The Microsoft Excel spread sheet calculated and processed the information and averaged it over all the photographs and gave a percentage for each component contained in that skip.

- The *background* of the photograph was taken as an individual component. This was due to the fact that a lot of areas in the photograph did not contain any waste and some squares contained a percentage of waste, e.g. plastic and a percentage of background – (plastic 60 per cent, background 40 per cent).

- When all the quantities for each component including the *background* were recorded, they were then averaged in the excel template. This involved totalling the figures for each component and averaging them over the 4 photographs (divide by 4) (Table 5.3).

- The next step was the removal of the *background* from these figures recorded. This involves taking the percentage that represented the background and subtracting it from 100. (100 – 27.4 = 72.6). The answer (72.6) is then divided into the percentage representing timber (1.6) and then multiplied by 100 to generate it as a percentage e.g. 1.6 / 72.6 x 100 = 2.2%. This is the new figure for timber after the background has been removed. This is repeated for each component (Table 5.3) (Appendix H).

The floor area completed during the period of the research was calculated through consultation with representatives of the main contractor. The site map outlining the floor areas complete during the research can be found in Appendix J.

Table 5.3 Compilation of the data from all the photographs after analysis

Material	Total %[13]	Average %[14]	PS %[15]	VC %[16]	*Weight (kg)*	
					PS*	*VC***
Timber	6.4	1.6	2.2	5.0	0.036	0.083
Plastic	96.8	24.2	33.3	20.0	0.550	0.330
Cardboard	148.8	37.2	51.2	47.5	0.845	0.784
Sweepings	33.2	8.3	11.4	20.0	0.189	0.330
Aeroboard	5.3	1.3	1.8	5.0	0.030	0.083
Blocks	0.0	0.0	0.0	2.5	0.000	0.041
Background	109.7	27.4	0.0	0.0	n/a	n/a
Total	*400.0*	*100.0*	*100.0*	*100.0*	*1.650*	*1.650*

* Photogrammetric sort
** Visual characterisation

Table 5.4 shows the monthly report for August 2005, created by averaging the data collected over the period of one month. All monthly reports can be found in Appendix K. The individual skip reports can be found in Appendix L.

The time factor attached to calculating the data from all the photographs analysed and transferred into the Microsoft Excel formation was aided by the formulae created at the outset. Therefore, it would take fifteen minutes to:

- Compile the total percentage for each C&D W component over all the photographs taken in that skip cycle.
- Find the average of these figures.
- Obtain a new value for all these components after removing the background. This is considered the final result for that skip using the photogrammetry method.
- List the results of other methods of C&D W auditing alongside these for comparison.

[13] With background
[14] With background
[15] Photogrammetric sorting without background
[16] Visual characterisation without background

Table 5.4 C&D W quantities for August 2005

Project Description					Residential Development in Roscam				
Completed Floor Area:					***Project Stage***				
Total Waste (m³)		36.700			**Total Waste (tonnes):**				
Unit Waste Factor (m³/m²)					**Unit Waste Factor (kg/m²)**				
Date:		Aug '05			**Auditor:**				
Visual Audit					**Photogrammetry Audit**				
Materials	**EWC Code**	**Volume (m³)**	**Conversion Factor**	**Weight (tonnes)**	**Weight (tonnes)***	**Volume (m³)**	**Conversion Factor**	**Weight (tonnes)**	**Weight (tonnes)***
Slab	170802	6.000	0.40	2.400	1.092	6.146	0.40	2.458	1.119
Cardboard		8.832	0.40	3.533	1.608	8.390	0.40	3.356	1.528
Timber	170201	2.320	0.60	1.392	0.422	3.974	0.60	2.385	0.724
Plastic	170203	7.656	0.15	1.148	1.394	9.531	0.15	1.430	1.735
Tiles	170103	0.664	1.00	0.664	0.121	0.009	1.00	0.009	0.002
Tile Bags		0.368	0.15	0.055	0.067	0.092	0.15	0.014	0.017
Sweepings		4.600	1.00	4.600	0.838	5.336	1.00	5.336	0.972
Floor Lino		0.296	1.00	0.296	0.050	0.000	1.00	0.000	0.000
Felt		3.672	1.00	3.672	0.670	1.251	1.00	1.251	0.228
Mattress		1.400	1.00	1.400	0.255	0.331	1.00	0.331	0.060
Aeroboard	170604	0.664	1.00	0.664	0.121	1.730	1.00	1.730	0.315
Wire		0.184	1.00	0.184	0.034	0.037	1.00	0.037	0.007
Carpet		0.112	1.00	0.112	0.017	0.000	1.00	0.000	0.000
Total		**36.700**		**20.120**	**6.700**	**36.700**		**18.337**	**6.700**

*Weight in tonnes as provided by the waste management company.

5.8 Summary of Timescale

The analysis of C&D W through photogrammetric sorting was a time consuming factor to be considered as documented by Reinhart *et al.* (2002):

'The photogrammetric method required approximately 5 man-hours per waste load and could only be done by one person.'

(Reinhart *et al.* 2002)

Table 5.5 displays the time taken to fully analyse and quantify the contents of a C&D W skip through photogrammetry analysing eight photographs. The table also takes into consideration any administrative time consumed planning the audits, creating spreadsheets, templates and formulae for storing data and calculating the data.

Table 5.5 Time allocations for each element of the photogrammetric sorting

Administrative time	Practical Functions	Minutes/Skip Cycle
Pre-audit information		5 mins
	Photography on site	20 mins
Photograph grid adjustment		2 mins
	Photograph analysis	90 mins
	Excel template adjustments	10 mins
	Data transfer- DAF to excel	40 mins
	Data Calculation	15 mins
	Total	182 mins (3hr 2 mins)

5.9 Observations

After analysing a large number of photographs and processing the data, it became clear that there was a scenario whereby overuse of photographs became an issue. If a visual audit was carried out on a given day and the quantity of waste in the skip was 40 per cent, two photos were taken and analysed for that day. Then, the following day when the visual audit is carried out the quantity is 45 per cent and again two photos are taken and analysed and the data is processed. Notice how the change in one day was only 5 per cent. This is a very small portion of the skip and when we look at it through the photograph we will find repetition between the two days. This essentially means in photogrammetric terms that we are doubling the quantity of the waste for certain items that were only covered once in the visual audit. i.e. the same waste gets measured twice. When this problem was identified and examined it was eventually decided that photographs would only be analysed when there was a change of 20 per cent or greater in the quantity. With each skip not exceeding 100 per cent, this meant that from then on there was no more than 5 series of photographs per skip and this in turn did help to reduce the workload.

5.9.1 One photograph or two?

As the analysis of photographs continued, it became necessary to find a way of reducing the workload involved in the research. It was eventually decided to reduce the number of photographs taken of each skip from two to one per audit. This would half the workload and focus on the capture of high quality photographs to provide an accurate analysis (Photograph 5.7).

Photograph 5.7 A photograph which was used to carry out the photogrammetric analysis audit for the day it was taken.

5.10 Comparison with Medeiros (2001)

There were various similarities and differences between the photogrammetric sorting method used on this case study and the method used in the US (Medeiros, 2001).

5.10.1 Similarities

The following are the main similarities between the two studies:

- All results acquired from the photographs of C&D W contents were averaged.
- Adobe Photo 6.0 was used.
- The *background* was documented as a C&D W component and then removed from the final results.
- Grey areas in which it was difficult to identify the C&D W components was also documented as *background*.

5.10.2 Differences

The following are the main differences between the two studies:

- Medeiros (2001) studied two photographs per C&D W load whereas Cahill (2007) examined up to 10 photographs of a C&D W skip as it went through a cycle.
- Medeiros (2001) analysed photographs of piles of waste taken from the side at a landfill facility. Cahill (2007) analysed a series of photographs taken of a skip's cycle from an elevated position looking down on the C&D W on site.
- Medeiros (2001) had a team of researchers e.g. on one analysis, 6 researchers were used. This project had only one researcher throughout.
- The grid imposed on the photographs by Medeiros (2001) had an equal amount of rows and columns. The grid applied in this project was made up of 10 columns by 7 rows.
- The data acquisition form created by Medeiros (2001) was set up to document the data from one row of the grid imposed on the photograph. The data acquisition form for this study was set up to document the data from an entire photograph.
- Medeiros (2001) assumed that the percentage area occupied by a component in the image was directly proportional to the percentage volume occupied. This project documented the percentage area occupied by a component in the image as though it was directly proportional to the percentage volume occupied but

compensated for any error through the number of photographs studied and the use of conversion factors.

- Medeiros (2001) compared the results from photogrammetric sorting with the results of a mass sort methodology used to characterise C&D W. This project compared the results of photogrammetric sorting with the visual characterisation method for C&D W auditing.

5.11 Limitations

The limitations encountered with this method of C&D W analysis can be split into two different categories:

- Limitations created by photography.
- Other limitations.

5.11.1 Limitation created by photography

As the method of photogrammetric sorting progressed, it became clear that the photograph was sometimes not a true reflection of what exactly was in the skip. A poor quality photograph is less accurate and reliable than a poorly carried out visual audit. There were many factors on site that would affect the quality of a photograph including:

- The quality of daylight available for the photograph setting,
- The effect that the flash of the camera had on the actual photograph.
    - The use of the flash on the camera to get the desired lighting sometimes resulted in the images on the photograph being contrasted to the brightness of the flash reflecting off the skips contents. (Photograph 5.8)

Photograph 5.8 Show the effects of the camera flash on the skips contents

The position at which the photograph was taken was another concern. It was more beneficial for the photograph to be taken from an elevated position (Photograph 5.9).

Photograph 5.9 Illustrates the benefits of good elevation and the calibre of photograph that can be produced

However, this was not always possible due to the positioning of the skip. Day to day activities on site could lead to skips being moved to other areas of the site, which did not provide the level of elevation required. (Photograph 5.10)

Photograph 5.10 Shows the poor quality photograph that is produced as a result of poor elevation when taking the photograph.

The content of the skips is another issue that very often could have an effect on photograph quality. This scenario would often occur where a sheet of plastic or cardboard was thrown into the skip near the top taking up a large area. (Photograph 5.11)

Photograph 5.11 Shows the result a large sheet of plastic can have on the visibility of the other items within the skip.

This component in visual characterisation terms may only occupy 5 per cent of the skip but when it came to analysing the photo in which it appears, the percentage allocation became much larger. This was mainly down to the system that was in use for analysing the photographs. A large number of cells in the grid contained plastic but from carrying out the visual audit, it became apparent that this was not a true reflection of what this component really represented.

There was also a situation where one item in the skip, which may not be large in proportion, would obscure the viewing of other components in the skip. The bulk density of certain items of C&D W enforces the need for conversion factors relative to construction waste. The auditor had to be aware of the presence of air voids throughout the C&D W skip. The level of compaction of the waste needed to be recorded on certain occasions. In photograph 5.12, a piece of timber is obscuring the view of the items towards the front of the skip. Although the audit might in fact measure the area this timber occupies in the skip accurately, the issue of the C&D W missed (not audited) because of the obstruction it has caused is another argument.

Photograph 5.12 Show the impact a single item can have on the visibility of the other items within the skip.

The accuracy of the audit through the photograph could be affected by the varying sizes of the component, albeit in density rather than quantity. Sheets of plastic were not the only culprits. Some components were smaller in size, which meant the photograph did not mark a true reflection of their percentage occupied in the skip or sometimes even their presence at all.

It also occurred on a number of occasions where materials that were visible on the visual audit as a very low percentage of occupancy were sometimes overlooked during the photo analysis. An example would be where the visual audit shows *Electrical Wire* as 1 per cent. This means that wire occupies a very small portion of the skip's contents. Such a small item in the skip would be very easily missed in the series of photographs analysed.

5.11.2 Other limitations

Some other limitations included:

- The removal of a full C&D W skip from site before the final audit could be carried out. Similar to the visual audit, this became one of the most significant limitations of the photogrammetric analysis method.

- The method devised for the analysis of the photographs did prove to be time consuming. The man-hours per analysis of photograph fluctuated from each photograph (averaged at ninety minutes per skip cycle). In the later stages of the project, it became apparent that, the longer the time spent analysing an individual photograph, the greater the accuracy.

- The listing of the figures obtained from the photographs in a Microsoft Excel format was also another time consuming issue. The process of entering all the figures recorded on the data acquisition form into the excel spreadsheet was very tedious and consumed a significant amount of the auditors time (averaged at sixty-five minutes per skip cycle).

Conclusions

The main aims of this chapter were to:

- Provide a full overview of how visual characterisation and photogrammetric sorting methods were applied for estimating C&D W quantities on a selected construction site.
- Discuss the validity of the methods used.

The main conclusions are as follows:

- A detailed photogrammetric sorting methodology was developed and tested on a residential construction site in Galway.
- It was calculated that it took 182 minutes to audit a skip through a full cycle using the photogrammetric sorting method.
- A number of limitations were identified, mainly to do with the accuracy and positioning of the photographs.

The next chapter will outline the results of the study and provide comparisons with previous methodologies.

Chapter 6 Construction and Demolition Waste Audit Results Generated from the Selected Case Study Construction Project

6.1 Introduction

This chapter outlines the results generated by the application of visual characterisation and photogrammetric sorting in auditing C&D W on site. The results are presented as waste production indicators (kg/m^2).

The main aims of the chapter are:

- Present the data compiled for the methods of C&D W analysis in a format that will provide waste production indicators for the construction industry.
- Compare the waste production indicators generated to the indicators provided by Medeiros (2001) and Kelly (2006).

6.2 Waste Production Indicators

The waste production indicators were calculated by using the conversion factors outlined in the *Waste Management (Landfill Levy) Regulations, 2002* (DoEHLG, 2002b). The percentage volumes contained in the Table 6.1 for each C&D W component are the total percentage of each individual component averaged over the 62 skips analysed as part of the research i.e. the percentages for the component encountered in each skip are totalled and then divided by 62. This is repeated for all 25 components encountered in each of the two methods. The appropriate conversion factor is then multiplied by the individual volumes for C&D W, which has been converted from a percentage of a 12yd^3 skip into m^3 of C&D W.

Table 6.1 The percentage for Visual Characterisation and Photogrammetric Sorting that each C&D W component occupied

C&D Waste	Visual Audit (%)	Visual Audit (m^3)	Conv. Factor*	Weight (tonnes)	Photo Audit (%)	Photo Audit (m^3)	Conv. Factor*	Weight (tonnes)
Cardboard	21.6	123.2	0.40	49.3	27.0	154.0	0.40	61.6
Plastic	25.5	145.5	0.15	21.8	32.8	187.1	0.15	28.1
Sweepings	20.2	115.2	0.60	69.1	17.5	99.8	0.60	59.9
Floor Cover	0.1	0.6	1.00	0.6	0	0.0	1.00	0.0
Timber	7.1	40.5	0.60	24.3	6.3	35.9	0.60	21.6
Tiles	0.3	1.7	1.00	1.7	0.1	0.6	1.00	0.6
Tile Adh Bag	0.8	4.6	0.15	0.7	0.5	2.9	0.15	0.4
Aeroboard	6.1	34.8	1.00	34.8	4.3	24.5	1.00	24.5
Felt	2.6	14.8	1.00	14.8	1.4	8.0	1.00	8.0
Slab	9.3	53.0	0.40	21.2	7.8	44.5	0.40	17.8
Carpet	0.6	3.4	1.00	3.4	0.4	2.3	1.00	2.3
Mattress	0.5	2.9	1.00	2.9	0.3	1.7	1.00	1.7
Wire	0.1	0.6	1.00	0.6	0.0	0.0	1.00	0.0
Concrete	0.6	3.4	1.50	5.1	0.1	0.6	1.50	0.9
Grass	0.2	1.1	1.00	1.1	0.1	0.6	1.00	0.6
Paint Cans	0	0.0	1.00	0.0	0	0.0	1.00	0.0
Metal	0.3	1.7	1.00	1.7	0.1	0.6	1.00	0.6
Canvas	0.2	1.1	1.00	1.1	0.1	0.6	1.00	0.6
Gravel/Clay	0.4	2.3	1.50	3.4	0.4	2.3	1.50	3.4
Rockwool	0.1	0.6	1.00	0.6	0.2	1.1	1.00	1.1
Cotton	0.1	0.6	1.00	0.6	0.2	1.1	1.00	1.1
Glass	0.1	0.6	1.00	0.6	0	0.0	1.00	0.0
Paper	0.1	0.6	0.15	0.1	0.1	0.6	0.15	0.1
Rubber	0	0.0	1.00	0.0	0	0.0	1.00	0.0
Other	3.1	17.7	1.00	17.7	0	0.0	1.00	0.0
Totals	**100.0**	**570.5**		**277.2**	**100.0**	**568.5**		**234.8**
Waste Production Indicator**				**50.8kg/m²**				**43kg/m²**

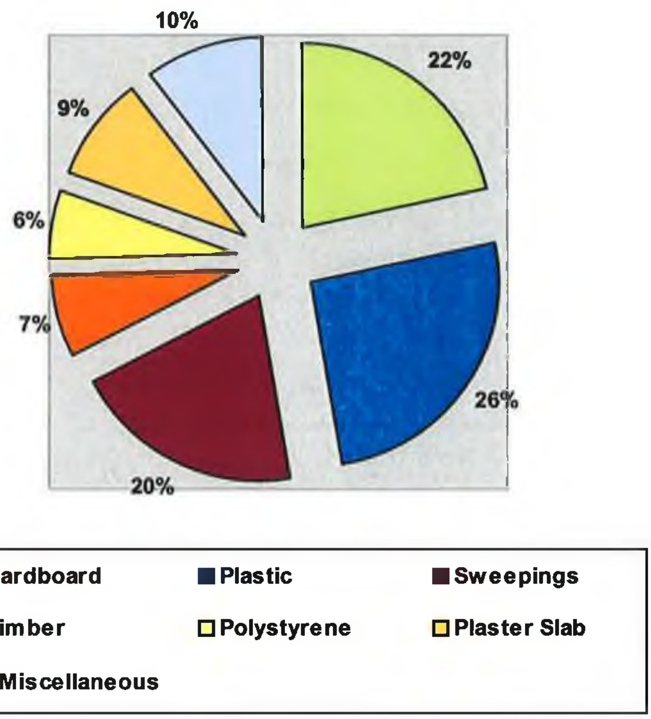
* Conversion factors provided by the landfill levy regulations.

** Based on a floor area 5455m².

The total floor area of residential construction completed during the period of time that this research was carried out was 5 455m². This figure was developed through consultation with representatives from the contractor on site (Appendix K).

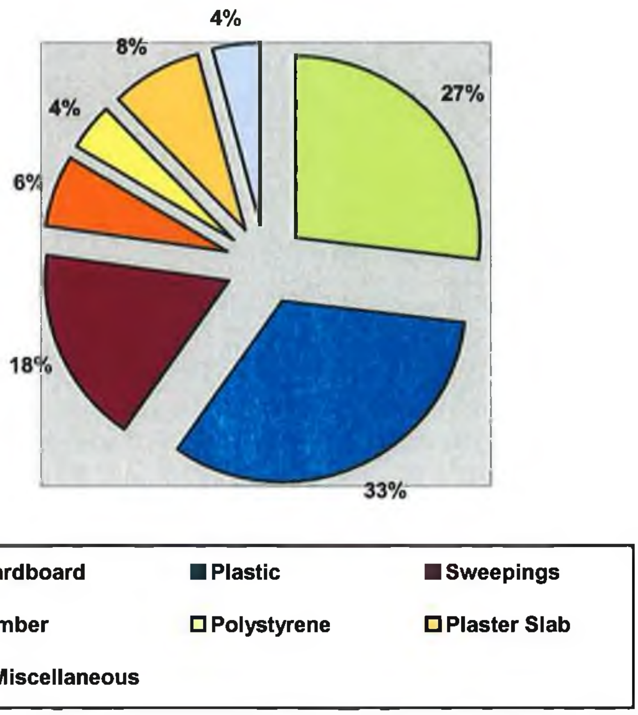
6.3 Volume Distribution

Twenty-five different C&D W components were encountered during the study. A significant number of these had a very low percentage when averaged over the sixty-two skips analysed. Components such as wire, metal and paper only amounted to 0.1 per cent. In order to illustrate the breakdown of components for the study, certain components had to be merged. In all nineteen components were merged under the label miscellaneous. This resulted in a total of 7 main components (Figures 6.1 & 6.2).



* Miscellaneous – Floor linoleum, tiles, tile adhesive bags, roofing felt, carpet, mattress, wire, concrete, grass, paint cans, metal, canvas, gravel/clay, Rockwool, cotton, glass, paper, rubber & other.

Figure 6.1 Visual Characterisation Composition



* Miscellaneous – Floor linoleum, tiles, tile adhesive bags, roofing felt, carpet, mattress, wire, concrete, grass, paint cans, metal, canvas, gravel/clay, Rockwool, cotton, glass, paper, rubber & other.

Figure 6.2 Photogrammetric Sorting Composition

6.4 Application of the Waste Management Contractor (WMC) Data.

The availability of the weights for each skip removed from site by the WMC gave the opportunity to provide an alternative quantity for each component encountered during the research. The figures in Table 6.2 are representative of the quantity of each C&D W component encountered. The total weight for each C&D W skip audited throughout the research provided by the WMC was multiplied by the percentage representing each component. For example, cardboard occupied 21.6 per cent for the visual characterisation method. The total tonnage of C&D W removed from site was 129.8 tonnes, 21.6 per cent of this was 28 tonnes. This was repeated for each component encountered, in both methods. The data recorded for each of the sixty-two skips analysed throughout the research can be seen in Appendix L.

Table 6.2 C&D W actual component weight[1].

C&D Waste	Visual Audit %	WMC (tonnes)	Photo Audit %	WMC (tonnes)
Cardboard	21.6	28.0	27.0	35.0
Plastic	25.5	33.1	32.8	42.6
Sweepings	20.2	26.2	17.5	22.7
Floor Covering	0.1	0.1	0.0	0.0
Timber	7.1	9.2	6.3	8.2
Tiles	0.3	0.4	0.1	0.1
Tile Adh Bags	0.8	1.0	0.5	0.6
Polystyrene	6.1	7.9	4.3	5.6
Felt	2.6	3.4	1.4	1.8
Plaster Slab	9.3	12.1	7.8	10.1
Carpet	0.6	0.8	0.4	0.5
Mattress	0.5	0.6	0.3	0.4
Wire	0.1	0.1	0.0	0.0
Concrete	0.6	0.8	0.1	0.1
Grass	0.2	0.3	0.1	0.1
Paint Cans	0.0	0.0	0.0	0.0
Metal	0.3	0.4	0.1	0.1
Canvas	0.2	0.3	0.1	0.1
Gravel/Clay	0.4	0.5	0.4	0.5
Rockwool	0.1	0.1	0.2	0.3
Cotton	0.1	0.1	0.2	0.3
Glass	0.1	0.1	0.0	0.0
Paper	0.1	0.1	0.1	0.1
Rubber	0.0	0.0	0.0	0.0
Other	3.1	4.0	0.0	0.0
Totals	100.0	129.8	100.0	129.8

A new set of waste production indicators for new residential construction was produced:

- 50.8 kg/m² for new residential construction using data provided by the visual characterisation method and the *Landfill Levy* conversion factors.

- 43 kg/m² for new residential construction using data provided by the photogrammetric sorting method and the *Landfill Levy* conversion factors.

[1] The data contained in Table 6.2 is a combination of the total volumes for each component generated by both audit methodologies and the total weight removed from site over the period of the research by the waste management contractor.

- 23.8 kg/m^2 for new residential construction using data provided by waste management contractor[2].

There is a significant difference between the waste production indicators provided by the WMC figures and the indicators provided by the two auditing methods. The conversion factors can again be attributed to this discrepancy. The failure of the landfill levy conversion factors to apply an appropriate weight to the waste components leads to their weight being overestimated and in turn provides a greater kg/m^2 indicator.

6.5 Comparison with Medeiros (2001); Grimes (2005) and Kelly (2006)

The research carried out by Medeiros (2001), Grimes (2005) and Kelly (2006) are used to compare with the results provided by this research. The visual characterisation method was the original method used by both Grimes (2005) and Kelly (2006). The difference between the results provided by Grimes (2005) and Kelly (2006) is that Grimes' work is based on specific case studies whereas Kelly's study is based on point source assessments from a number of sites.

To present the data in a suitable format (Table 6.3) that would allow for comparison, adjustments had to be made to the components. This involved merging some components together and documenting their results as one waste type. One set of results had to be chosen as the benchmark. The composition provided by Kelly (2006) was selected and the following adjustments were made to Grimes (2005):

- Inert waste
- Paper plastic and packaging included cement bags; plastic; cardboard; paper; k render bags; skim coat bags; facia & soffit
- Plasterboard.
- Canteen and office waste.
- Wood/timber.
- Metals including steel.
- Insulation.

[2] The waste production indicator produced using the data provided by the WMC is calculated by dividing the total weight removed by the WMC from site (129800kg) by the total floor area completed for the same period (5455m^2) which gives 23.8 kg/m^2

- Mixed C&D W included off-site waste, tiles and other.

A similar adjustment was required for the results produced by Cahill (2007):

- Inert waste included gravel/clay and concrete.
- Cardboard included plastic; tile adhesive bags and paper.
- Plasterboard.
- Canteen and office waste.
- Wood/timber.
- Metals including wiring.
- Insulation included polystyrene; rockwool; canvas and felt.
- Mixed C&D W included tiles; sweepings; floor covering; rubber; glass; carpet; mattress; and other.

Table 6.3 Results from 3 studies (Grimes, 2005; Kelly, 2006 and Cahill, 2007) where visual characterisation was used

C&D W	Grimes (2005) %	Kelly (2006) %	Cahill (2007) %
Inert waste	0.0	24.0	1.0
Paper plastic and packaging	13.3	17.0	48.0
Plasterboard	6.2	10.0	9.3
Canteen and office waste	3.9	2.0	0.0
Wood timber	21.8	25.0	7.1
Metals	0.8	8.0	0.4
Insulation	9.8	4.0	9.1
Mixed C&D W	44.4	10.0	25.1
Total	**100**	**100**	**100**

The research carried out by Grimes (2005) and Kelly (2006) provided waste production indicators for new residential construction in the format of kg/m^2. It is compared to the waste production indicator provided by this project in Table 6.4.

Table 6.4 Comparison of the total weight waste factor with Grimes (2005) and Kelly (2006)

	Grimes (2005)*	Grimes (2005)*	Kelly (2006)**	Cahill (2007)*
Total weight waste factors (kg/m²)	66.1	64.4	70.3	50.8

*based on 1 residential construction case study

(Grimes carried out 2 residential construction case studies)

** based on 19 point source assessments

The total weight waste factor provided by Kelly (2006) shows far greater waste production than that of both Grimes (2005) and the figures provided by this project. The difference between the results of Kelly's and Grimes' could be due to the fact that Kelly's was based on 19-point source assessments and the results from these were averaged to give this waste factor. The variation between the results provided by Grimes' and this project's results can be linked to the longer period of time spent by Grimes analysing the C&D W on both case studies. The results provided by this project are obtained from a case study carried out over a shorter period of time.

The research carried out by Grimes (2005) and Kelly (2006) also provided a waste production indicator for new residential construction in the format of m^3/m^2.

Table 6.5 Comparison of volumetric waste factors with Grimes (2005) and Kelly (2006)

	Grimes (2005)*	Grimes (2005)*	Kelly (2006)**	Cahill (2007)*
Total volume waste factors (m^3/m^2)	0.131	0.126	0.107	0.104

*based on 1 residential construction case study

(Grimes carried out 2 residential construction case studies)

** based on 19 point source assessments

The results listed in Table 6.5 are from the same case studies outlined in Table 6.4. The data in Table 6.5 shows the volume of C&D W from both Grimes' case studies are greater than the volume from Kelly's case study. This is different from the trend set in Table 6.5, which could due to the auditors encountering differing waste components, which leads to different conversion factors being applied.

6.6 Comparison of Volume Distribution Results produced by the Photogrammetric Sorting Method

The results produced by Medeiros (2001) on the Florida study were based on the analysis of ten piles of waste, each of which was taken as an individual case study (Appendix H). The photogrammetric sorting and the mass sort methodologies were applied to each of these case studies. The data in Table 6.6 is an average of each component encountered across the ten case studies. They were averaged to allow comparisons to be made with the results produced in this study for photogrammetric sorting and visual characterisation.

The component data provided by the photogrammetric and visual methods used in this project had to be adjusted to cater for differing quantities of components. This led to the merging of components encountered in this study as follows:

- Wood/timber.
- Concrete.
- Paper included cardboard.
- Drywall.
- Metal included wiring.
- Insulation included polystyrene, rockwool and canvas.
- Roofing included felt.
- Plastic.
- Flooring included tiles, floor covering and carpet.
- MSW included glass, rubber and sweepings.
- Land Clearing included grass and gravel/clay.
- Other included mattresses.

Table 6.6 Comparison between Medeiros' Photogrammetric and Mass Sort methodologies with the Photogrammetric and Visual Characterisation methods applied in this study.

Waste Component	Photo Sort Vol. Dist. % Medeiros, 2001	Mass Sort Vol. Dist. % Medeiros, 2001	Photo Sort Vol. Dist.% Cahill,2007	Visual Sort Vol. Dist. % Cahill,2007
Wood	23.5	26.9	6.3	7.1
Concrete	8.0	9.9	0.1	0.6
Paper	31.9	29.8	27.1	21.7
Drywall	6.1	2.9	7.8	9.3
Metal	2.5	3.6	0.1	0.4
Insulation	4.1	4.3	4.8	6.5
Roofing	7.5	6.3	1.4	2.6
Plastic	11.9	10.8	32.8	25.5
Flooring	1.6	1.3	1.0	1.8
MSW	1.5	1.9	17.5	20.3
Land Clearing	0.8	1.5	0.6	0.6
Other	0.6	0.7	0.3	3.6
TOTAL	**100**	**100**	**100**	**100**

These results are difficult to compare considering the different methodologies used but do provide an interesting benchmark from which to work. It is evident that there is a greater correlation between the two sets of results from Medeiros' research than the correlation between the photogrammetric and visual audit results. One of the reasons for this is that Medeiros only analysed 10 piles of C&D W whereas this project analysed 62 C&D W skips using the two methods. It should be considered that if Medeiros' methodology was applied over a greater number of waste piles, it more show a different trend.

6.7 Time Frames

Reinhart *et al.* (2002) stated that the visual characterisation method is capable of analysing approximately ten to fifty times as many waste loads compared to photogrammetric and mass sorting techniques respectively for the same analysis cost. However, taking the time frame identified by this study, such a comparison cannot be made. The average time per skip cycle to carry out a visual audit is forty minutes. The time taken to carry out a photogrammetric audit of a skip is 182 minutes. This is just over 4.5 times the time it takes to carry out the visual audit (Table 6.7).

Table 6.7 Time allocations for each element of the photogrammetric sorting process.

Administrative time	**Practical Functions**	**Minutes/Skip Cycle (Photo)**	**Minutes/Skip Cycle (Visual)**
Pre-audit information		5 mins	**10 mins per visual audit @ an average of 4 audits per skip cycle**
	Photography on site	20 mins	
Photograph grid adjustment		2 mins	
	Photograph analysis	90 mins	
	Excel template adjustments	10 mins	
	Data transfer- DAF to Excel	40 mins	
	Data Calculation	15 mins	
	Total	**182 mins (3hr 2 mins)**	**40 mins**

6.8 Limitations

6.8.1 EWC codes

The European waste catalogue provides codes for the various C&D W encountered on this case study. Their intended use is for the purpose of identification. However, referring to the catalogue, it was recognised that the number of wastes identified using an EWC code was very limited. Twenty-five different waste types were encountered in this case study with only ten having an appropriate EWC code.

6.8.2 Conversion factors

The *Landfill Levy* Regulations 2002 conversion factors were applied to all waste types encountered in this research where possible but similar to the EWC codes, not all waste types had a relevant conversion factor. There is only nine of the C&D W identified with an appropriate conversion factor.

When comparing the results provided by the waste management contractor to that of the results provided by the conversion factors, it is evident that there is a large discrepancy between both methods. There is a difference of over one hundred tonnes for both sets of results. Considering that the waste management contractor provided a weight each time a skip was emptied and the fact that the *Landfill Levy* conversion factors (DoEHLG, 2002b) were not even specific to the C&D W stream, the figures provided by the waste management contractor could are more accurate. However, the weight for each C&D W skip provided by the WMC is reliant on the application of the volume distribution percentages provided by the auditing method used. This does raise questions towards the relevance of these *Landfill Levy* conversion factors in their application to C&D W analysis data.

Conclusions

The main aims of the chapter were:

- Present the data compiled for the methods of C&D W analysis in a format that will provide waste production indicators for the construction industry.
- Compare the waste production indicators generated to the indicators provided by Medeiros (2001), Grimes (2005) and Kelly (2006).

The main conclusions are as follows:

- A set of waste production indicators for new residential construction was produced:
    - 50.8 kg/m^2 for new residential construction using data provided by the visual characterisation method.
    - 43 kg/m^2 for new residential construction using data provided by the photogrammetric sorting method.
    - 23.8 kg/m^2 for new residential construction using data provided by waste management contractor.

- Volume waste factors were also provided in the form of m^3/m^2. Comparisons were made with the results provided by Grimes (2005) and Kelly (2006) identifying similarities in the results.

- The presentation of the monthly reports made provision for the inclusion of the results provided by the application of the conversion factors from the *Landfill Levy* Regulations, 2002 (DoEHLG 2002) and where possible, the results provided by the waste management contractor. The main conclusion was that there was considerable difference between them and it was felt that the lack of conversion factors specific to the construction industry contributed to this.

Chapter 7 Conclusions and Recommendations

7.1 Introduction

All of the initial objectives stated at the outset will be addressed individually in this section. This will help establish the conclusions, limitations and any recommendations that are to be made. The main aims of the study were to:

- Design and test a waste audit methodology using photogrammetric sorting on an Irish construction project.

- Provide waste production indicators for C&D W volumes arising from a case study where the method was used.

7.2 Objectives

To achieve these aims, a number of objectives must be met:

- Identify the legal responsibilities associated with the production and management of C&D W in Ireland.
- Outline the characteristics of the waste stream.
- Examine the development and testing on an original C&D W auditing tool on construction sites in Ireland (Grimes, 2005 and Kelly, 2006).
- Investigate the use of photogrammetry applications in the construction industry.
- Develop and test a photogrammetric sorting methodology on a residential construction site in Ireland.
- Present the results for analysis and comparison.

7.3 Conclusions

7.3.1 Objective no. 1

- Identify the legal responsibilities associated with the production and management of C&D W in Ireland.

This was achieved by examining the legislation throughout Europe and Ireland. Any proposed legislation awaiting approval was also covered.

Conclusions

- The various waste legislation that has been introduced into Irish law since the implementation of the Waste Management Act 1996 (DoEHLG, 1996) has required the construction industry to be aware of the responsibilities associated with waste management. The Waste Management Act 1996 (DoEHLG, 1996) is considered to be the primary legislative instrument that governs waste management in Ireland. It clearly outlines the circumstances by which the legislation was introduced.

- The legal responsibilities associated with the production of hazardous waste, packaging waste, shipment of waste are outlined as well as the permits, licensing and the landfill levy regulations. All the responsibilities associated with this type of waste are placed on the producers of this waste.

- The construction industry initially responded well to the change in legal responsibilities. The establishment of the National Construction and Demolition Waste Council (NCDWC) in 2002 has raised awareness. However, there is still a lack of awareness towards improving on-site waste management.

7.3.2 Objective no.2

- Outline the characteristics of the waste stream using information about C&D W classification.

This was achieved by analysing methods for characterising C&D W in Ireland and Europe. The nature, source and composition of C&D W and the quantification of C&D W were examined.

Conclusions

- An overview of the composition of C&D W in Europe by Symonds *et al.* (1999) identified 3 types of waste originating from: new construction; renovation and demolition. Renovation waste and demolition waste were found to be similar in composition.

- The analysis of a study carried out in the UK between 1999 and 2001 of the C&D W accepted at landfill sites and waste transfer stations in the Greater Nottingham area (APT Environmental, 2002) provided a background on the classification of C&D W.

7.3.3 Objective no.3

- Examine the development and testing on an original C&D W auditing tool on construction sites in Ireland (Grimes, 2005 and Kelly, 2006).

This was achieved by providing a critical analysis of the development and testing of the methodology. The results and limitations of the studies were also outlined.

Conclusions

- The 5 National Waste Database Reports (EPA, 1996a, 2000, 2003, 2005a, 2006) are considered to be the definitive resource for waste statistics in Ireland. The earliest report in 1995 recorded C&D W production to be at 1.3 million tonnes. The most recent report showed that this has risen to 14.9 million tonnes in 2005. This is a dramatic increase over a decade and it shows that difficulties may arise when attempting to reach the ambitious target of 85 per cent recycling by 2013 (DoEHLG, 1998).

- The visual characterisation method used by Grimes (2005) and Kelly (2006) tested an audit methodology on 58 construction sites in Ireland over a two-year period. A set of waste production indicators were produced for the industry.

7.3.4 Objective no.4

- Investigate the use of photogrammetry applications in the construction industry.

This was achieved by investigating the development of photogrammetry and focusing on its applications in the construction industry. The application of photogrammetric sorting to audit C&D W in the US (Medeiros, 2001) was examined in detail.

Conclusions

- Photogrammetry has many interesting applications in the engineering field, such as mapping, civil engineering, planning, archaeology and environmental studies.

- The study by Medeiros (2001) outlined the application of photogrammetric sorting on landfill sites to audit C&D W. This provided a benchmark from which to work.

- The main limitation of Medeiros' work (2001) is that the photographic analysis tries to interpret images of waste piles, which does not provide a reliable and accurate dataset.

7.3.5 Objective no. 5

- Develop and test a photogrammetric sorting methodology on a residential construction site in Ireland.

This was achieved by designing and testing a methodology based on the visual characterisation method (Kelly, 2006) and the photogrammetric sorting method (Medeiros, 2001).

Conclusions

- The visual characterisation methodology (Kelly, 2006) was used on this site to provide waste production indicators based on visual assessment. The photogrammetric sorting method (Medeiros, 2001) was adapted to incorporate the use of multiple photographs for each skip cycle to provide more reliable data and produce waste production indicators based on photogrammetric analysis.

- A full methodology and testing procedure was outlined in the use of photogrammetric sorting on a residential construction site in Galway.

- The variation between the waste production indicators provided by the WMC figures and the indicators provided by the two auditing methods is attributed to the failure of the landfill levy conversion factors to provide an appropriate weight to the waste components which occasionally lead to their weight being overestimated and in turn provide a greater kg/m^2 indicator.

- It was calculated that it took an estimated 3 hours and 2 minutes for an auditor to photogrammetrically sort through a full C&D W skip cycle and it an estimated 40 minutes using the visual characterisation method.

7.3.6 Objective no. 6

- Present the results for analysis and comparison.

This was achieved by the production of waste production indicators based on visual characterisation, photogrammetric sorting and data provided by the waste management contractor.

Conclusions

- A new set of waste production indicators for new residential construction were produced:
    - 50.8 kg/m^2 for new residential construction using data provided by the visual characterisation method and the *Landfill Levy* conversion factors.
    - 43 kg/m^2 for new residential construction using data provided by the photogrammetric sorting method and the *Landfill Levy* conversion factors.
    - 23.8 kg/m^2 for new residential construction using data provided by waste management contractor.
- The main components of waste identified on the case study by visual characterisation were: plastic (26%); cardboard (22%); and sweepings (20%).
- The main components of waste identified on the case study by photogrammetric sorting were: plastic (33%); cardboard (27%); and sweepings (18%).
- The variation between the waste production indicators of Kelly's and Grimes' was due to the fact that Kelly's was based on 19-point source assessments and the results from these were averaged to give this waste factor.

- The variation between the results provided by Grimes' and this project's results were linked to the longer period of time spent by Grimes analysing the C&D W on both case studies. The results provided by this project are obtained from a case study carried out over a shorter period of time.

- It is evident that there is a greater correlation between the two sets of results from Medeiros' research than the correlation between the photogrammetric and visual audit results. It can concluded that one of the reasons for this is that Medeiros only analysed 10 piles of C&D W whereas this project analysed 62 C&D W skips using the two methods.

7.4 Limitations

The following limitations have been identified during the study:

- Construction output had an effect on waste flow and the accuracy of waste auditing by either method. In a period of high construction output, the level of waste flow would be high. This led to difficulties when keeping account of both the waste volume and its characteristics through the audits. When a high volume of waste was being produced it became difficult to keep track of the waste activity within the skips with only one audit being carried out daily. Occasions occurred where on the first audit the skips volume would be at 80 – 90%.

- On the other hand, during a phase of low construction output, the waste flow was relatively low and it was the lack of activity that became the issue. There were scenarios where a skip would be recorded as having no change in volume for two or three days running.

- The final audit of a skip during the cycle was another area that became problematic. On 62 C&D W skips that were audited, there were nine occasions where that skip had been removed or emptied before the final audit could take place. Wherever this occurred the volume required to reach 100 per cent was documented as the item 'Other'.

- The influx of off-site waste was another factor. Off-site waste could range from household waste to general dumping of waste into the skips without permission. This could not be categorised as a C&D W. Twenty-five waste types were encountered during this study, two were considered to be off site waste (mattress & grass).

- Waste that was concealed in bags, very often black plastic bags was virtually impossible to identify. It was not an option to open and examine these bags contents due to health and safety issues. Therefore, when this situation occurred, it was usually documented as the component sweepings because there was every indication that this is what these bags contained.

- There were also limitations attached to the use of photogrammetry as a method for auditing the C&D W. These included:
    - The failure to obtain the last set of photographs for the final audit before the skip was removed similar to the visual audit.
    - The time scale involved in auditing a skip through photogrammetry was a major factor. It was averaged at 3 hours and two minutes per skip.

7.5 Recommendations

- The application of the conversion factors provided by the Waste Management (Landfill Levy) Regulations, 2002 (DoEHLG, 2002b) on this project and the results it provided has highlighted the fact that they are not specific to the waste types generated in the construction industry and are therefore unsuitable for use on any C&D W research. The future accuracy of C&D W auditing is dependent on specific C&D W conversion factors being developed. This can be considered one of the primary targets for any other research in the area.

- The current draft *Waste Management (Facility Permits and Registrations) Regulations 2005* (DoEHLG, 2005a) will provide increased tonnage capacity for the inert fraction of the C&D W stream. The local authorities must assess their regional capacities before granting any permits or registrations under this impending legislation.

- The use of the photogrammetric sorting method on this project did prove to be successful but it should be noted that the use of the same auditor carrying out both analyses using the two methods was a concern. The issue of bias and judgement being affected by the first audit method used leads to the recommendation that a more stringent testing of the photogrammetric sorting method could be carried out if there were a different auditor used for each method and results were compared at a later stage.

- Medeiros (2001) assumed that the percentage area occupied by a component in the image was directly proportional to the percentage volume occupied. This project documented the percentage area occupied by a component in the image as though it was directly proportional to the percentage volume occupied but compensated for any error through the number of photographs studied and the use of conversion factors. This was a critically important adjustment to Medeiros' method, which contributed to a greater accuracy in the results.

- The photogrammetric sorting method used on this project was carried out using the basic functions of Adobe Photo 6.0. The analysis of all functions on the Photoshop software should be considered to determine if the technique of photograph analysis used on this project could be improved.

- The calculation of floor area (m^2) of construction completed during the course of the research proved to be quite difficult. This data is vital for providing a waste factor (kg/m^2) for any case study. The actual floor area of a residential unit was available from the design drawings. However, when the period of research was coming to an end there were some units that were not fully complete where other units were still at block work stage. It would be recommended that each type of unit be examined fully and a percentage allocated to each significant stage of construction. e.g. total completion of the roof would be to deem the house to be 20 per cent complete.

- In the area of new residential construction or any new construction the finishing process has can be accountable for a large volume of the waste produced on site. The various materials involved and the enormous volume of packing waste that the finishing process creates. It is recommended that an analysis of waste produced in the final finishing stages of construction be analysed. The composition of certain elements of C&D W on this project indicates a large volume arises from this stage of construction.

- Designers of buildings have a role to play in reduction of C&D W. In the future it is important that a design become geared towards C&D W and methods of reduction. Their eventual design can have a significant bearing on the level of waste produced by a construction project.

- When the use of photographs began at the outset, two photographs were taken at each audit. This was seen as the best possible way of recording all a C&D W skip's contents. As the analysis of the data from the photographs began, it became clear that the time frame involved was quite demanding. A re-think was required half way through the research because of the time consuming factors involved. It became apparent from looking at the photographs day after day that, an accurate depiction of the skips contents could be achieved with one photograph. It required care to be taken when photographing the skips on site to ensure a good quality photograph. It was therefore decided to reduce the number of photographs per audit to one

7.6 Summary

This research project provided a new system for auditing C&D W through the analysis of photographs. This method was tested against a visual method which has been used to good effect on other research initiatives (Grimes, 2005 and Kelly, 2006). These two methods provided C&D W production indicators in kg/m² for new residential construction. The application of these methods also catered for the analysis of conversion factors provided by the Waste Management (Landfill Levy) Regulations, 2002 (DoEHLG, 2002b).

The significant contributions to knowledge in this thesis are:

- The development and testing of a new C&D W auditing methodology on a construction project in Ireland.
- The comparison between the C&D W production data provided by the use of volume conversion factors and the actual weight data provided by the waste management contractor.
- The generation of waste production indicators for new residential construction.

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Appendix A

SECTION 17 OF THE EUROPEAN WASTE CATALOGUE

17 CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES)

* Hazardous Waste

17 01 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 (18)

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 resin-based floorings, pcb-containing sealed glazing units, pcb-containing, capacitors)
17 09 03* other construction and demolition wastes (including mixed wastes) containing dangeroussubstances
17 09 04 mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 0902 and 17 09 03

APPENDIX B

C1 Form

WASTE MANAGEMENT (MOVEMENT OF HAZARDOUS WASTE) REGULATIONS, 1998

Form C.1. Consignment Note for consignments of hazardous waste transported within the State (NOT to be used for transhipment into or out of the State) **B 372270**

PART A (to be completed by the consignor)

1. Name and address of consignor[1]: ....
   .... Tel: .... Fax: ....
2. Name and chemical composition of waste*: ....
   ....
3. European Waste Catalogue/Hazardous Waste List Description(s) and Code(s)[2]: ....
4. Origin of waste (name and address of producer, if different from 1.): ....
   ....
5. Process(es) that waste originates from: ....
   ....
6. Quantity (indicate kg or litres): ....
7. Size, type[3] and number of containers: ....
8. Physical characteristics[4]: ....
9. Components which are hazardous (giving concentrations in each case): ....
   ....
10. Hazardous properties[5] and special handling instructions (if any): ....
    ....
11. Name and address of consignee[6]: ....
    ....
12. I, the consignor, certify that the information given in Part A above is complete and correct to the best of my knowledge.

Signed .... Date ....

Name (Block Letters) .... on behalf of ....

Position held by person signing ....

PART B (to be completed by the carrier)

13. I, the carrier,[7] certify that I collected the waste described in Part A in vehicle (reg. no.) .... at (time) .... on (date) .... and that I have been informed of the hazardous nature of the waste, as set out in that Part.

Signed .... on behalf of ....

Name (Block Letters) .... Signature of consignor as witness ....

PART C (to be completed by the consignee)

14. Name and address of consignee: ....
    .... Tel.: .... Fax: ....
15. Waste licence number (if applicable)[8] .... Waste permit number (if applicable)[9] ....
    Certificate of registration (if applicable)[10] ....
16. The waste described in Part A was delivered to me by (carrier) .... in vehicle (reg.no.) ....
    at (time) .... on (date) .... on behalf of (consignor) ....
17. (a) The consignment was accepted: .... (b) The consignment was rejected: ....
18. If the consignment of waste was rejected, state the reason(s): ....
    ....
19. If the consignment of waste was accepted, state the recovery/disposal activity(ies) to which it will be subject and provide code number and description of the technology involved[11]
    ....
20. I, the consignee, certify that the information given in Part C above is complete and correct to the best of my knowledge.

Signed .... Date ....

Name (Block Letters) .... on behalf of ....

Position held by person signing ....

* full description may be attached on separate page

Footnotes [1] to [11] see relevant definitions and lists in the "Instructions for Completion of Consignment Notes for Hazardous Waste".

CARRIER' S COPY - to be given to the carrier of the waste, after completion of PART C by the consignee, and retained by the carrier.

APPENDIX C

Sample Audit Book Pages

SITE LOCATION:

JOB DESCRIPTION:

SKIP SIZE REFERENCE: **AREA CODE:** **COMPACTED/NON-COMPACTED**

AUDITOR: 0001

Date	Material	EWC Code	% Full	Quantity (m^3)	Weight (tonnes)	Notes/Comments

SITE LOCATION:

JOB DESCRIPTION:

SKIP SIZE REFERENCE: **AREA CODE:** **COMPACTED/NON-COMPACTED**

AUDITOR: 0001

Date	Material	EWC Code	% Full	Quantity (m^3)	Weight (tonnes)	Notes/Comments

SITE LOCATION:

JOB DESCRIPTION:

SKIP SIZE REFERENCE: **AREA CODE:** **COMPACTED/NON-COMPACTED**

AUDITOR: 0001

Date	Material	EWC Code	% Full	Quantity (m^3)	Weight (tonnes)	Notes/Comments

APPENDIX D

Skip Size Conversion Factors

12 cubic yard = 9.175m³			
% Full	m³	% Full	m³
5	0.459	55	5.046
10	0.918	60	5.505
15	1.376	65	5.964
20	1.835	70	6.423
25	2.294	75	6.881
30	2.753	80	7.340
35	3.211	85	7.799
40	3.670	90	8.258
45	4.129	95	8.716
50	4.588	100	9.175

Conversion factors – cubic yards to m³

APPENDIX E

Medeiros' Results (2001)

Citrus 1

Waste Component	Photogrammetric Sort Predicted Volume Distribution (percent)	Mass Sort Distribution (percent)
Wood	27.1	23.0
Concrete	35.9	45.5
Paper	15.1	22.5
Drywall	0.0	0.0
Metal	1.8	1.9
Insulation	0.1	0.0
Roofing	3.5	0.3
Plastic	12.5	3.9
Flooring	0.0	0.0
MSW	2.1	1.0
Land Clearing	1.5	1.9
Other	0.5	0.0
TOTAL	100	100

Citrus 2

Waste Component	Photogrammetric Sort Predicted Volume Distribution (percent)	Mass Sort Distribution (percent)
Wood	8.2	20.6
Concrete	0.7	1.2
Paper	35.5	36.8
Drywall	2.9	0.1
Metal	4.6	2.4
Insulation	3.1	8.7
Roofing	32.6	23.0
Plastic	11.0	5.0
Flooring	0.0	0.0
MSW	0.5	1.4
Land Clearing	0.0	0.9
Other	1.2	0.0
	100	100

Citrus 3

Waste Component	Photogrammetric Sort Predicted Volume Distribution (percent)	Mass Sort Distribution (percent)
Wood	52.0	57.4
Concrete	5.5	10.2
Paper	14.7	21.3
Drywall	1.4	0.0
Metal	6.1	1.9
Insulation	14.2	7.5
Roofing	0.6	0.1
Plastic	1.0	0.9
Flooring	0.2	0.1
MSW	3.4	0.8
Land Clearing	0.0	0.0
Other	0.9	0.0
TOTAL	100	100

Citrus 4

Waste Component	Photogrammetric Sort Predicted Volume Distribution (percent)	Mass Sort Distribution (percent)
Wood	20.3	15.9
Concrete	0.4	0.4
Paper	47.1	32.7
Drywall	7.2	5.2
Metal	4.9	2.9
Insulation	3.6	9.6
Roofing	1.3	23.9
Plastic	13.1	7.5
Flooring	0.0	0.1
MSW	1.7	1.4
Land Clearing	0.0	0.4
Other	0.6	0.0
TOTAL	100	100

Citrus 5

Waste Component	Photogrammetric Sort Predicted Volume Distribution (percent)	Mass Sort Distribution (percent)
Wood	6.2	8.1
Concrete	0.7	1.7
Paper	61.4	53.6
Drywall	0.1	0.0
Metal	1.1	3.7
Insulation	2.9	0.5
Roofing	10.6	1.5
Plastic	8.1	15.5
Flooring	7.2	10.5
MSW	0.9	2.3
Land Clearing	0.5	1.7
Other	0.6	1.0
TOTAL	100	100

Citrus 6

Waste Component	Photogrammetric Sort Predicted Volume Distribution (percent)	Mass Sort Distribution (percent)
Wood	4.6	1.8
Concrete	0.2	2.2
Paper	75.7	65.4
Drywall	0.5	0.0
Metal	1.1	1.5
Insulation	3.1	3.4
Roofing	1.4	0.9
Plastic	10.3	18.3
Flooring	0.0	1.3
MSW	2.3	4.9
Land Clearing	0.0	0.0
Other	1.0	0.4
TOTAL	100	100

Citrus 7

Waste Component	Photogrammetric Sort Predicted Volume Distribution (percent)	Mass Sort Distribution (percent)
Wood	2.5	17.6
Concrete	3.2	5.2
Paper	10.4	16.4
Drywall	40.7	14.9
Metal	1.2	8.0
Insulation	4.6	8.0
Roofing	19.7	10.5
Plastic	16.3	15.5
Flooring	0.0	0.0
MSW	0.8	1.1
Land Clearing	0.5	0.0
Other	0.0	2.9
TOTAL	100	100

Brevard 1

Waste Component	Photogrammetric Sort Predicted Volume Distribution (percent)	Mass Sort Distribution (percent)
Wood	76.5	70.9
Concrete	2.6	3.4
Paper	10.4	7.5
Drywall	0.0	0.0
Metal	0.7	4.4
Insulation	0.2	0.0
Roofing	0.0	0.0
Plastic	6.9	4.2
Flooring	0.0	0.0
MSW	2.0	3.7
Land Clearing	0.5	5.3
Other	0.0	0.5
TOTAL	100	100

Brevard 2

Waste Component	Photogrammetric Sort Predicted Volume Distribution (percent)	Mass Sort Distribution (percent)
Wood	7.0	21.2
Concrete	1.4	3.6
Paper	33.8	16.6
Drywall	7.6	8.8
Metal	2.2	9.1
Insulation	9.4	3.1
Roofing	1.8	1.6
Plastic	30.5	27.5
Flooring	0.0	0.0
MSW	0.3	0.7
Land Clearing	5.4	5.2
Other	0.6	2.6
TOTAL	100	100

Brevard 3

Waste Component	Photogrammetric Sort Predicted Volume Distribution (percent)	Mass Sort Distribution (percent)
Wood	30.8	32.8
Concrete	29.4	25.6
Paper	14.5	25.3
Drywall	0.3	0.0
Metal	1.2	0.6
Insulation	0.2	2.6
Roofing	3.8	1.3
Plastic	9.4	9.3
Flooring	8.7	1.2
MSW	1.0	1.2
Land Clearing	0.0	0.0
Other	0.7	0.0
TOTAL	100	100

APPENDIX F

SKIP No. 46 – Photographs and Data Acquisition Forms

Photograph 24-5-06 (1)

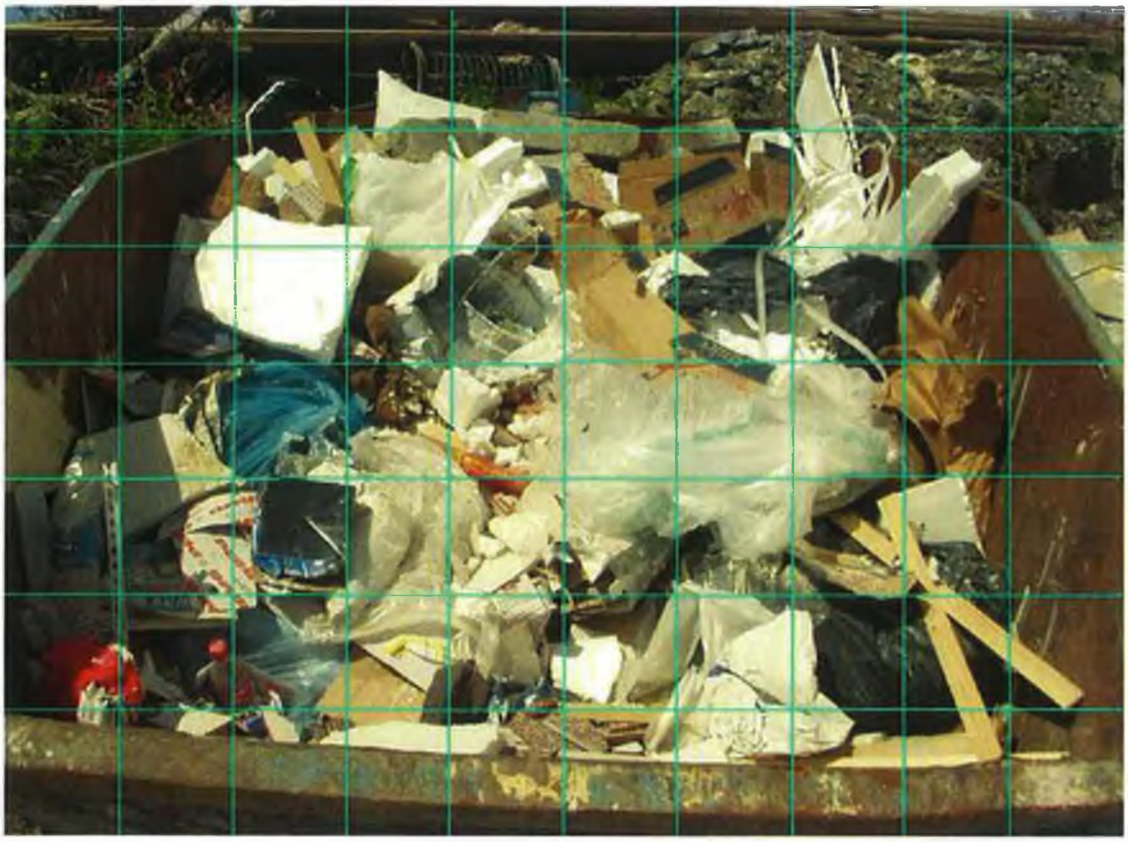
B100							C30 B70	C40 B60	B100
B100	T5 B95	T30 P10 B60	B100	C10 B90	C30 B70	C40 B60	C70 B30	C95 B5	C30 B70
B100	P70 C10 B20	P95 T5	P10 C30 B60	C100					
B100	B40 C40 P20	P100	P40 C60	C100					
B90 P10	P50 C40 B10	P100	P95 T5	C85 P10 T5	C100	C70 S30	C100		
P80 T20		P100		T50 P10 B40	T30 C10 S60	S100	S80 C20	C100	
P80 B20	P40 C40 B20	B10 C60 P30	C50 P50	P30 T70	T100	C90 T10	C80 T20	C100	

Data Acquisition Form for Photograph 24-5-06 (1)

Photograph 25-5-06 (2)

B100	—	—	C30 T10 B60	C90 B10	C100	—	—	B100	—
B100	—	—	C100	C50 S50	C100	—	C50 B50	C10 B90	B100
B100	—	C20 B80	P100	C50 P50	C100	C40 A40 P20	A60 C40	A30 C20 B50	B100
B100	—	P70 B30	P30 C70	C80 P20	C100	S70 C30	S100	S90 B10	B100
S5 B95	C10 B90	C95 B5	C95 B5	P70 C30	P60 C40	S70 C30	S95 T5	S30 C30 P30 T10	B100
P100	C70 P30	C100	C40 P60	S100	—	P90 C10	P100	C70 P30	C5 B95
S90 B10	C60 S30 B10	C20 S80	S100	S50 C50	S70 P30	C40 P60	P100	—	P70 B30

Data Acquisition Form for Photograph 25-5-06 (2)



Photograph 30-5-06 (2)

B100	→	P10 B90	→	B100	→	→	P20 B80	B100	→
B100	→	C30 P10 B10	P80 T10 B10	P70 A10 B20	C50 S50	C80 S20	P70 C30	P30 A30 B60	A70 B90
B100	C10 A10 B80	A100	A30 C30 P40	P100	C90 P10	C60 P40	P95 C5	P85 A10 C5	B100
B95 C5	C60 B40	S80 C10 A10	C85 S10 A5	P100	P90 C10	C50 P50	P90 K10	P30 C70	C30 B70
P35 B65	C100	C50 S50	P100	→	→	→	→	P40 C60	C40 A5 B55
C100	→	C80 P20	P90 C10	P100	C100	P10 S90	P10 S90	T30 C10 S60	S30 A10 T10 B50
C90 B10	C100	P100	C80 P20	C100	→	→	→	C80 S20	S95 T5

Data Acquisition Form for Photograph 30-5-06 (2)

Photograph 1-6-06 (1)

B100	P30 B70	P90 B10	P60 B20	P5 S10 B85	C30 S20 B50	C100	C60 B40	B100	
P15 B85	P100			C90 P10	C100	S80 C20	S70 C30	C50 B50	C10 B90
P15 B85	P90 C10	P100	C70 B30	C95 P5	P50 A50	P90 S10	P95 S5	P10 C90	C100
C70 B30	C100				C50 A40 P10	C70 P30	P100	P50 C50	C100
C40 B60	C100			P100		C20 P80	C100	C50 P50	P100
P15 B85	P85 C15	P100	P40 C60	C90 P10	P50 A50	P70 S30	P90 S5	C70 P30	C100
B100	C100	P100	P90 C10	C90 P10	C100				

Data Acquisition Form for Photograph 1-6-06 (1)

APPENDIX G

Electronic Data Acquisition Form

Row 1												Average over
Column no.	1	2	3	4	5	6	7	8	9	10	Total	Photo
Timber												
Plastic												
Cardboard												
Sweepings												
Polystyrene												
Blocks												
Background												

Row 2												Average over
Column no.	1	2	3	4	5	6	7	8	9	10	Total	Photo
Timber												
Plastic												
Cardboard												
Sweepings												
Polystyrene												
Blocks												
Background												

Row 3												Average over
Column no.	1	2	3	4	5	6	7	8	9	10	Total	Photo
Timber												
Plastic												
Cardboard												
Sweepings												
Polystyrene												
Blocks												
Background												

Row 4												**Average over**
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber												
Plastic												
Cardboard												
Sweepings												
Polystyrene												
Blocks												
Background												

Row 5												**Average over**
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber												
Plastic												
Cardboard												
Sweepings												
Polystyrene												
Blocks												
Background												

Row 6												**Average over**
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber												
Plastic												
Cardboard												
Sweepings												
Polystyrene												
Blocks												
Background												

Row 7												Average over
Column no.	1	2	3	4	5	6	7	8	9	10		Photo
Timber												
Plastic												
Cardboard												
Sweepings												
Polystyrene												
Blocks												
Background												

APPENDIX H

Data for skip no. 46 presented in electronic format

Photograph											
24-5-06 (1)											
		Row	1								Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber										0	0.0
Plastic										0	0.0
Cardboard								30	40		70	1.0
Sweepings										0	0.0
Aeroboard										0	0.0
Blocks										0	0.0
Background	100	100	100	100	100	100	100	70	60	100	930	13.3
											1000	14.3

		Row	2									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber		5	40								45	0.6
Plastic			10								10	0.1
Cardboard					10	30	40	70	95	30	[illegible]	3.9
Sweepings											0	0.0
Aeroboard											0	0.0
Blocks											0	0.0
Background	100	95	60	100	90	70	60	30	5	70	680	9.7
											1010	14.4

		Row	3									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber			5								5	0.1
Plastic		70	95	10							175	2.5
Cardboard		10		30	100	100	100	100	100	100	640	9.1
Sweepings											0	0.0
Aeroboard											0	0.0
Blocks											0	0.0
Background	100	20		60							180	2.6
											1000	14.3

		Row	4									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	[illegible]	**Photo**
Timber											0	0.0
Plastic		20	100	90							210	3.0
Cardboard		40		10	100	100	100	100	100	100	650	9.3
Sweepings											0	0.0
Aeroboard											0	0.0
Blocks											0	0.0
Background	100	40									140	2.0
											1000	14.3

		Row	[illegible]									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber				5	5						10	0.1
Plastic	10	50	100	95	10						265	3.8
Cardboard		40			85	100	70	100	100	100	595	8.5
Sweepings							30				30	0.4
Aeroboard											0	0.0
Blocks											0	0.0
Background	90	10									100	1.4
											1000	14.3

		Row	[illegible]									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber	20	20			50	30					120	1.7
Plastic	80	80	100	100	10						370	5.3
Cardboard						10		20	100	100	230	3.3
Sweepings						60	100	80			240	3.4
Aeroboard											0	0.0
Blocks											0	0.0
Background					40						40	0.6
											1000	14.3

		Row	7									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber					70	100	10	20			200	2.9
Plastic	80	40	30	50	30						230	3.3
Cardboard		40	60	50			90	80	100	100	[illegible]	7.4
Sweepings											0	0.0
Aeroboard											0	0.0
Blocks											0	0.0
Background	20	20	10								50	0.7
											1000	14.3

Photograph												
25-5-06 (2)												
		Row	1									Average over
Column no.	1	2	3	4	5	6	7	8	9	10	Total	Photo
Timber				10							10	0.1
Plastic											0	0.0
Cardboard				30	90	100	100	100			420	6.0
Sweepings											0	0.0
Aeroboard											0	0.0
Blocks											0	0.0
Background	100	100	100	60	10				100	100	570	8.1
											1000	14.3

		Row	2									Average over
Column no.	1	2	3	4	5	6	7	8	9	10	Total	Photo
Timber											0	0.0
Plastic											0	0.0
Cardboard				100	50	100	100	50	10		410	5.9
Sweepings					50						50	0.7
Aeroboard											0	0.0
Blocks											0	0.0
Background	100	100	100					50	90	100	540	7.7
											1000	14.3

		Row	3									Average over
Column no.	1	2	3	4	5	6	7	8	9	10	Total	Photo
Timber											0	0.0
Plastic				100	50						150	2.1
Cardboard			20		50	100	100	50	10		330	4.7
Sweepings											0	0.0
Aeroboard											0	0.0
Blocks											0	0.0
Background	100	100	80					50	90	100	520	7.4
											1000	14.3

		Row	4									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic			70	30	20						120	1.7
Cardboard				70	80	100	30				280	4.0
Sweepings							70	100	90		260	3.7
Aeroboard											0	0.0
Blocks											0	0.0
Background	100	100	30						10	100	340	4.9
											1000	14.3

		Row	5									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic				5	70	60					135	1.9
Cardboard		10	95	95	30	40	30				300	4.3
Sweepings	5						70	100	90		265	3.8
Aeroboard											0	0.0
Blocks											0	0.0
Background	95	90	5						10	100	300	4.3
											1000	14.3

		Row	6									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic	100	30		60			90	100	30		410	5.9
Cardboard		70	100	40			10		70	5	295	4.2
Sweepings					100	100					200	2.9
Aeroboard											0	0.0
Blocks											0	0.0
Background										95	95	1.4
											1000	14.3

		Row	7									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											[illegible]	0.0
Plastic						30	60	100	100	70	360	5.1
Cardboard		60	20		50		40				[illegible]	2.4
Sweepings	90	30	80	100	50	70					[illegible]	6.0
Aeroboard											0	0.0
Blocks											0	0.0
Background	10	10								30	50	0.7
											[illegible]	14.3

Photograph												
30-5-06 (2)												
		Row	1									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic			10	10				20			40	0.6
Cardboard											0	0.0
Sweepings											0	0.0
Aeroboard											0	0.0
Blocks											0	0.0
Background	100	100	90	90	100	100	100	80	100	100	960	13.7
											1000	14.3

		Row	2									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber				10							10	0.1
Plastic			10	80	70			70	30		260	3.7
Cardboard			80			50	80	30			240	3.4
Sweepings				10	20	50	20				100	1.4
Aeroboard					10				30	10	50	0.7
Blocks											0	0.0
Background	100	100	10						40	90	340	4.9
											1000	14.3

		Row	3									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic				40	100	90	40	95	85		450	6.4
Cardboard		10		30		10	60	5	5		120	1.7
Sweepings											0	0.0
Aeroboard		10	100	30					10		150	2.1
Blocks											0	0.0
Background	100	80								100	280	4.0
											1000	14.3

		Row	4									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic					100	90	50	90	30		360	5.1
Cardboard	5	60	10	85		10	50	10	70	30	330	4.7
Sweepings			80	10							90	1.3
Aeroboard			10	5							15	0.2
Blocks											0	0.0
Background	95	40								70	205	2.9
											1000	14.3

		Row	5									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic	35			100	100	100	100	100	40		575	8.2
Cardboard		100	50						60	40	250	3.6
Sweepings			50								50	0.7
Aeroboard										5	5	0.1
Blocks											0	0.0
Background	65									55	120	1.7
											1000	14.3

		Row	6									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber									30	10	40	0.6
Plastic			20	90	100		10	10			230	3.3
Cardboard	100	100	80	10		100			10		400	5.7
Sweepings							90	90	60	30	270	3.9
Aeroboard										10	1[illegible]	0.1
Blocks											0	0.0
Background										50	50	0.7
											1000	14.3

		Row	7									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber										5	5	0.1
Plastic			100	20							12[illegible]	1.7
Cardboard	90	100		80	100	100	100	100	80		750	10.7
Sweepings									20	95	[illegible]	1.6
Aeroboard											[illegible]	0.0
Blocks											0	0.0
Background	10										10	0.1
											1000	14.3

Photograph												
1-6-06 (1)												
		Row	1									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic		30	90	60	5						185	2.6
Cardboard						30	100	60			190	2.7
Sweepings					10	20					30	0.4
Aeroboard											[illegible]	0.0
Blocks											0	0.0
Background	100	70	10	40	85	50		40	100	100	595	8.5
											1000	14.3

		Row	2									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic	15	100	100	100	10						325	4.6
Cardboard					90	100	20	30	50	10	300	4.3
Sweepings							80	70			150	2.1
Aeroboard											0	0.0
Blocks											0	0.0
Background	85								50	90	225	3.2
											1000	14.3

		Row	3									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic	15	90	100	30	5	50	90	95	10		485	6.9
Cardboard		10		70	95				90	100	365	5.2
Sweepings							10	5			15	0.2
Aeroboard						50					50	0.7
Blocks											0	0.0
Background	85										85	1.2
											1000	14.3

		Row	4									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic						10	30	100	50		190	2.7
Cardboard	70	100	100	100	100	50	70		50	100	740	10.6
Sweepings											0	0.0
Aeroboard						40					40	0.6
Blocks											0	0.0
Background	30										30	0.4
											1000	14.3

		Row	[illegible]									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic					100	100	80		50	100	430	6.1
Cardboard	40	100	100	100			20	100	50		510	7.3
Sweepings											0	0.0
Aeroboard											0	0.0
Blocks											0	0.0
Background	60										60	0.9
											1000	14.3

		Row	6									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	[illegible]	**Photo**
Timber											0	0.0
Plastic	15	85	100	40	10	50	70	90	30		490	7.0
Cardboard		15		60	90				70	100	[illegible]	4.8
Sweepings							30	10			40	0.6
Aeroboard						50					50	0.7
Blocks											0	0.0
Background	85										85	1.2
											1000	14.3

		Row	7									Average over
Column no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Photo**
Timber											0	0.0
Plastic			100	90	10						200	2.9
Cardboard		100		10	90	100	100	100	100	100	700	10.0
Sweepings											0	0.0
Aeroboard											0	0.0
Blocks											0	0.0
Background	100										100	1.4
											1000	14.3

		Total %		Ave %			Photo %		Visual %		Weight (ton)	
											Photo	Visual
Timber		6.4		1.6			2.2		5.0		0.036	0.083
Plastic		96.8		24.2			33.3		20.0		0.550	0.330
Cardboard		148.8		37.2			51.2		47.5		0.845	0.784
Sweepings		33.2		8.3			11.4		20.0		0.189	0.330
Aeroboard		5.3		1.3			1.8		5.0		0.030	0.083
Blocks		0.0		0.0			0.0		2.5		0.000	0.041
Background		109.7		27.4			100.0		100.0		1.650	1.650
		400.0		100.0								

APPENDIX J

Site Layout used to calculate Floor Areas

39 Houses 4337 sq.m
100 % Complete

62 Apartments 4307 sq.m
10 % Complete

67 Houses 6876 sq.m
10 % Complete

Units Not Included

Total Floor Area Completed = 5455 sq.m

APPENDIX K

Monthly Reports

Project Description	Residential Development in Roscam		
Completed Floor Area:		**Project Stage**	
Total Waste (m³)	18.350	**Total Waste (tonnes):**	
Unit Waste Factor (m³/m²)		**Unit Waste Factor (kg/m²)**	
Date:	July '05	**Auditor:**	

Visual Audit						**Photogrammetry Audit**			
Materials	EWC Code	Volume (m³)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m³)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Cardboard		4.048	0.40	1.619	0.682	3.570	0.40	1.428	0.601
Plastic	107203	3.496	0.15	0.524	0.589	9.062	0.15	1.359	1.527
Sweepings		5.336	0.60	3.202	0.899	1.270	0.60	0.762	0.214
Floor Lino		0.460	1.00	0.460	0.078	0.000	1.00	0.000	0.000
Timber	170201	0.920	0.60	0.552	0.156	1.362	0.60	0.817	0.229
Tiles	107103	0.092	1.00	0.092	0.016	0.000	1.00	0.000	0.000
Tile Adh Bag		0.184	0.15	0.028	0.031	0.000	0.15	0.000	0.000
Aeroboard	170604	1.288	1.00	1.288	0.217	0.736	1.00	0.736	0.124
Felt		0.460	1.00	0.460	0.078	0.092	1.00	0.092	0.016
Carpet		0.276	1.00	0.276	0.047	1.076	1.00	1.076	0.181
Slab	170802	1.840	0.40	0.736	0.310	1.214	0.40	0.486	0.205
Total		**18.350**		**9.237**	**3.100**	**18.350**		**6.756**	**3.100**

* weight in tonnes as provided by the waste management company

Project Description	**Residential Development in Roscam**		
Completed Floor Area:		**Project Stage**	
Total Waste (m^3)	36.700	**Total Waste (tonnes):**	
Unit Waste Factor (m^3/m^2)		**Unit Waste Factor (kg/m^2)**	
Date:	Aug '05	**Auditor:**	
Visual Audit		**Photogrammetry Audit**	

Materials	EWC Code	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Slab	170802	6.000	0.40	2.400	1.092	6.146	0.40	2.458	1.119
Cardboard		8.832	0.40	3.533	1.608	8.390	0.40	3.356	1.528
Timber	170201	2.320	0.60	1.392	0.422	3.974	0.60	2.385	0.724
Plastic	170203	7.656	0.15	1.148	1.394	9.531	0.15	1.430	1.735
Tiles	170103	0.664	1.00	0.664	0.121	0.009	1.00	0.009	0.002
Tile Bags		0.368	0.15	0.055	0.067	0.092	0.15	0.014	0.017
Sweepings		4.600	1.00	4.600	0.838	5.336	1.00	5.336	0.972
Floor Lino		0.296	1.00	0.296	0.050	0.000	1.00	0.000	0.000
Felt		3.672	1.00	3.672	0.670	1.251	1.00	1.251	0.228
Mattress		1.400	1.00	1.400	0.255	0.331	1.00	0.331	0.060
Aeroboard	170604	0.664	1.00	0.664	0.121	1.730	1.00	1.730	0.315
Wire		0.184	1.00	0.184	0.034	0.037	1.00	0.037	0.007
Carpet		0.112	1.00	0.112	0.017	0.000	1.00	0.000	0.000
Total		**36.700**		**20.120**	**6.700**	**36.700**		**18.337**	**6.700**

* weight in tonnes as provided by the waste management company

Project Description	Residential Development in Roscam		
Completed Floor Area:		Project Stage	
Total Waste (m^3)	36.700	Total Waste (tonnes):	
Unit Waste Factor (m^3/m^2)		Unit Waste Factor (kg/m^2)	
Date:	Sep '05	Auditor:	
Visual Audit		Photogrammetry Audit	

Materials	EWC Code	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Cardboard		7.397	0.40	2.959	2.058	11.224	0.40	4.490	3.123
Plastic	170203	5.557	0.15	0.834	1.546	9.605	0.15	1.441	2.673
Sweepings		8.170	0.60	4.902	2.273	7.176	0.60	4.306	1.997
Timber	170201	5.152	0.60	3.091	1.434	4.232	0.60	2.539	1.178
Felt		3.312	1.00	3.312	0.922	1.840	1.00	1.840	0.512
Concrete	170101	1.656	1.50	2.484	0.461	0.552	1.50	0.828	0.154
Grass		1.251	1.00	1.251	0.348	0.221	1.00	0.221	0.061
Paint cans		0.920	1.00	0.920	0.256	0.810	1.00	0.810	0.225
Aeroboard	170604	0.092	1.00	0.092	0.026	0.000	1.00	0.000	0.000
Tile bags		2.134	0.15	0.320	0.594	0.883	0.15	0.132	0.246
Wire		0.092	1.00	0.092	0.026	0.037	1.00	0.037	0.010
Metal	170407	0.184	1.00	0.184	0.051	0.000	1.00	0.000	0.000
Total		**36.700**		**20.440**	**10.240**	**36.700**		**16.643**	**10.240**

* weight in tonnes as provided by the waste management company

Project Description	Residential Development in Roscam		
Completed Floor Area:		**Project Stage**	
Total Waste (m^3)	50.050	**Total Waste (tonnes):**	
Unit Waste Factor (m^3/m^2)		**Unit Waste Factor (kg/m^2)**	
Date:	Oct '05	**Auditor:**	
Visual Audit		**Photogrammetry Audit**	

		Visual Audit				**Photogrammetry Audit**			
Materials	**EWC Code**	**Volume (m^3)**	**Conversion Factor**	**Weight (tonnes)**	**Weight (tonnes)***	**Volume (m^3)**	**Conversion Factor**	**Weight (tonnes)**	**Weight (tonnes)***
Cardboard		8.832	0.40	3.533	1.597	11.592	0.40	4.637	2.096
Sweepings		7.176	0.60	4.306	1.297	6.127	0.60	3.676	1.108
Plastic	170203	18.216	0.15	2.732	3.293	24.288	0.15	3.643	4.391
Metal	170407	0.276	1.00	0.276	0.050	0.221	1.00	0.221	0.040
Timber	170201	2.926	0.60	1.756	0.529	1.270	0.60	0.762	0.230
Tiles	170103	0.276	1.00	0.276	0.050	0.110	1.00	0.110	0.020
Tile Bags		0.276	0.15	0.041	0.050	0.017	0.15	0.002	0.003
Aeroboard	170604	2.926	1.00	2.926	0.529	0.938	1.00	0.938	0.170
Slab	170802	7.728	0.40	3.091	1.397	5.906	0.40	2.363	1.068
Felt		3.643	1.00	3.643	0.659	1.987	1.00	1.987	0.359
Canvass		0.276	1.00	0.276	0.050	0.718	1.00	0.718	0.130
Mattress		0.331	1.00	0.331	0.060	0.552	1.00	0.552	0.100
Concrete	170101	0.442	1.50	0.663	0.080	0.000	1.50	0.000	0.000
Carpet		0.442	1.00	0.442	0.080	0.000	1.00	0.000	0.000
Gravel	170504	1.380	1.50	2.070	0.250	1.435	1.50	2.153	0.259
Total		**55.050**		**26.362**	**9.980**	**55.050**		**21.762**	**9.980**

Project Description	Residential Development in Roscam		
Completed Floor Area:		Project Stage	
Total Waste (m³)	36.700	Total Waste (tonnes):	
Unit Waste Factor (m³/m²)		Unit Waste Factor (kg/m²)	
Date:	Nov '05	Auditor:	
Visual Audit		Photogrammetry Audit	

Materials	EWC Code	Volume (m³)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m³)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Sweepings		6.698	0.60	4.019	1.583	6.698	0.60	4.019	1.157
Plastic	170203	13.800	0.15	2.070	3.263	13.800	0.15	2.070	4.141
Tile Bags		0.920	0.15	0.138	0.218	0.920	0.15	0.138	0.139
Cardboard		7.102	0.40	2.841	1.679	7.102	0.40	2.841	1.931
Slab	170802	1.840	0.40	0.736	0.435	1.840	0.40	0.736	0.626
Carpet		0.478	1.00	0.478	0.113	0.478	1.00	0.478	0.000
Aeroboard	170604	2.907	1.00	2.907	0.687	2.907	1.00	2.907	0.174
Timber	170201	1.950	0.60	1.170	0.461	1.950	0.60	1.170	0.392
Wire		0.184	1.00	0.184	0.044	0.184	1.00	0.184	0.000
Felt		0.920	1.00	0.920	0.218	0.920	1.00	0.920	0.122
Total		**36.700**		**15.463**	**8.700**	**36.700**		**15.463**	**8.700**

* weight in tonnes as provided by the waste management company

Project Description	Residential Development in Roscam		
Completed Floor Area:		Project Stage	
Total Waste (m^3)	36.700	Total Waste (tonnes):	
Unit Waste Factor (m^3/m^2)		Unit Waste Factor (kg/m^2)	
Date:	Dec '05	Auditor:	
Visual Audit		Photogrammetry Audit	

Materials	EWC Code	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Plastic	170203	11.960	0.15	1.794	15.640	0.15	2.346	4.675	15.640
Cardboard		6.882	0.40	2.753	11.702	0.40	4.681	3.498	11.702
Felt		1.362	1.00	1.362	1.178	1.00	1.178	0.352	1.178
Slab	170802	1.840	0.40	0.736	0.478	0.40	0.191	0.143	0.478
Timber	170201	5.078	0.60	3.047	2.834	0.60	1.700	0.847	2.834
Sweepings		4.158	0.60	2.495	2.355	0.60	1.413	0.704	2.355
Rockwool	170603	0.478	1.00	0.478	0.478	1.00	0.478	0.143	0.478
Canvas		0.920	1.00	0.920	0.000	1.00	0.000	0.000	0.000
Aeroboard	170604	3.238	1.00	3.238	2.208	1.00	2.208	0.660	2.208
Other		0.920	1.00	0.920	0.275	-	-	-	-
Total		**36.700**		**17.742**	**11.000**	**36.700**		**14.195**	**11.000**

* weight in tonnes as provided by the waste management company

Project Description	Residential Development in Roscam		
Completed Floor Area:		**Project Stage**	
Total Waste (m^3)	50.050	**Total Waste (tonnes):**	
Unit Waste Factor (m^3/m^2)		**Unit Waste Factor (kg/m^2)**	
Date:	Jan '06	**Auditor:**	
Visual Audit		**Photogrammetry Audit**	

Materials	EWC Code	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Timber	170201	3.478	0.60	2.087	0.818	4.361	0.60	2.617	1.025
Plastic	170203	10.543	0.150	1.581	2.479	15.787	0.150	2.368	3.712
Cardboard		12.420	0.40	4.968	2.921	18.216	0.40	7.286	4.283
Aeroboard	170604	3.202	1.00	3.202	0.753	2.318	1.00	2.318	0.545
Sweepings		14.683	0.60	8.810	3.453	8.998	0.60	5.399	2.116
Cotton		0.442	1.00	0.442	0.104	1.049	1.00	1.049	0.247
Slab	170802	4.582	0.40	1.833	1.077	3.919	0.40	1.568	0.922
Tiles	170103	0.442	1.00	0.442	0.104	0.276	1.00	0.276	0.065
Glass	170202	0.718	1.00	0.718	0.169	0.221	1.00	0.221	0.052
Other		4.582	1.00	4.582	1.077	-	-	-	-
Total		**55.050**		**28.665**	**12.980**	**55.050**		**23.101**	**12.980**

* weight in tonnes as provided by the waste management company

Project Description	Residential Development in Roscam		
Completed Floor Area:		Project Stage	
Total Waste (m^3)	50.050	Total Waste (tonnes):	
Unit Waste Factor (m^3/m^2)		Unit Waste Factor (kg/m^2)	
Date:	Feb '06	Auditor:	
Visual Audit		Photogrammetry Audit	

Materials	EWC Code	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Slab	170802	3.202	0.40	1.281	0.574	4.030	0.40	1.612	0.723
Sweepings		7.783	0.60	4.670	1.396	12.199	0.60	7.319	2.188
Cardboard		12.475	0.40	4.990	2.237	11.923	0.40	4.769	2.138
Plastic	170203	13.855	0.15	2.078	2.485	19.541	0.15	2.931	3.505
Timber	170201	2.926	0.60	1.756	0.525	1.380	0.60	0.828	0.248
Metal	170407	0.442	1.00	0.442	0.079	0.331	1.00	0.331	0.059
Wire		0.110	1.00	0.110	0.020	0.055	1.00	0.055	0.010
Aeroboard	170604	8.777	1.00	8.777	1.574	5.630	1.00	5.630	1.010
Carpet		0.883	1.00	0.883	0.158	0.055	1.00	0.055	0.010
Other		4.582	1.00	4.582	0.822	-	-	-	-
Total		**50.050**		**29.568**	**9.900**	**50.050**		**23.531**	**9.900**

* weight in tonnes as provided by the waste management company

Project Description	Residential Development in Roscam		
Completed Floor Area:		**Project Stage**	
Total Waste (m^3)	36.700	**Total Waste (tonnes):**	
Unit Waste Factor (m^3/m^2)		**Unit Waste Factor (kg/m^2)**	
Date:	March '06	**Auditor:**	
Visual Audit		**Photogrammetry Audit**	

Materials	EWC Code	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Slab	170802	3.238	0.40	1.295	0.612	5.005	0.40	2.002	0.947
Sweepings		10.672	0.60	6.403	2.018	8.464	0.60	5.078	1.601
Cardboard		7.581	0.40	3.032	1.434	9.384	0.40	3.754	1.775
Carpet		0.920	1.00	0.920	0.174	0.957	1.00	0.957	0.181
Gravel	170504	0.920	1.50	1.380	0.174	0.846	1.50	1.269	0.160
Timber	170201	3.680	0.60	2.208	0.696	2.686	0.60	1.612	0.508
Plastic	170203	6.219	0.15	0.933	1.176	5.925	0.15	0.889	1.121
Aeroboard	170604	2.318	1.00	2.318	0.438	2.944	1.00	2.944	0.557
Felt		0.294	1.00	0.294	0.056	0.092	1.00	0.092	0.017
Tile bags		0.920	0.15	0.138	0.174	0.552	0.15	0.083	0.104
Total		**36.700**		**18.922**	**6.960**	**36.700**		**18.679**	**6.960**

* weight in tonnes as provided by the waste management company

Project Description		**Residential Development in Roscam**	
Completed Floor Area:		**Project Stage**	
Total Waste (m^3)	36.700	**Total Waste (tonnes):**	
Unit Waste Factor (m^3/m^2)		**Unit Waste Factor (kg/m^2)**	
Date:	April '06	**Auditor:**	
Visual Audit		**Photogrammetry Audit**	

		Visual Audit				Photogrammetry Audit			
Materials	**EWC Code**	**Volume (m^3)**	**Conversion Factor**	**Weight (tonnes)**	**Weight (tonnes)***	**Volume (m^3)**	**Conversion Factor**	**Weight (tonnes)**	**Weight (tonnes)***
Tile bags		1.398	0.15	0.210	0.332	1.141	0.15	0.171	0.271
Sweepings		4.784	0.60	2.870	1.136	3.901	0.60	2.341	0.926
Cardboard		11.150	0.40	4.460	2.648	13.395	0.40	5.358	3.181
Plastic	170203	6.918	0.15	1.038	1.643	12.365	0.15	1.855	2.937
Concrete	170101	0.478	1.50	0.717	0.114	0.294	1.50	0.441	0.070
Slab	170802	9.862	0.40	3.945	2.342	3.422	0.40	1.369	0.813
Timber	170201	0.221	0.60	0.133	0.052	0.626	0.60	0.376	0.149
Felt		0.699	1.00	0.699	0.166	0.736	1.00	0.736	0.175
Aeroboard	170604	0.478	1.00	0.478	0.114	0.258	1.00	0.258	0.061
Mattress		0.920	1.00	0.920	0.219	0.626	1.00	0.626	0.149
Total		**36.700**		**15.469**	**8.740**	**36.700**		**13.530**	**8.740**

* weight in tonnes as provided by the waste management company

Project Description	Residential Development in Roscam		
Completed Floor Area:		**Project Stage**	
Total Waste (m^3)	18.350	**Total Waste (tonnes):**	
Unit Waste Factor (m^3/m^2)		**Unit Waste Factor (kg/m^2)**	
Date:	May '06	**Auditor:**	
Visual Audit		**Photogrammetry Audit**	

Materials	EWC Code	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Slab	170802	0.460	0.40	0.184	0.083	0.460	0.40	0.184	0.083
Plastic	170203	2.760	0.15	0.414	0.495	4.140	0.15	0.621	0.743
Cardboard		9.421	0.40	3.768	1.690	9.752	0.40	3.901	1.749
Sweepings		4.140	0.60	2.484	0.743	3.367	0.60	2.020	0.604
Aeroboard	170604	0.920	1.00	0.920	0.165	0.460	1.00	0.460	0.083
Timber	170201	0.460	0.60	0.276	0.083	0.202	0.60	0.121	0.036
Concrete	170101	0.239	1.50	0.385	0.043	0.000	1.50	0.000	0.000
Total		**18.350**		**8.405**	**3.300**	**18.350**		**7.307**	**3.300**

* weight in tonnes as provided by the waste management company

Project Description	Residential Development in Roscam		
Completed Floor Area:		Project Stage	
Total Waste (m^3)	36.700	Total Waste (tonnes):	
Unit Waste Factor (m^3/m^2)		Unit Waste Factor (kg/m^2)	
Date:	June '06	Auditor:	
Visual Audit		Photogrammetry Audit	

Materials	EWC Code	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Timber	170201	4.600	0.60	2.760	0.815	1.178	0.60	0.707	0.209
Plastic	170203	11.261	0.15	1.689	1.995	8.685	0.15	1.303	1.539
Cardboard		10.598	0.40	4.239	1.878	16.192	0.40	6.477	2.869
Sweepings		5.998	0.60	3.599	1.063	6.661	0.60	3.997	1.180
Aeroboard	170604	3.238	1.00	3.238	0.574	3.606	1.00	3.606	0.639
Felt		0.221	1.00	0.221	0.039	0.478	1.00	0.478	0.085
Other		0.920	1.00	0.920	0.163	-	-	-	-
Total		**36.700**		**16.666**	**6.520**	**36.700**		**16.567**	**6.520**

* weight in tonnes as provided by the waste management company

Project Description	Residential Development in Roscam		
Completed Floor Area:		**Project Stage**	
Total Waste (m³)	36.700	**Total Waste (tonnes):**	
Unit Waste Factor (m³/m²)		**Unit Waste Factor (kg/m²)**	
Date:	July '06	**Auditor:**	
Visual Audit		**Photogrammetry Audit**	

Materials	EWC Code	Volume (m³)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m³)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Plastic	170203	11.224	0.15	1.684	2.599	14.131	0.15	2.120	3.272
Cardboard		9.678	0.40	3.871	2.241	11.334	0.40	4.534	2.624
Sweepings		8.758	0.60	5.255	2.028	7.360	0.60	4.416	1.704
Slab	170802	4.158	0.40	1.663	0.963	2.650	0.40	1.060	0.613
Timber	170201	1.104	0.60	0.662	0.256	0.773	0.60	0.464	0.179
Concrete	170101	0.920	1.50	1.380	0.213	0.294	1.50	0.441	0.068
Tiles	170103	0.110	1.00	0.110	0.026	0.221	1.00	0.221	0.051
Other		0.920	1.00	0.920	0.213	-	-	-	-
Total		**36.700**		**15.545**	**8.520**	**36.700**		**13.255**	**8.520**

* weight in tonnes as provided by the waste management company

Project Description	Residential Development in Roscam		
Completed Floor Area:		Project Stage	
Total Waste (m^3)	36.700	Total Waste (tonnes):	
Unit Waste Factor (m^3/m^2)		Unit Waste Factor (kg/m^2)	
Date:	Aug '06	Auditor:	
Visual Audit		Photogrammetry Audit	

Materials	EWC Code	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Plastic	170203	5.557	0.15	0.834	1.626	11.261	0.15	1.689	3.296
Cardboard		6.293	0.40	2.517	1.842	8.538	0.40	3.415	2.499
Sweepings		11.776	0.60	7.066	3.446	9.163	0.60	5.498	2.682
Slab	170802	2.944	0.40	1.178	0.862	2.502	0.40	1.001	0.732
Rockwool	170603	0.221	1.00	0.221	0.065	0.478	1.00	0.478	0.140
Timber	170201	2.392	0.60	1.435	0.700	3.165	0.60	1.899	0.926
Felt		2.760	1.00	2.760	0.808	0.662	1.00	0.662	0.194
Aeroboard	170604	0.920	1.00	0.920	0.269	0.184	1.00	0.184	0.054
Tile bags		0.368	0.15	0.055	0.108	0.662	0.15	0.099	0.194
Other		3.680	1.00	3.680	1.077	-	-	-	-
Total		**36.700**		**20.665**	**10.770**	**36.700**		**14.925**	**10.770**

* weight in tonnes as provided by the waste management company

Project Description	Residential Development in Roscam		
Completed Floor Area:		Project Stage	
Total Waste (m^3)	36.700	Total Waste (tonnes):	
Unit Waste Factor (m^3/m^2)		Unit Waste Factor (kg/m^2)	
Date:	Sep '06	Auditor:	
Visual Audit		Photogrammetry Audit	

Materials	EWC Code	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*	Volume (m^3)	Conversion Factor	Weight (tonnes)	Weight (tonnes)*
Plastic	170203	14.536	0.15	2.180	4.874	12.770	0.15	1.916	4.282
Cardboard		2.797	0.40	1.119	0.938	3.643	0.40	1.457	1.222
Sweepings		10.120	0.60	6.072	3.394	11.224	0.60	6.734	3.764
Timber	170201	5.336	0.60	3.202	1.789	7.544	0.60	4.526	2.530
Aeroboard	170604	1.104	1.00	1.104	0.370	0.294	1.00	0.294	0.099
Slab	170802	0.552	0.40	0.221	0.185	1.104	0.40	0.442	0.370
Rubber		0.184	1.00	0.184	0.062	0.184	1.00	0.184	0.062
Carpet		0.184	1.00	0.184	0.062	0.037	1.00	0.037	0.012
Other		1.840	1.00	1.840	0.617	-	-	-	-
Total		**36.700**		**16.106**	**12.340**	**36.700**		**15.590**	**12.340**

* weight in tonnes as provided by the waste management company

APPENDIX L

Individual Skip Reports for each Skip Cycle

	Total %	Ave %	Photo %	Visual %	Weight (ton)	Weight (ton)
Cardboard	9.9	2.5	9.7	12.0	0.150	0.186
Plastic	78.9	19.7	77.6	30.0	1.203	0.465
Sweepings	4.3	1.1	4.2	30.0	0.065	0.465
Floor Lino	0.0	0.0	0.0	5.0	0.000	0.078
Timber	4.8	1.2	4.7	5.0	0.073	0.078
Tiles	0.0	0.0	0.0	1.0	0.000	0.016
Tile Adh	0.0	0.0	0.0	2.0	0.0	0.031
Polystyrene	2.7	0.7	2.7	10.0	0.041	0.155
Felt	1.0	0.3	1.0	5.0	0.015	0.078
Background	298.5	74.6	**100.0**	**100.0**	**1.550**	**1.550**
	400.0	**100.0**				

Skip no.1

	Total %	Ave %	Photo %	Visual %	Weight (ton)	Weight (ton)
Cardboard	54.2	13.6	29.1	32.0	0.452	0.496
Plastic	38.8	9.7	20.9	8.0	0.323	0.124
Sweepings	17.8	4.4	9.6	28.0	0.148	0.434
Slab	24.6	6.2	13.2	20.0	0.205	0.310
Timber	18.9	4.7	10.1	5.0	0.157	0.078
Carpet	21.8	5.4	11.7	3.0	0.182	0.047
Polystyrene	9.8	2.4	5.3	4.0	0.082	0.062
Background	214.1	53.5	**100.0**	**100.0**	**1.550**	**1.550**
	400.0	**100.0**				

Skip no. 2

	Total %	Ave %	Photo %	Visual %	Weight (ton)	Weight (ton)
Plaster Slab	237.7	29.7	44.7	40.0	0.773	0.692
Cardboard	71.4	8.9	13.4	20.0	0.232	0.346
Timber	171.8	21.5	32.3	10.0	0.559	0.173
Plastic	19.1	2.4	3.6	10.0	0.062	0.173
Tiles	0.0	0.0	0.0	3.0	0.0	0.052
Tile Bags	1.4	0.2	0.3	2.0	0.005	0.035
Sweepings	30.2	3.8	5.7	12.0	0.098	0.208
Floor Cov	0.0	0.0	0.0	3.0	0.0	0.052
Background	268.3	33.5	**100.0**	**100.0**	**1.730**	**1.730**
	800.0	**100.0**				

Skip no. 3

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Felt		9.9		1.2		2.0		20.0		0.034	0.346
Plastic		204.9		25.6		41.1		36.0		0.711	0.623
Mattress		17.8		2.2		3.6		5.0		0.062	0.087
Sweepings		75.3		9.4		15.1		15.0		0.261	0.260
Cardboard		119.6		15.0		24.0		12.0		0.415	0.208
Timber		22.3		2.8		4.5		7.0		0.077	0.121
Tiles		0.0		0.0		0.0		3.0		0.0	0.052
Polystyrene		48.9		6.1		9.8		2.0		0.170	0.035
Background		301.3		37.7		**100.0**		**100.0**		**1.730**	**1.730**
		800.0		**100.0**							

Skip no. 4

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Cardboard		184.8		15.4		25.6		42.0		0.415	0.680
Plastic		177.5		14.8		24.6		5.0		0.399	0.081
Sweepings		84.4		7.03		11.7		9.0		0.190	0.146
Plaster Slab		129.3		10.8		17.9		25.0		0.290	0.405
Timber		29.5		2.46		4.1		5.0		0.066	0.081
Polystyrene		23.6		1.96		3.3		2.0		0.053	0.032
Felt		89.8		7.49		12.5		10.0		0.202	0.162
Wire		3.1		0.26		0.4		2.0		0.007	0.032
Background		478.3		39.9		**100.0**		**100.0**		**1.620**	**1.620**
		1200.0		**100.0**							

Skip no. 5

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Felt		4.6		0.6		1.0		10.0		0.016	0.162
Plastic		173.9		21.7		36.8		32.0		0.597	0.518
Mattress		0.0		0.0		0.0		10.0		0.0	0.162
Sweepings		125.9		15.7		26.7		14.0		0.432	0.227
Cardboard		127.0		15.9		26.9		22.0		0.436	0.356
Timber		11.1		1.4		2.3		3.0		0.038	0.049
Tiles		0.3		0.0		0.1		1.0		0.001	0.016
Polystyrene		25.8		3.2		5.5		5.0		0.089	0.081
Carpet		0.2		0.0		0.0		1.0		0.001	0.016
Tile Bags		3.1		0.4		0.7		2.0		0.011	0.032
Background		328.1		41.0		**100.0**		**100.0**		**1.620**	**1.620**
		800.0		**100.0**							

Skip no. 6

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Cardboard		167.0		16.7		28.3		10.5		0.719	0.267
Plastic		111.7		11.2		18.9		19.5		0.481	0.495
Sweepings		15.8		1.6		2.7		10.0		0.068	0.254
Slab		186.0		18.6		31.5		30.0		0.801	0.762
Timber		31.2		3.1		5.3		7.0		0.134	0.178
Felt		10.1		1.0		1.7		5.0		0.044	0.127
Concrete		15.4		1.5		2.6		8.0		0.066	0.203
Grass		51.5		5.2		8.7		10.0		0.222	0.254
Background		411.3		41.1		**100.0**		**100.0**		**2.540**	**2.540**
		1000.0		**100.0**							

Skip no. 7

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Sweepings		101.6		11.3		22.8		32.0		0.424	0.595
Paint Cans		0.0		0.0		0.0		1.0		0.0	0.019
Timber		16.2		1.8		3.6		10.0		0.068	0.186
Cardboard		161.9		18.0		36.3		30.0		0.676	0.558
Polystyrene		29.4		3.3		6.6		9.0		0.123	0.167
Felt		18.1		2.0		4.1		10.0		0.075	0.186
Plastic		114.6		12.7		25.7		5.0		0.479	0.093
Slab		4.1		0.5		0.9		3.0		0.017	0.056
Background		454.1		50.5		**100.0**		**100.0**		**1.860**	**1.860**
		900.0		**100.0**							

Skip no. 8

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Sweepings		140.7		14.1		26.4		30.0		0.769	0.876
Timber		37.6		3.8		7.0		14.0		0.205	0.409
Cardboard		204.3		20.4		38.3		20.0		1.117	0.584
Plastic		119.6		12.0		22.4		9.0		0.654	0.263
Tile Bags		3.0		0.3		0.6		1.0		0.016	0.029
Polystyrene		15.5		1.6		2.9		14.0		0.085	0.409
Slab		13.0		1.3		2.4		10.0		0.071	0.292
Wire		0.1		0.0		0.0		2.0		0.001	0.058
Background		466.1		46.6		**100.0**		**100.0**		**2.920**	**2.920**
		1000.0		**100.0**							

Skip no. 9

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Cardboard		95.7		12.0		18.9		20.0		0.551	0.584
Sweepings		131.1		16.4		25.9		17.0		0.755	0.496
Blocks		0.0		0.0		0.0		5.0		0.0	0.146
Plastic		189.8		23.7		37.4		27.0		1.0926	0.788
Felt		0.0		0.0		0.0		3.0		0.0	0.088
Timber		21.4		2.7		4.2		5.0		0.123	0.146
Metal		13.5		1.7		2.7		10.0		0.0777	0.292
Slab		56.1		7.0		11.1		13.0		0.3228	0.380
Background		292.4		36.6		**100.0**		**100.0**		**2.920**	**2.920**
		800.0		**100.0**							

Skip no. 10

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Cardboard		214.8		26.8		46.9		30.5		0.787	0.512
Sweepings		25.4		3.2		5.5		16.0		0.093	0.269
Plastic		200.4		25.0		43.7		32.5		0.734	0.546
Metal		0.1		0.0		0.0		1.0		0.001	0.017
Timber		11.6		1.4		2.5		15.0		0.042	0.252
Tiles		5.1		0.6		1.1		3.0		0.019	0.050
Tile Bags		0.7		0.1		0.2		2.0		0.003	0.034
Background		341.9		42.7		**100.0**		**100.0**		**1.680**	**1.680**
		800.0		**100.0**							

Skip no. 11

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Sweepings		47.1		5.9		11.1		30.0		0.186	0.504
Cardboard		55.0		6.9		12.9		5.0		0.217	0.084
Plastic		225.5		28.2		52.9		39.0		0.888	0.655
Polystyrene		6.6		0.8		1.6		1.0		0.026	0.017
Slab		75.4		9.4		17.7		15.0		0.297	0.252
Felt		9.7		1.2		2.3		10.0		0.038	0.168
Timber		6.8		0.8		1.6		0.0		0.027	0.000
Background		373.8		46.7		**100.0**		**100.0**		**1.680**	**1.680**
		800.0		**100.0**							

Skip no. 12

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Polystyrene		48.5		4.9		8.7		11.0		0.173	0.219
Plastic		223.4		22.3		40.0		35.0		0.795	0.697
Timber		2.3		0.2		0.4		5.0		0.008	0.100
Cardboard		177.6		17.8		31.8		20.0		0.632	0.398
Metal		7.4		0.7		1.3		1.0		0.026	0.020
Canvas		43.1		4.3		7.7		3.0		0.154	0.060
Slab		1.4		0.1		0.3		20.0		0.005	0.398
Sweepings		54.8		5.5		9.8		5.0		0.195	0.100
Background		441.4		44.1		100.0		100.0		1.990	1.990
		1000.0		100.0							

Skip no. 13

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Slab		79.0		11.3		22.2		4.0		0.441	0.080
Skim Bags		0.0		0.0		0.0		1.0		0.0	0.020
Mattress		23.2		3.3		6.5		4.0		0.13	0.080
Plastic		172.6		24.7		48.4		61.0		0.964	1.214
Concrete		0.0		0.0		0.0		5.0		0.0	0.100
Timber		14.7		2.1		4.1		2.0		0.082	0.040
Sweepings		24.9		3.6		7.0		7.0		0.139	0.139
Cardboard		39.0		5.6		10.9		10.0		0.218	0.199
Carpet		0.0		0.0		0.0		5.0		0.0	0.100
Metal		3.1		0.4		0.9		1.0		0.017	0.020
Background		343.5		49.1		100.0		100.0		1.990	1.990
		700.0		100.0							

Skip no. 14

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Slab		20.1		4.0		8.2		25.0		0.109	0.330
Gravel/Clay		38.1		7.6		15.7		15.0		0.207	0.198
Felt		43.5		8.7		17.9		20.0		0.236	0.264
Plastic		48.1		9.6		19.8		10.0		0.261	0.132
Cardboard		43.0		8.6		17.7		10.0		0.233	0.132
Polystyrene		0.0		0.0		0.0		10.0		0.0	0.132
Sweepings		50.4		10.1		20.7		10.0		0.273	0.132
Background		256.7		51.3		100.0		100.0		1.320	1.320
		500.0		100.0							

Skip no. 15

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Felt		3.8		0.8		1.6		10.0		0.021	0.132
Plastic		141.6		28.3		59.1		20.0		0.781	0.264
Timber		12.1		2.4		5.0		10.0		0.067	0.132
Slab		37.9		7.6		15.8		20.0		0.209	0.264
Polystyrene		0.0		0.0		0.0		10.0		0.000	0.132
Cardboard		14.3		2.9		6.0		20.0		0.079	0.264
Sweepings		29.9		6.0		12.5		10.0		0.165	0.132
Background		260.5		52.1		**100.0**		**100.0**		**1.320**	**1.320**
		500.0		**100.0**							

Skip no. 16

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Sweepings		161.9		20.2		28.4		33.0		0.631	0.733
Plastic		199.1		24.9		34.9		20.0		0.776	0.444
Skim Bags		37.1		4.6		6.5		10.0		0.145	0.222
Cardboard		76.9		9.6		13.5		10.0		0.300	0.222
Slab		33.2		4.2		5.8		5.0		0.129	0.111
Carpet		0.0		0.0		0.0		5.0		0.000	0.111
Polystyrene		34.2		4.3		6.0		15.0		0.133	0.333
Timber		27.4		3.4		4.8		2.0		0.107	0.044
Background		230.2		28.8		**100.0**		**100.0**		**2.220**	**2.220**
		800.0		**100.0**							

Skip no. 17

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Sweepings		115.4		14.4		20.8		30.0		0.462	0.666
Timber		22.9		2.9		4.1		6.0		0.091	0.133
Polystyrene		2.9		0.4		0.5		7.0		0.012	0.155
Plastic		215.7		27.0		38.9		40.0		0.863	0.888
Wire		0.0		0.0		0.0		2.0		0.000	0.044
Cardboard		198.0		24.8		35.7		15.0		0.792	0.333
Background		245.1		30.6		**100.0**		**100.0**		**2.220**	**2.220**
		800.0		**100.0**							

Skip no. 18

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Timber		6.1		0.9		1.4		8.0		0.031	0.170
Plastic		271.6		38.8		63.8		55.0		1.359	1.172
Cardboard		70.6		10.1		16.6		25.0		0.354	0.533
Polystyrene		2.2		0.3		0.5		7.0		0.011	0.149
Slab		74.9		10.7		17.6		5.0		0.375	0.107
Background		274.5		39.2		**100.0**		**100.0**		**2.130**	**2.130**
		700.0		**100.0**							

Skip no. 19

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Slab		26.0		3.7		5.5		10.0		0.118	0.213
Plastic		248.0		35.4		52.8		35.0		1.125	0.746
Cardboard		108.4		15.5		23.1		27.5		0.491	0.586
Felt		26.1		3.7		5.6		10.0		0.119	0.213
Sweepings		19.2		2.7		4.1		10.0		0.087	0.213
Polystyrene		6.1		0.9		1.3		2.5		0.028	0.053
Timber		36.1		5.2		7.7		5.0		0.164	0.107
Background		230.1		32.9		**100.0**		**100.0**		**2.130**	**2.130**
		700.0		**100.0**							

Skip no. 20

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		207.1		51.8		55.7		35.0		1.906	1.197
Cardboard		97.9		24.5		26.4		10.0		0.901	0.342
Felt		26.8		6.7		7.2		10.0		0.247	0.342
Slab		19.2		4.8		5.2		20.0		0.177	0.684
Timber		20.5		5.1		5.5		25.0		0.189	0.855
Background		28.4		7.1		**100.0**		**100.0**		**3.420**	**3.420**
		400.0		**100.0**							

Skip no. 21

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Cardboard		84.8		21.2		28.0		30.0		0.959	1.026
Sweepings		3.0		0.8		1.0		35.0		0.034	1.197
Timber		47.5		11.9		15.7		15.0		0.537	0.513
Rockwool		16.1		4.0		5.3		5.0		0.182	0.171
Plastic		151.0		37.8		49.9		15.0		1.708	0.513
Background		97.6		24.4		**100.0**		**100.0**		**3.420**	**3.420**
		400.0		**100.0**							

Skip no. 22

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		264.0		33.0		46.0		50.0		0.956	1.040
Polystyrene		86.2		10.8		15.0		15.0		0.312	0.312
Canvas		0.0		0.0		0.0		10.0		0.000	0.208
Felt		34.0		4.3		5.9		5.0		0.123	0.104
Cardboard		90.0		11.3		15.7		10.0		0.326	0.208
Sweepings		77.7		9.7		13.5		5.0		0.281	0.104
Timber		22.6		2.8		3.9		5.0		0.082	0.104
Background		225.5		28.2		**100.0**		**100.0**		**2.080**	**2.080**
		800.0		**100.0**							

Skip no. 23

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		59.4		11.9		18.5		30.0		0.384	0.624
Cardboard		182.9		36.6		56.9		25.0		1.183	0.520
Timber		17.6		3.5		5.5		10.0		0.114	0.208
Polystyrene		29.8		6.0		9.3		20.0		0.193	0.416
Sweepings		31.7		6.3		9.9		5.0		0.205	0.104
Background		178.6		35.7	Other			10.0			0.208
		500.0		**100.0**		**100.0**		**100.0**		**2.080**	**2.080**

Skip no. 24

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Timber		91.0		22.8		30.2		7.5		0.727	0.181
Plastic		66.0		16.5		21.9		30.0		0.527	0.723
Cardboard		79.9		20.0		26.5		30.0		0.639	0.723
Polystyrene		0.6		0.1		0.2		7.5		0.005	0.181
Sweepings		28.4		7.1		9.4		20.0		0.227	0.482
Cotton		35.6		8.9		11.8		5.0		0.285	0.121
Background		98.5		24.6		**100.0**		**100.0**		**2.410**	**2.410**
		400.0		**100.0**							

Skip no. 25

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Slab		85.1		14.2		24.3		35.0		0.585	0.844
Sweepings		125.1		20.9		35.7		25.0		0.859	0.603
Plastic		38.2		6.4		10.9		5.0		0.262	0.121
Timber		17.1		2.9		4.9		15.0		0.118	0.362
Cardboard		85.1		14.2		24.3		20.0		0.585	0.482
Background		249.2		41.5		**100.0**		**100.0**		**2.410**	**2.410**
		600.0		**100.0**							

Skip no. 26

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Sweepings		21.0		7.0		12.0		25.0		0.256	0.533
Cardboard		90.2		30.1		51.7		10.0		1.101	0.213
Plastic		58.5		19.5		33.5		10.0		0.714	0.213
Tiles		4.9		1.6		2.8		5.0		0.059	0.107
Background		125.4		41.8	Other			50.0			1.065
		300.0		**100.0**		**100.0**		**100.0**		**2.130**	**2.130**

Skip no. 27

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Cardboard		136.6		27.3		33.0		25.0		0.704	0.533
Sweepings		126.3		25.3		30.5		60.0		0.651	1.278
Timber		32.7		6.5		7.9		5.0		0.169	0.107
Glass		5.7		1.1		1.4		3.0		0.029	0.064
Plastic		112.1		22.4		27.1		5.0		0.578	0.107
Polystyrene		0.0		0.0		0.0		2.0		0.0	0.043
Background		86.5		17.3		**100.0**		**100.0**		**2.130**	**2.130**
		500.0		**100.0**							

Skip no. 28

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		85.0		28.3		47.2		50.0		0.921	0.975
Cardboard		71.8		23.9		39.9		35.0		0.778	0.683
Polystyrene		15.0		5.0		8.3		5.0		0.163	0.098
Timber		8.1		2.7		4.5		10.0		0.088	0.195
Background		120.1		40.0		**100.0**		**100.0**		**1.950**	**1.950**
		300.0		**100.0**							

Skip no. 29

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Polystyrene		76.6		10.9		16.9		20.0		0.331	0.390
Sweepings		44.6		6.4		9.9		30.0		0.192	0.585
Glass		4.3		0.6		0.9		5.0		0.018	0.098
Plastic		141.3		20.2		31.2		15.0		0.609	0.293
Cardboard		103.1		14.7		22.8		15.0		0.445	0.293
Slab		82.4		11.8		18.2		15.0		0.355	0.293
Background		247.6		35.4		**100.0**		**100.0**		**1.950**	**1.950**
		700.0		**100.0**							

Skip no. 30

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Slab		54.4		13.6		18.4		12.5		0.332	0.226
Sweepings		24.7		6.2		8.3		5.0		0.151	0.091
Cardboard		111.6		27.9		37.7		40.0		0.683	0.724
Plastic		103.7		25.9		35.0		40.0		0.634	0.724
Timber		1.7		0.4		0.6		2.5		0.010	0.045
Background		103.9		26.0		**100.0**		**100.0**		**1.810**	**1.810**
		400.0		**100.0**							

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		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		86.4		21.6		34.4		25.0		0.622	0.453
Cardboard		66.0		16.5		26.3		25.0		0.476	0.453
Metal		9.9		2.5		4.0		5.0		0.072	0.091
Wire		1.6		0.4		0.6		1.0		0.011	0.018
Timber		0.0		0.0		0.0		6.5		0.000	0.118
Sweepings		84.4		21.1		33.6		35.0		0.608	0.634
Polystyrene		3.0		0.8		1.2		2.5		0.022	0.045
Background		148.8		37.2		**100.0**		**100.0**		**1.810**	**1.810**
		400.0		**100.0**							

Skip no. 32

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Polystyrene		59.4		14.9		18.8		30.0		0.262	0.417
Sweepings		95.7		23.9		30.3		25.0		0.422	0.348
Slab		28.9		7.2		9.1		5.0		0.127	0.070
Plastic		131.5		32.9		41.7		20.0		0.579	0.278
Background		84.5		21.1	Other			20.0			0.278
		400.0		**100.0**		**100.0**		**100.0**		**1.390**	**1.390**

Skip no. 33

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Cardboard		50.1		16.7		27.1		30.0		0.376	0.417
Timber		26.9		9.0		14.5		12.5		0.202	0.174
Slab		0.0		0.0		0.0		2.5		0.0	0.035
Plastic		108.1		36.0		58.4		35.0		0.812	0.487
Background		114.9		38.3	Other			20.0			0.278
		300.0		**100.0**		**100.0**		**100.0**		**1.390**	**1.390**

Skip no. 34

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Sweepings		52.1		13.0		17.4		10.0		0.304	0.175
Cardboard		47.0		11.8		15.7		31.0		0.275	0.543
Carpet		1.7		0.4		0.6		10.0		0.010	0.175
Plastic		110.5		27.6		36.9		26.0		0.645	0.455
Timber		0.0		0.0		0.0		10.0		0.0	0.175
Polystyrene		44.5		11.1		14.9		3.0		0.260	0.053
Slab		43.9		11.0		14.7		10.0		0.257	0.175
Background		100.3		25.1		**100.0**		**100.0**		**1.750**	**1.750**
		400.0		**100.0**							

Skip no. 35

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Slab		4.4		1.1		1.8		5.0		0.031	0.088
Plastic		14.3		3.6		5.8		5.0		0.102	0.088
Cardboard		56.4		14.1		23.0		10.0		0.402	0.175
Sweepings		105.8		26.4		43.1		10.0		0.755	0.175
Polystyrene		64.3		16.1		26.2		60.0		0.459	1.050
Background		154.9		38.7	Other			10.0			0.175
		400.0		**100.0**		**100.0**		**100.0**		**1.750**	**1.750**

Skip no. 36

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Slab		100.2		16.7		28.1		25.0		0.419	0.373
Sweepings		64.0		10.7		18.0		7.0		0.268	0.104
Cardboard		60.6		10.1		17.0		13.0		0.253	0.194
Carpet		36.9		6.2		10.4		10.0		0.154	0.149
Gravel		33.0		5.5		9.3		10.0		0.138	0.149
Timber		15.6		2.6		4.4		5.0		0.065	0.075
Plastic		46.3		7.7		13.0		30.0		0.194	0.447
Background		243.4		40.6		**100.0**		**100.0**		**1.490**	**1.490**
		600.0		**100.0**							

Skip no. 37

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Cardboard		106.5		17.8		32.6		32.0		0.486	0.477
Plastic		146.9		24.5		45.0		35.0		0.671	0.522
Polystyrene		63.2		10.5		19.4		20.0		0.289	0.298
Felt		3.3		0.5		1.0		3.0		0.015	0.045
Sweepings		6.4		1.1		2.0		10.0		0.029	0.149
Background		273.6		45.6		**100.0**		**100.0**		**1.490**	**1.490**
		600.0		**100.0**							

Skip no. 38

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		16.3		4.1		6.6		2.5		0.132	0.050
Sweepings		79.8		19.9		32.5		40.0		0.646	0.796
Skim Bags		14.5		3.6		5.9		10.0		0.117	0.199
Cardboard		22.5		5.6		9.2		7.5		0.182	0.149
Slab		64.6		16.1		26.3		10.0		0.523	0.199
Timber		48.1		12.0		19.6		30.0		0.390	0.597
Background		154.3		38.6		**100.0**		**100.0**		**1.990**	**1.990**
		400.0		**100.0**							

Skip no. 39

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Sweepings		115.1		28.8		39.6		60.0		0.789	1.194
Cardboard		125.1		31.3		43.1		30.0		0.858	0.597
Polystyrene		35.6		8.9		12.2		5.0		0.244	0.100
Timber		14.8		3.7		5.1		5.0		0.101	0.100
Background		109.4		27.4		**100.0**		**100.0**		**1.990**	**1.990**
		400.0		**100.0**							

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		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Skim Bags		63.8		9.1		12.5		15.0		0.330	0.396
Sweepings		73.6		10.5		14.4		10.0		0.381	0.264
Cardboard		158.0		22.6		31.0		30.0		0.817	0.792
Plastic		154.9		22.1		30.3		25.0		0.801	0.660
Brick Rubble		16.8		2.4		3.3		5.0		0.087	0.132
Slab		43.0		6.1		8.4		15.0		0.222	0.396
Background		189.9		27.1		**100.0**		**100.0**		**2.640**	**2.640**
		700.0		**100.0**							

Skip no. 41

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Slab		59.4		8.5		10.8		65.0		0.205	1.235
Sweepings		63.9		9.1		11.6		14.0		0.221	0.266
Cardboard		153.1		21.9		27.9		11.0		0.529	0.209
Plastic		273.4		39.1		49.8		10.0		0.945	0.190
Background		150.2		21.5		**100.0**		**100.0**		**1.900**	**1.900**
		700.0		**100.0**							

Skip no. 42

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Slab		27.4		3.9		6.3		7.0		0.133	0.147
Sweepings		22.6		3.2		5.2		8.0		0.110	0.168
Cardboard		176.1		25.2		40.6		45.0		0.853	0.945
Plastic		101.6		14.5		23.5		15.0		0.493	0.315
Timber		29.3		4.2		6.8		2.5		0.142	0.053
Felt		35.2		5.0		8.1		7.5		0.171	0.158
Polystyrene		11.1		1.6		2.6		5.0		0.054	0.105
Bed & Matt		29.7		4.2		6.9		10.0		0.144	0.210
Background		266.9		38.1		**100.0**		**100.0**		**2.100**	**2.100**
		700.0		**100.0**							

Skip no. 43

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Slab		38.2		9.6		11.6		20.0		0.243	0.420
Plastic		102.0		25.5		30.8		25.0		0.648	0.525
Cardboard		152.9		38.2		46.2		35.0		0.970	0.735
Sweepings		37.9		9.5		11.4		20.0		0.240	0.420
Background		69.1		17.3		**100.0**		**100.0**		**2.100**	**2.100**
		400.0		**100.0**							

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		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Slab		18.9		3.8		5.0		5.0		0.083	0.083
Plastic		44.2		8.8		11.7		10.0		0.194	0.165
Cardboard		206.6		41.3		54.9		55.0		0.905	0.908
Sweepings		94.7		18.9		25.2		25.0		0.415	0.413
Polystyrene		12.1		2.4		3.2		5.0		0.053	0.083
Background		123.5		24.7		**100.0**		**100.0**		**1.650**	**1.650**
		500.0		**100.0**							

Skip no. 45

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Timber		6.4		1.6		2.2		5.0		0.036	0.083
Plastic		96.8		24.2		33.3		20.0		0.550	0.330
Cardboard		148.8		37.2		51.2		47.5		0.845	0.784
Sweepings		33.2		8.3		11.4		20.0		0.189	0.330
Polystyrene		5.3		1.3		1.8		5.0		0.030	0.083
Blocks		0.0		0.0		0.0		2.5		0.000	0.041
Background		109.7		27.4		**100.0**		**100.0**		**1.650**	**1.650**
		400.0		**100.0**							

Skip no. 46

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Timber		5.1		1.3		1.6		20.0		0.022	0.276
Plastic		97.1		24.3		31.0		45.0		0.428	0.621
Cardboard		119.7		29.9		38.3		20.0		0.528	0.276
Sweepings		61.1		15.3		19.5		10.0		0.270	0.138
Polystyrene		29.9		7.5		9.6		5.0		0.132	0.069
Background		87.1		21.8		**100.0**		**100.0**		**1.380**	**1.380**
		400.0		**100.0**							

Skip no. 47

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		36.1		18.0		18.4		35.0		0.254	0.483
Cardboard		140.5		70.3		71.8		35.0		0.990	0.483
Sweepings		19.3		9.6		9.8		20.0		0.136	0.276
Background		4.1		2.1	Other			10.0		0.000	0.138
		200.0		**100.0**		**100.0**		**100.0**		**1.380**	**1.380**

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		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		52.9		17.6		25.6		35.0		0.482	0.658
Cardboard		89.3		29.8		43.3		30.0		0.813	0.564
Sweepings		55.1		18.4		26.7		25.0		0.502	0.470
Timber		9.1		3.0		4.4		10.0		0.083	0.188
Background		93.6		31.2		**100.0**		**100.0**		**1.880**	**1.880**
		300.0		**100.0**							

Skip no. 49

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		60.1		15.0		19.4		7.5		0.364	0.141
Cardboard		69.8		17.4		22.5		30.0		0.423	0.564
Sweepings		51.0		12.8		16.5		10.0		0.309	0.188
Timber		21.1		5.3		6.8		20.0		0.128	0.376
Felt		16.2		4.1		5.2		2.5		0.098	0.047
Polystyrene		91.8		22.9		29.6		30.0		0.557	0.564
Background		90.1		22.5		**100.0**		**100.0**		**1.880**	**1.880**
		400.0		**100.0**							

Skip no. 50

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		204.4		40.9		45.7		20.0		0.713	0.312
Cardboard		142.8		28.6		31.9		25.0		0.498	0.390
Sweepings		49.9		10.0		11.2		15.0		0.174	0.234
Slab		50.1		10.0		11.2		30.0		0.175	0.468
Background		52.8		10.6	Other			10.0			0.156
		500.0		**100.0**		**100.0**		**100.0**		**1.560**	**1.560**

Skip no. 51

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		102.9		34.3		38.8		35.0		0.605	0.546
Cardboard		92.8		30.9		35.0		25.0		0.546	0.390
Sweepings		46.6		15.5		17.6		20.0		0.274	0.312
Timber		14.9		5.0		5.6		10.0		0.087	0.156
Conc Blocks		8.0		2.7		3.0		10.0		0.047	0.156
Background		34.9		11.6		**100.0**		**100.0**		**1.560**	**1.560**
		300.0		**100.0**							

Skip no. 52

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		199.7		39.9		46.2		45.0		1.247	1.215
Sweepings		157.0		31.4		36.3		40.0		0.980	1.080
Slab		75.9		15.2		17.5		15.0		0.474	0.405
Background		67.4		13.5		**100.0**		**100.0**		**2.700**	**2.700**
		500.0		**100.0**							

Skip no. 53

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		79.5		19.9		23.1		22.0		0.623	0.594
Cardboard		194.1		48.5		56.4		55.0		1.521	1.485
Sweepings		51.8		12.9		15.0		20.0		0.406	0.540
Timber		9.6		2.4		2.8		2.0		0.075	0.054
Tiles		9.3		2.3		2.7		1.0		0.073	0.027
Background		55.8		13.9		**100.0**		**100.0**		**2.700**	**2.700**
		400.0		**100.0**							

Skip no. 54

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		65.6		32.8		48.4		20.0		1.240	0.512
Cardboard		26.1		13.1		19.3		10.0		0.494	0.256
Sweepings		22.9		11.4		16.9		10.0		0.432	0.256
Slab		6.2		3.1		4.6		20.0		0.117	0.512
Rockwool		6.7		3.4		5.0		2.5		0.127	0.064
Timber		5.1		2.6		3.8		2.5		0.097	0.064
Felt		0.0		0.0		0.0		5.0		0.000	0.128
Polystyrene		2.9		1.4		2.1		10.0		0.054	0.256
Background		64.5		32.3	Other			20.0			0.512
		200.0		**100.0**		**100.0**		**100.0**		**2.560**	**2.560**

Skip no. 55

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		108.3		36.1		43.8		25.0		1.120	0.640
Timber		48.0		16.0		19.4		15.0		0.496	0.384
Sweepings		54.7		18.2		22.1		25.0		0.566	0.640
Polystyrene		9.1		3.0		3.7		5.0		0.095	0.128
Skim Bags		16.7		5.6		6.8		5.0		0.173	0.128
Felt		10.7		3.6		4.3		5.0		0.111	0.128
Background		52.4		17.5				20.0		0.000	0.512
		300.0		**100.0**		**100.0**		**100.0**		**2.560**	**2.560**

Skip no. 56

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		75.4		18.9		30.2		16.0		0.854	0.452
Cardboard		92.8		23.2		37.2		19.0		1.050	0.537
Sweepings		53.2		13.3		21.3		49.0		0.602	1.384
Timber		22.4		5.6		9.0		6.0		0.254	0.170
Felt		5.8		1.4		2.3		10.0		0.065	0.283
Background		150.4		37.6		**100.0**		**100.0**		**2.825**	**2.825**
		400.0		**100.0**							

Skip no. 57

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Timber		6.0		1.5		2.2		4.0		0.063	0.113
Cardboard		97.5		24.4		36.3		40.0		1.026	1.130
Sweepings		104.9		26.2		39.1		44.0		1.104	1.243
Slab		60.0		15.0		22.4		12.0		0.632	0.339
Background		131.6		32.9		**100.0**		**100.0**		**2.825**	**2.825**
		400.0		**100.0**							

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		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		80.9		40.4		52.0		50.0		1.353	1.300
Cardboard		23.3		11.6		15.0		10.0		0.390	0.260
Sweepings		42.8		21.4		27.5		20.0		0.716	0.520
Timber		8.4		4.2		5.4		20.0		0.141	0.520
Background		44.6		22.3		**100.0**		**100.0**		**2.600**	**2.600**
		200.0		**100.0**							

Skip no. 59

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		57.3		28.6		36.8		50.0		0.956	1.300
Timber		92.7		46.4		59.5		20.0		1.547	0.520
Sweepings		2.6		1.3		1.7		20.0		0.043	0.520
Polystyrene		3.3		1.6		2.1		10.0		0.055	0.260
Background		44.1		22.1		**100.0**		**100.0**		**2.600**	**2.600**
		200.0		**100.0**							

Skip no. 60

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		80.2		26.7		30.8		40.0		1.100	1.428
Cardboard		6.4		2.1		2.4		5.0		0.087	0.179
Sweepings		99.4		33.1		38.2		40.0		1.363	1.428
Slab		30.2		10.1		11.6		5.0		0.414	0.179
Timber		44.2		14.7		17.0		10.0		0.606	0.357
Background		39.6		13.2		100.0		100.0		3.570	3.570
		300.0		100.0							

Skip no. 61

		Total %		Ave %		Photo %		Visual %		Weight (ton)	Weight (ton)
Plastic		48.6		12.1		19.2		17.0		0.685	0.607
Cardboard		40.6		10.1		16.0		15.0		0.572	0.536
Sweepings		138.3		34.6		54.6		30.0		1.950	1.071
Timber		0.9		0.2		0.3		8.0		0.012	0.286
Paper		15.4		3.9		6.1		5.0		0.218	0.179
Rubber		5.0		1.3		2.0		2.0		0.070	0.071
Carpet		1.4		0.4		0.6		2.0		0.020	0.071
Polystyrene		2.9		0.7		1.2		1.0		0.041	0.036
Background		146.9		36.7	Other			20.0			0.714
		400.0		100.0		100.0		100.0		3.570	3.570

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